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Quantity-based cost forecasting system for street construction projects

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QUANTITY-BASED COST FORECASTING SYSTEM FOR STREET CONSTRUCTION PROJECTS

by

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ABSTRACT

Quantity-Based Cost Forecasting System for Street Construction Projects

by

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Construction projects typically are not withdrawn after going into the competitive bidding process. The decision of contracting authorities regarding which projects will proceed to the bidding stage depends, in part, upon the early estimates of probable cost. Efforts are made to make this estimate as realistic as possible. Irrespective of the estimate of probable cost, the actual project cost is established by the amount of the winning bid.

This study analyzed historical bid data of street construction projects undertaken by the Public Works Department, Clark County, Nevada, from 1991 through 2006. The focus of this study was on utilizing statistical models to develop improved methodologies for predicting bid-item unit pricing and reducing variances resulting in large discrepancies between project estimates and actual bid-award amounts. A regression model was developed to improve predictions of actual project costs based on calculations using all bid items. The resulting models were incorporated into a database and integrated into a computer software program to facilitate the predictive process for future projects.

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CHAPTER 1

INTRODUCTION

1.1 Background

Cost, time and quality need special consideration in the planning phase of every construction project. Among these, cost is often the prime factor that determines the feasibility of a project. The commencement of a project is not only a function of need, but is also dependent upon the estimated cost of the project and the budget availability of the contracting authority. In today's economic climate, budget has become an even more crucial planning factor, one needing to be keenly optimized. Newer methods of doing more and more with limited resources has become the key driver during the current economic downturn. Unfortunately, due to the many variable factors involved in construction, the accurate prediction of the cost of any construction project is problematic.

When it comes to public works, it is even more important for contracting authorities to optimize the taxpayer's money by utilizing it as responsibly as possible. Yet authorities often have to choose between different projects during the feasibility stage. Sometimes, under the pressure of time constraints, decisions are made before project scopes are fully finalized. In such cases, the accurate estimation of a project budget is note easily done. However, it is in preliminary stages of the project that control over budget is most necessary.

In Clark County, Nevada, most public works' contracts are awarded to contractors through competitive bidding. In competitive bidding, regardless of the engineer's estimate of probable cost, the lowest responsive bid generally determines which contractor wins the bid. Hence, the bid amount is of special concern to the contracting authority. Ideally, the lowest bid should tend to approach, as near as possible, the estimate made by the engineer for the project.

Early estimates, done long before bidding the project, are used for feasibility studies and other internal evaluation procedures. But when a project is advertised as open for bid, the engineer's estimate is not made known. In other words, the actual cost of a project to the owner will be the winning contractor's bid amount irrespective of the engineer's estimate.

Competitive bidding is done after completion of the detailed engineering design, when all the quantities are known. There are two types of items in the bidding process: 1) Quantity is estimated for items that are bid according to unit price. 2) A lump sum amount is used for other items for which quantity cannot be estimated, is unknown or is not relevant.

It is often found that as the quantity of a unit price item increases, the cost decreases. For lump sum items, it is often found that as the bid cost increases, the percentage of bid cost decreases. If such a trend in bidding can be mapped, it may be possible to obtain a more accurate estimate, based on historical bidding data.

Similarly, various changes are found to occur during the actual construction phase of any project. These changes may occur because of changes in design, changes in scope (additions to or omissions of some parts of the project), unanticipated site conditions, or other items. As a result, the cost of a project may further increase even after bidding is complete. In such a case, items that change in quantity are adjusted and additive or deductive change orders are made to the construction contract. Such change orders can lead to disputes between the owner and the contractor. Hence, the actual completion costs and bid costs of historical projects, when compared, may yield valuable information about the trends of change orders, as well.

1.2 Scope and Objectives

This research specifically focused on street construction projects undertaken by Clark County Public Works, Nevada, from year 1991 through 2006. Various items that repeatedly appeared in the competitive bids of county street construction projects were the items that were considered for inclusion in the research data set. The items were selected from bids from throughout the study period and a time adjustment was done to adjust the costs to the equivalent value in 2008 dollars. Both unit-price and lump-sum items were considered in this study.

The main goal of this research is to develop a tool that will provide an early basis upon which estimators can prepare reliable estimates before projects go to bid. Estimates based on historical data are expected to be more convincing and realistic. This tool would be helpful to contracting authorities in planning and selecting projects for bidding when the potential for choosing between different projects is available.

The objectives of the thesis are as follows:

- To develop a model based on historical data for predicting the unit price of items in a project based on the estimated quantities of the items in a project
- To develop a model based on historical data for predicting the percentage of bid cost based on the actual bid cost of a project
- To develop a model based on historical data for predicting the completion cost of a project based on the actual bid cost of a project

- To develop a software application incorporating all the prediction models developed and, hence, build an automated estimation system for use in street construction projects.

1.3 Research Hypothesis

The research hypothesis for this research is threefold:

Research Hypothesis 1: For unit-price items, there is a relationship between the estimated quantity and the unit price of the bid item. An increase in quantity tends to lead to a decrease in unit price.

Research Hypothesis 2: For lump-sum items, there is a relationship between the percentage of the bid cost assigned to the item and the bid cost of the project. An increase in the bid cost tends to lead to a decrease in the percentage of the bid cost assigned to the item.

Research Hypothesis 3: There is a relationship between the bid cost and the completion cost of a project. As the bid cost increases, the completion cost increases.

For the purpose of conducting statistical tests, the equivalent null hypotheses for the above mentioned research hypotheses are:

Null Hypothesis 1: For unit-price items, there is no relationship between the estimated quantity and the unit price of the bid item. The slope coefficient of the regression equation is not significantly different from zero, as expressed by the equation:

$$\beta_{0_1} = 0 \tag{1}$$

Null Hypothesis 2: For lump-sum items, there is no relationship between the percentage of bid cost assigned to the item and the bid cost of the project. The slope coefficient of the regression equation is not statistically different from zero, as expressed by the equation:

$$\beta_{0_2} = 0 \qquad (2)$$

Null Hypothesis 3: There is no relationship between the bid cost and the completion cost of a project. The slope coefficient of the regression equation is not significantly different from zero, as expressed by the equation:

$$\beta_{0_3} = 0 \qquad (3)$$

1.4 Thesis Structure

This thesis is comprised of seven chapters. It is a report documenting the background research undertaken to familiarize myself with the application of statistical methodologies to construction estimation, in particular the application of regression models to improve the accuracy of construction estimation. In addition, it reports on the original research I undertook in seeking to develop an improved construction estimation software program. As such, these chapters discuss the materials described briefly below:

Chapter 1 Introduction: This chapter consists of introduction to the subject matter of the research. It talks about the importance of early estimate and bid cost in planning and decision-making level. It also emphasize on the use of historical data in predicting probable bid cost and hence, optimize the decision making process. The scopes and objectives of this research are introduced and hypotheses are stated.

Chapter 2 Literature Review: This chapter demonstrates the building blocks for this research. Different literature referred to for this thesis is summarized and discussed in brief. The literature gradually paves the way to the gist of the study from the importance of the early estimate to use of regression analysis for different construction projects.

Chapter 3 Research Methodology: Research Methodology followed for this chapter is discussed and all the steps have been pointed out. Collection of data and statistical background needed for analysis are discussed.

Chapter 4 Data Description: The data set used for this research is introduced and step-wise description of analysis is shown. Descriptive statistics of costs of the projects are shown with the description of data analysis. Regression models used in this study are also discussed.

Chapter 5 Results/Findings: The regression models formed from Data Analysis are demonstrated. Validation of the model is done and limitations of the study listed.

Chapter 6 Computer Model: The software application developed with the result of analysis is explained.

Chapter 7 Conclusions and Recommendations: Conclusions of the research have been discussed along with recommendations for future research potentials.

CHAPTER 2

LITERATURE REVIEW

Literature from various research works done in different fields was reviewed. Study of the research done on development of regression models for prediction of cost or quantity of construction projects was the main focus of this section. All papers reviewed did not have a direct impact on the regression models developed for this study, but they helped in forming a base for the research and developing an understanding required for the research.

A study of highway construction projects performed in Louisiana claimed that the variation of actual cost from the estimated cost is not a random phenomenon. If it were so, the study surmised that the amount in underestimates should have been cancelled out by the overestimates for similar situations (Wilmot and Cheng 2003). The objective of this study was to produce a powerful estimating model for construction of highways in future. This model was designed to incorporate all the pertinent variables, as far as possible, and based on quantitative historical data. The variables that were included were contract price, type of construction, functional class of facility, letting date, contract duration, location and any changes to the duration or price of the contract that were made between the letting of the contract and its completion. Here, the major variables were classified into models and sub-models for the relevant items.

The sub-models with the least number of observations were found to be more variable than those with a greater number of observations. The total number of observations accounted for 2,827 highway and bridge contracts. These contracts were let by the Louisiana Department of Transportation and Development (DOTD) from 1984 through 1997. The sub-models were individually non-linear in their relationships, so summing up these variables produced erroneous results. Still, when the data was tested independently,, the results were found to produce a confidence level of 95 percent.

Whenever an incomplete dataset was encountered, the absent terms were replaced with terms closely resembling surrogate variables from available data resources. Examples of such surrogate variables were: construction machinery for construction equipment, construction sand/gravel/crushed stone for embankment material, concrete reinforcing bars and carbon for deformed reinforcing steel.

The model was proposed for use by the Louisiana DOTD for management of future highway construction and for assessing the impact of alternative future conditions. It predicted that the cost of highway construction in Louisiana would double from 1998 to 2015. Even after considering new cost-cutting policies and assuming input costs of 20 percent less than anticipated, at that time, highway construction costs were predicted to increase by 75 percent, overall.

Another study was done for petrochemical industry projects, resulting in the formulation of a roadmap for conceptual cost estimating (Kinney and Soubiran 2004). The steps for conceptual cost estimating as prescribed by the study were, first, to develop a plan and then to develop the costs of the major equipment (comparable to the major items in other types of projects). These initial steps were followed by applying different, relevant factors to the cost of the equipment. After that, indirect costs were added to the estimate and, if applicable, risks and contingency as well. This resulted in final estimates for the projects.

This petrochemical industry study also noted the behavior and accuracy of estimates in different project phases, from preliminary design to the post-construction phase. The study results showed that the accuracy of an estimate was low in the early stages, but became more accurate as the project advanced. The convergence of accuracy as projects progress is well demonstrated in Fig. 1.

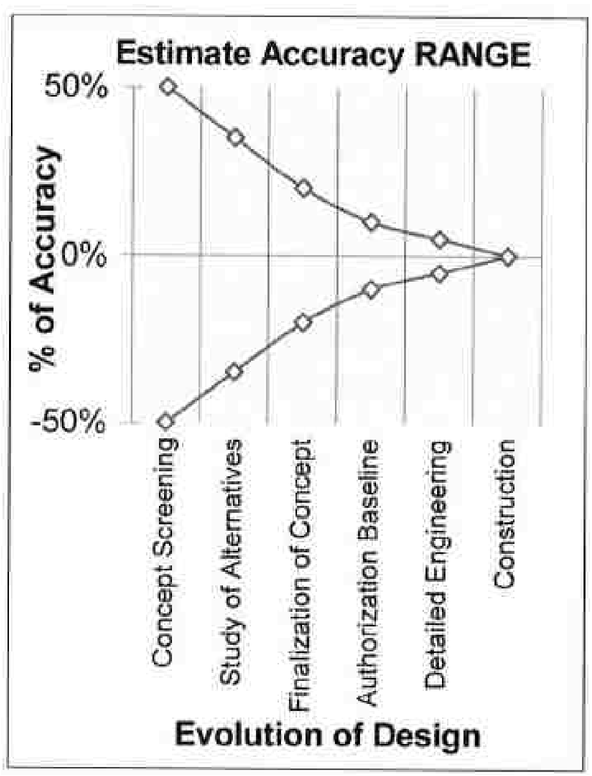


Fig. 1.Convergence of estimation range (Adopted from Kinney and Soubiran 2004)

Another study was conducted in which regression analysis and neural network models were studied, simultaneously, for 30 continuing-care retirement community (CCRC) projects built by a contractor in the United States (Sonmez 2004). The CCRC projects provided housing, health care and other services to people of retirement age. The variables considered for this study were construction year, location, total building area, combined percent of health care center and common areas, area per unit, number of floors and percent of structured parking area. Buildings from one to twelve floors in height, built in fourteen different states from 1975 to 1995, were considered. A statistical regression analysis approach was compared with a neural network model, which simulates the interconnectedness of biological structures such as human neurons. Since two types of approaches were compared, parsimonious models were applied. Parsimonious models are those which seek to avoid unnecessary variables and have only the required number of variables needed to accurately represent the data.

The regression analysis employs a backward pass technique to eliminate variables. Using this method, initial models were created that included all the independent variables associated with the projects. Then, those variables that were not contributing substantively to the models were removed. The factors used for determining the variables to be eliminated were significance level (P value) and coefficient of determination (R^2). In this model, total project cost was the dependent variable.

In case of the neural network analysis, two feed-forward neural network models with a different number of hidden units were developed and trained using the same variables as those selected for the regression model. Feed-forward models respond in a pre-defined way and lack a feedback, or response, mechanism. The neural networks were trained with all 30 project cases used for regression model. A back-propagation algorithm incorporating a sigmoid transfer function was used for training the units to perform. Two neural networks were trained so as to identify the number of hidden units required to adequately predict the project cost within reasonable closeness.

The study concluded that neural networks could represent the correlation of variables better and project costs in a more finite manner, but it requires additional variables. Regression analysis, on the other hand, requires fewer variables, but it requires a detailed study to determine the type of relationships that exist between the variables (linear, quadratic, cubic, log linear, etc.).

Additionally, a comparison between the models developed by the neural network and the regression analysis can be undertaken to determine if the relationships between the variables have been adequately studied. The neural network and regression analyses may also be used hand-in-hand to develop a conceptual-cost model. Such a comparison can done using mean-squared error (MSE) and mean-absolute percent error (MAPE) for the two methods of error measurement,

Bridge repair projects for the Alabama Highway Research Center were studied to improve the prediction of costs for future bridge repair work (Sanders et al. 1992). The purpose of this study was to create preliminary cost estimates for urban highway bridge-widening projects done by Alabama Highway Department. Forty three different work items were categorized into nine different groups and regression analyses were done for each group. Each analysis would predict one selected item, and the final cost was obtained by summing up all the parts. These individual regression models were not intended to be used as stand-alone models or to be used in conjunction with any other models. The independent variable in each of these regression models was in quantity of feet, tons, square yards, pounds and lane miles. Cost was viewed as the dependent variable. In this study, a program was written and a dBase III Plus database was maintained for each item.

The purpose of the model was to predict the lowest bidder. All the bidders were considered for the regression analysis, but the predicted value would, therefore, be greater than that bid by the lowest bidder. This problem was addressed by applying a factor to the work items in the projects that was not accounted for in the prediction model. For the adjustment of costs, like contractor mobilization, the values of individual items were divided by selected factors. The factors were determined by initially assigning a value, like 0.63, and then calculating the sums of the squares of the variations for all the data. An optimal point was reached by iteration where, in increasing and decreasing fashion, both made the result of the factor an increased sum of the squares of the variations.

A study of 258 transportation infrastructure projects in industrialized countries revealed the following facts: the costs of nine out of ten transportation projects were underestimated, the actual costs of roads were 20 percent more than estimated (with a standard deviation of 30 percent), and project cost underestimation was a global phenomenon (Flyvberg et al. 2002). Current approaches of early estimates were discussed, such as historic lane-mile averages (where lane-mile cost averages were considered for estimation), but unique features of each project were neglected (Chau et al. 2006). The conventional quantity-take-off and adjusted historical unit price method was also addressed. With this method a project is broken down into different items and the current unit cost is taken as the preference, but if unit quantities are not known, this is not a good for use in preparing a preliminary estimate. Another method is a component-level parametric unit price range with qualitative-adjustment factors. This deals with conventional quantity takeoffs and items built up from detailed information related to various work items. Again, if only the conceptual design is available, the quantities may not be accurately known. Finally, work-item unit price according to quantity range was addressed. This is a method whereby costs are stratified according to quantity ranges, location and other factors that are updated from time to time.

In this transportation study, a useful statistical model and a quantity-based cost estimate methodology, using historical data, was formulated. Twelve inputs were taken from new projects sufficiently far enough along in the planning phase to allow quantities to be calculated. The model was run to develop their cost estimates. Sixty-eight items were considered, which comprised 80 percent of the total cost. An influence diagram of the model used in this study is shown in Fig. 2.

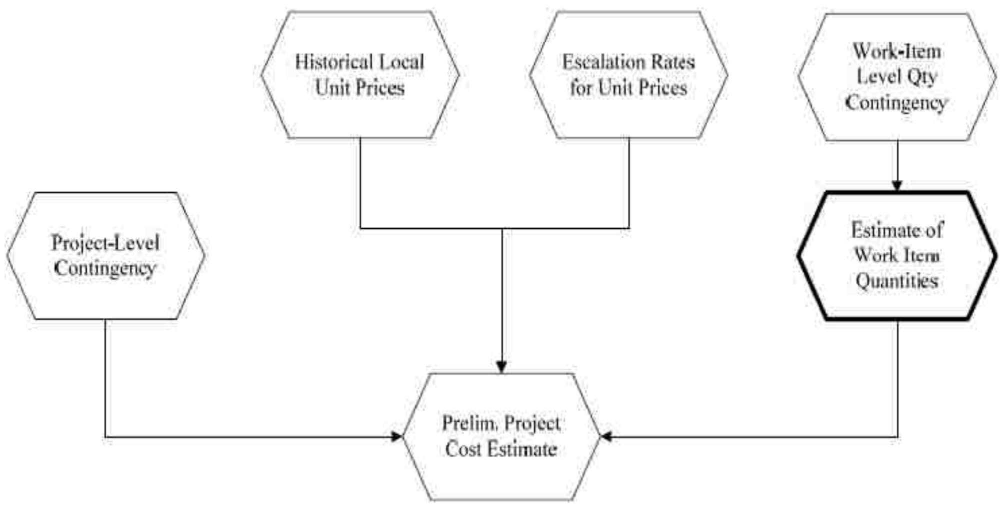


Fig. 2. Influence diagram of preliminary project cost estimates (Adopted form Chau et al 2006)

The different factors affecting these cost estimates were studied and classified as external, internal, predictable (controllable) and unpredictable (uncontrollable) (Peng 2006). The factors were listed according to the categories, as shown in Fig. 3. Another study examined bridge projects in Texas and, here, the project work breakdown structures played a key role. The work breakdown structures were consistent with the Texas

Department of Transportation (TxDOT) specifications (1993). Work items contributing 90 percent of the total cost of a project were identified initially, but ultimately only those associated with 80 percent of the project cost were taken (the number of items increased significantly once the 80 percent level was crossed). Thirty-two major work items comprising a cumulative total of 80.23 percent were selected. (The remaining 19.77 percent comprised 371 other work items.)

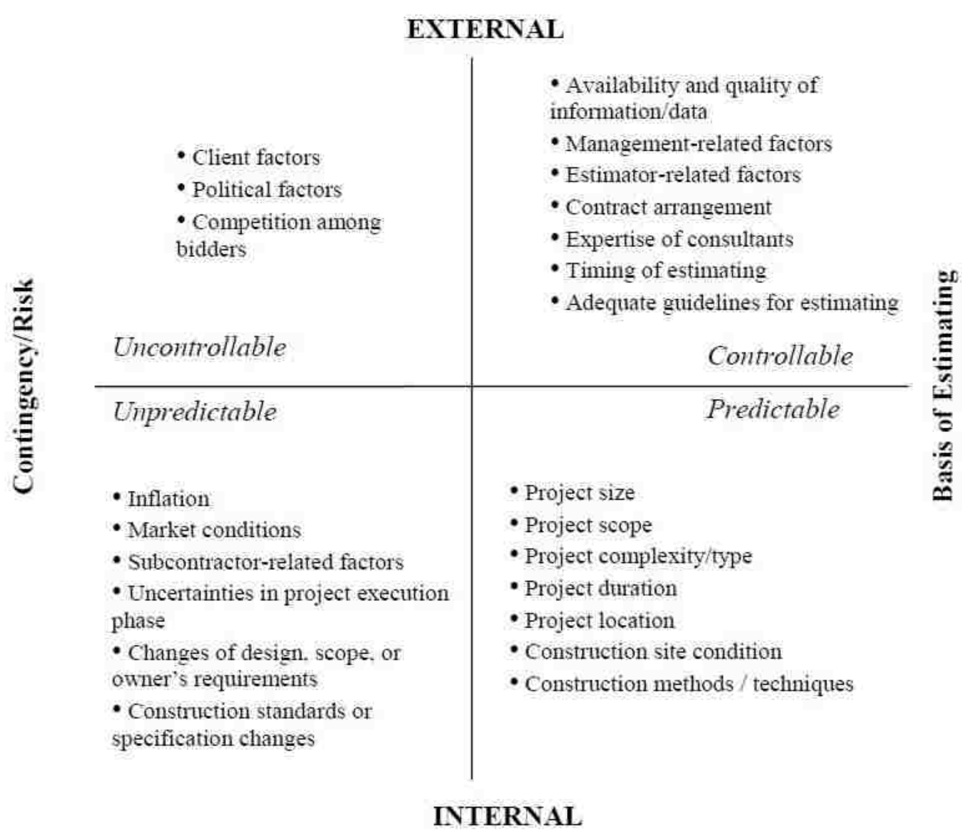


Fig. 3. Factors affecting cost estimate (Adopted from Peng 2006)

The factors were identified on the basis of the availability of information in the early stages of the projects and also on the availability of database information. Then, a multivariate regression model was developed using Statistical Package for Social Sciences (SPSS) software. In this regression anaylsis, the independent variables were different factors associated with the item. The dependent variable was the quantity of the item.

The regression model consisted of a multiplicative model with a statistical power model for predictors representing numerical data and an exponential model for predictors representing categorical data. This multiplicative model, demonstrating a non-linear relationship between the variables, was then logarithmically transformed to a linear model for flexibility and ease of interpretation. The validity of the model was tested by plotting a scatter of predicted values versus observed values. The transformed models were found to exhibit better fitness after those models were transformed back.

A cost estimating software system was developed to provide the following advantages: minimal training requirements, ease of use, less knowledge of and experience in design, minimal and non-redundant input, different modules for different type of projects, storage of estimates, retrieval upon request, output and interface compatibility with all general computers, easy data update for unit prices, indexes, and more. The average R-squared predictive value was found to be 0.47 with this system. This software system is called Preliminary Item-Level Cost Estimate System (PILCES).

Chou and O'Conner developed a web-based preliminary highway construction cost estimating version of PILCES, called WBPILCES (2007). The statistical model for it was developed from a statistical analysis of the basic parameters of the initial PILCES methodology combined with an internet-based relational database management system capable of computation and the storage of data. Centralized maintenance was done both for simplicity and to provide for the uniformity of estimates. The application uses open source software including a hypertext preprocessor (PHP), an Apache server and a structured query language (MySQL) database server. Data used for initial system development came from the TxDOT Design and Construction Information System (DCIS).

CHAPTER 3

RESEARCH METHODOLOGY

This study examined factors in street construction projects in Clark County, Nevada in the 1991-2006 timeframe, using statistical regression analysis in order to identify key variables useful in improving business results. A search of relevant literature identified typical factors in project failure to be late delivery, cost overruns, failure to meet scope, ignored risks, and inadequate resources. Understanding the role these factors play in the planning of street construction projects can be useful in improving business results for the County, including: mitigating reputation damage, minimizing the need for liquidated damages, and avoiding litigation. Controlling these business consequences is a positive benefit of the use of statistical methods in construction risk management. Hence, the methodology followed for this statistical analysis is discussed below.

3.1 Overview of Research Methodology

The Research Methodology adopted for this research is shown in Fig. 4. The steps involved in applying this methodology to the study described in this thesis are discussed below:

3.1.1 Problem Statement

The Problem Statement defines the objective and scope of the research. It describes the importance and need for the research. The research background, purpose of the study, and research hypotheses were presented in Chapter 1.

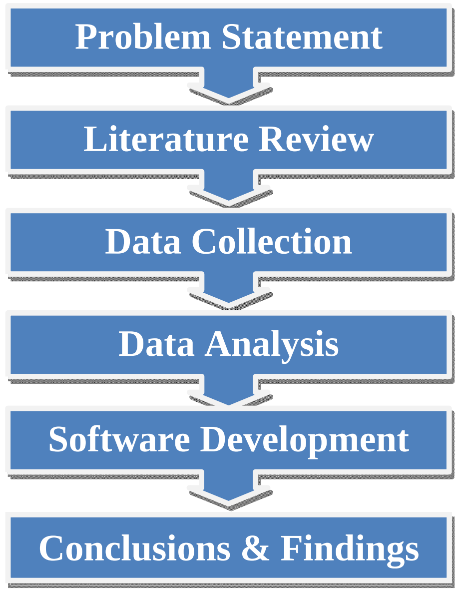


Fig. 4. Flowchart of research methodology

3.1.2 Literature Review

Various literature was reviewed before finalizing the study methodology. Journals, conference proceedings, books and articles were examined to refine the scope and limitation of the research. The review of literatures was discussed in Chapter 2 and listed in the Bibliography Section.

3.1.3 Data Collection

Data is the essence of any research. Statistical analysis cannot be conducted without adequate data. For this study, original data was collected from unpublished sources. Parameters were developed and provided to a correspondent and data was collected electronically as the primary method of data collection. Questionnaires, surveys, and personal interviews are other methods of data collection, but these were determined to be inadequate for this project. The number of samples, type, and size of the samples depend on the scope and limitation of the research question. These are discussed in depth in Section 3.2 Data Collection.

3.1.4 Data Analysis

Data was analyzed and regression models were built. The detail description of the data analysis is presented in Chapter 4.

3.1.5 Software Development

The resulting models were incorporated into a database and integrated into a computer software program to facilitate the predictive process for future projects as discussed in Chapter 6.

3.1.6 Conclusion and Findings

Conclusions and findings of the research are presented in Chapter 7. Some future research areas were also identified and presented.

3.2 Data Collection

The data for this research were collected from Clark County Public Works Department (CCPWD), Clark County, Nevada. A graduate of UNLV's Construction Management Program, now working as construction manager in CCPWD, helped to collect the data for this study. The data consists of bid schedule item information from Clark County's standard construction bid form for street projects constructed by Clark County Public Works from 1991 to 2006.

Clark County uses Global 360 Software, previously known as Kovis, to archive data of completed projects (Burns 2009). These data are public information and are available, when requested thorough proper channels, from the County Archives. Once a project is completed, a final affidavit of settlement is signed by the contractor. The project records are then stamped, delivered to the Construction Management Division of the CCPWD, scanned, and stored into the Global 360 database. Hard copies of completed projects are destroyed to reduce the storage space the physical retention of records demands.

For this study, project data were obtained in pdf format and manually entered into a spreadsheet. The data obtained included project year, lists of items (by number and description), quantities, units, engineer's estimates of probable cost, bid price for each item, total estimates of cost, and bids for each projects. Final completion costs for each project were entered separately in an Excel worksheet format.

3.3 Statistical Background

Street construction bid form data for Clark County was analyzed by conducting univariate regression analysis. The terms and methodologies used in this analysis are described below.

3.3.1 Types of variables

Two types of variables are used in any statistical regression model. The "prediction equation," or the "model," is an expression that reveals the relations between these variables. The variables are the dependent/response variable and the independent variable.

3.3.1.1 Dependent/Response Variable

The dependent, or response, variable is the factor to be predicted or modeled. The value of a response variable is dependent on an independent variable. It is not controlled by the researcher. It is plotted on the Y axis in regression charts. The dependent variables in this research are: unit price of items, percentage of total bid amount for lump-sum items, and final completion cost of the projects.

3.3.1.2 Independent Variable

A variable that can be controlled during the period of research is considered an independent variable. It is used to predict the dependent variables. There can be one or more than one independent variables in a regression model. The independent variables are usually plotted on the X axis. If there is more than one independent variable, then they are termed as x_1, x_2, x_3….etc. The independent variables in this research are quantity of items, bid cost and total bid cost of the projects.

3.3.2 Types of Regression Models

The research dealt only with a simple regression model with one dependent and one independent variable. The models used in the research are discussed below. The symbol "x" stands for the independent variable and "y" stands for the dependent variable in each case. "β_0" and "β_1" are the constant and the coefficient of the independent variable respectively (Devore 1999).

3.3.2.1 Linear Model

In this model, the correlation between the dependent variables – unit price of items, percentage of total bid amount for lump sum items, and final completion cost of the projects – and the independent variables – quantity of items, bid cost and total bid cost of the projects – are plotted linearly. The measurement between them results graphically in a straight line. Eq. 4. represents a simple linear model.

$$y = \beta_0 + \beta_1 x \tag{4}$$

3.3.2.2 Exponential Model

In this model, the dependent variables –unit price of items, percentage of total bid amount for lump sum items, and final completion cost of the projects – and the independent variables – quantity of items, bid cost and total bid cost of the projects – are exponentially correlated with the independent variable. Eq. 5. represents an exponential model.

$$y = \beta_0 e^{\beta_1 x} \tag{5}$$

3.3.2.3 Power Model

In the power model, the dependent variables are correlated with the independent variable raised to a certain power. Eq. 6. represents the power model.

$$y = \beta_0 x^{\beta_1} \tag{6}$$

3.3.2.4 Logarithmic Model

The dependent variable is a function of logarithm of the independent variable. Eq. 7. represents a logarithmic model.

$$y = \beta_0 + \beta_1 \log(x) \tag{7}$$

3.3.2.5 Reciprocal/Inverse Model

The dependent variable is correlated with a reciprocated value of the independent variable. Eq. 7. represents a reciprocal/inverse model.

$$y = \beta_0 + \beta_1 \frac{1}{x} \tag{8}$$

3.3.2.6 Other Models

Other models, like the polynomial of x with different degrees, moving average with different periods of x, and various logistic models, can also be used to predict the dependent variable from the independent variable. These models were not used in this research.

3.3.3 Types of Modeling Approaches

3.3.3.1 Deterministic Approach

In the deterministic model, all the points should exactly lie on a fitted-line plot. There is no provision for errors in prediction. This is an ideal situation in research. Some points always substantially deviate from a fitted line plot with real field data. Eq. 9. represents a Linear Deterministic Model.

$$y = \beta_0 + \beta_1 x \tag{9}$$

3.3.3.2 Probabilistic Approach

In this approach, the points do not all lie exactly on a fitted line plot. This is always found with real field data. The prediction value is not expected to be exactly accurate. In a deterministic equation, an error term is introduced to account for the error due to real field data. Eq. 10. represents a Linear Probabilistic Model.

$$y = \beta_0 + \beta_1 x + \varepsilon \tag{10}$$

3.3.4 Least Squares Line

In a probabilistic model, the error term cannot be eliminated completely, though it is generally preferable to try to minimize it. In the Least Squares Method, the deviation of the predicted values from the actual value is minimized. In doing so, only one line for the given data, yielding a nil sum of deviation, is obtained. The obtained line is called the Least Squares Line, Regression Line, or the Least Squares Prediction Equation. The Least Squares Method is used, therefore, to make the fitted line plot best represent the data.

Let $\hat{y}_i$ be the estimated value for case *i* among *n* number of cases, x_i and y_i be the observed values, and $\bar{x}$ and $\bar{y}$ be the averages for *x* and *y* series respectively. Then, the term to be minimized is $\sum_{i=1}^{n}(y_i - \hat{y}_i)^2$. But, we know, $\hat{y}_i = \beta_0 + \beta_1 x_i$. Hence, our term to be minimized is $\sum_{i=1}^{n}(y_i - \beta_0 - \beta_1 x_i)^2$. Taking the partial derivative and solving for it, we get Eq. 11.

$$\beta_1 = \frac{\sum_{i=1}^{n}(x_i - \overline{x})(y_i - \overline{y})}{\sum_{i=1}^{n}(x_i - \overline{x})^2} \tag{11}$$

Hence, resulting in Eq.12 from Eq. 9. and Eq. 11.,

$$\beta_0 = \overline{y} - \beta_1 \overline{x} \tag{12}$$

3.3.5 Coefficient of Determination

The Coefficient of Determination used in the regression analysis is actually the square of the Pearson Correlation Coefficient between *y* and $\hat{y}$. The general expression for "r" is shown in Eq. 13.

$$r = \frac{\sum_{i=1}^{n}(x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \overline{x})^2 \sum_{i=1}^{n}(y_i - \overline{y})^2}} \tag{13}$$

The above equation gives the correlation between the two random variables. If *x* is replaced by $\hat{y}$ in the above equation, it will actually give the correlation between *y* and $\hat{y}$ for the regression model, which is *R*.

The value of *r* lies in the interval $-1 \leq r \leq 1$ in the case of the simple correlation. In multiple correlations, *R* cannot be negative and lies in the interval $0 \leq R \leq 1$. The value is the same regardless of the interchange of the axis and their units. The higher value of R^2 means a higher correlation and better fit of the curve representing the data when graphically plotted.

CHAPTER 4

DATA DESCRIPTION AND ANALYSIS

This chapter discusses how the data were obtained and presents descriptive statistics about the data evaluated in this study. These are presented with written descriptions as well as graphic representations. A preliminary analysis was conducted to identify the items whose regression models were developed. This chapter also covers the theory behind the development of regression model which is the Data Analysis Part.

4.1 Data Set

In this study, a data set was compiled from information obtained in pdf format from the CCPWD, consisting of the list of items, quantities, estimated and bid unit prices, and estimated and bid total amounts for the projects. All data were from street construction projects completed in Clark County, Nevada, between 1991 and 2006. A total of 147 projects were considered for inclusion in the data set; however, final completion costs were obtained for only 112 projects. The data are graphically represented in three histograms encompassing the scope of the study.

Fig. 5, below, shows that the maximum number of projects completed per year was 14, in 1993. The least number of projects completed per year was two, in 1991 and in 2006. The histogram in Fig. 5 shows the distribution of projects over the study period.

The total bid value of all 147 projects was $649,253,090 converted to the 2008 equivalent dollar amount. Statistics describing the individual estimated costs, bid costs, and final completion costs for all projects are given in Table 1

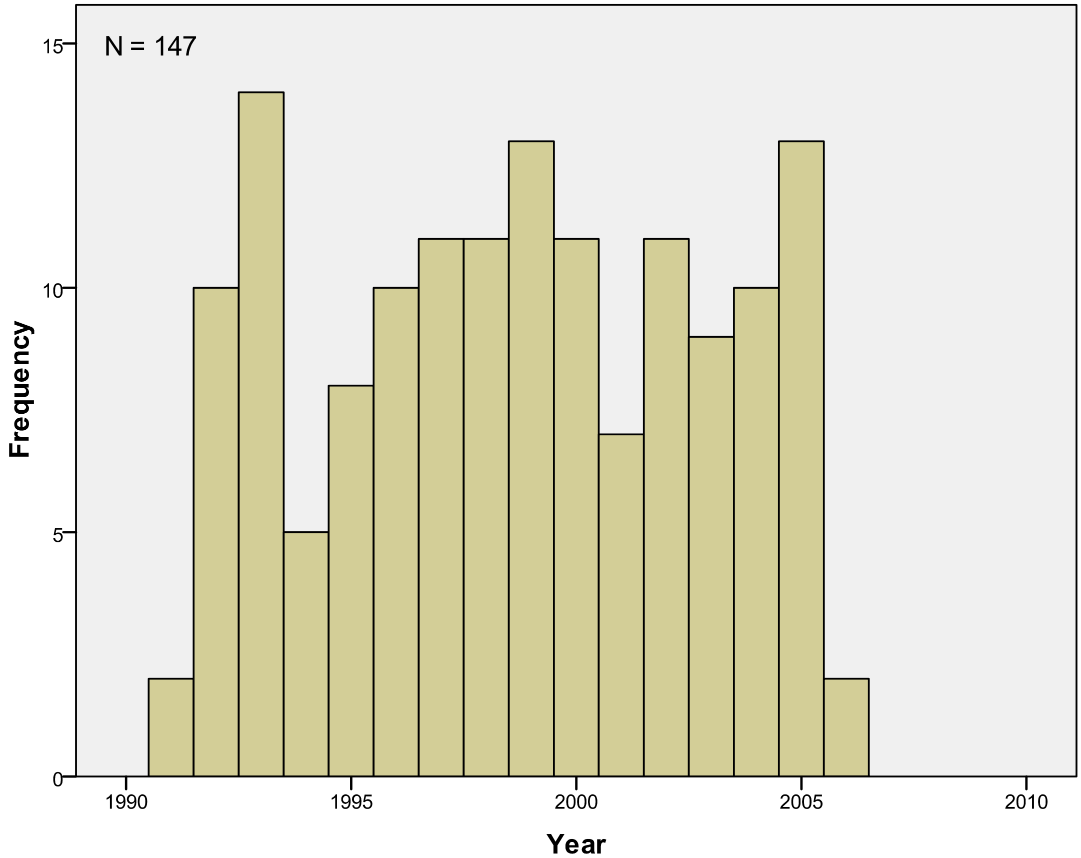


Fig. 5. Histogram of the projects by year

Table 1. Descriptive Statistics of Selected Costs for All Projects ($)

	N	Minimum	Maximum	Mean	Std. Deviation
Estimated Cost	147	49,930	67,834,676	4,621,145	8,780,772
Bid Cost	147	44,111	66,394,773	4,416,688	8,377,372
Final Completion Cost	112	74,779	42,965,987	4,072,838	6,196,127

The mean of Bid Cost was $4,416,688 while it ranged from $44,111 to $66,394,773. Mean of Estimated Cost was $49,930; the range was from $49,930 to $67,834,676. Final Completion Cost ranged from $74,779 to $42,965,987; its mean was $4,072,838.

The maximum and minimum Final Completion Cost shown in Table 1 appears to deviate from Total Estimated and Total Bid because Completion Cost is not available for all projects and the values in the table represents the maximum and minimum of the available data. The full listing of the projects and corresponding amount is listed in Table A-1.

In Table A-1, the histograms for Estimated Cost, Bid Cost and Final Completion Cost appear extremely skewed considering the dollar amounts in the data set. For construction of these histograms, the data was transformed into its logarithmic scale and the y-axis represents the frequency of the logarithm of what is shown in x-axis.

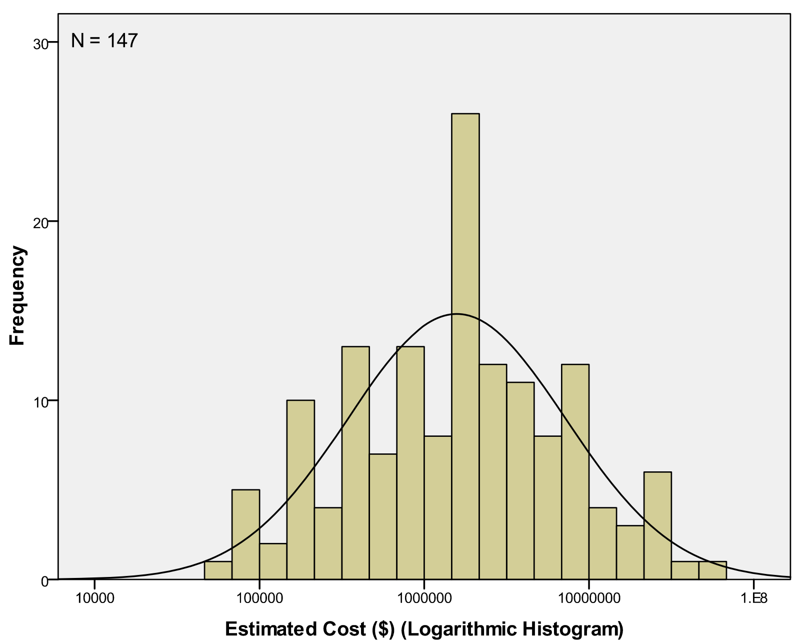


Fig. 6. Logarithmic histogram of total estimated cost

Fig. 6 represents the logarithmic histogram of Estimated Cost of all 147 projects. After the data is transformed to log, the histogram shows that the data are normally distributed.

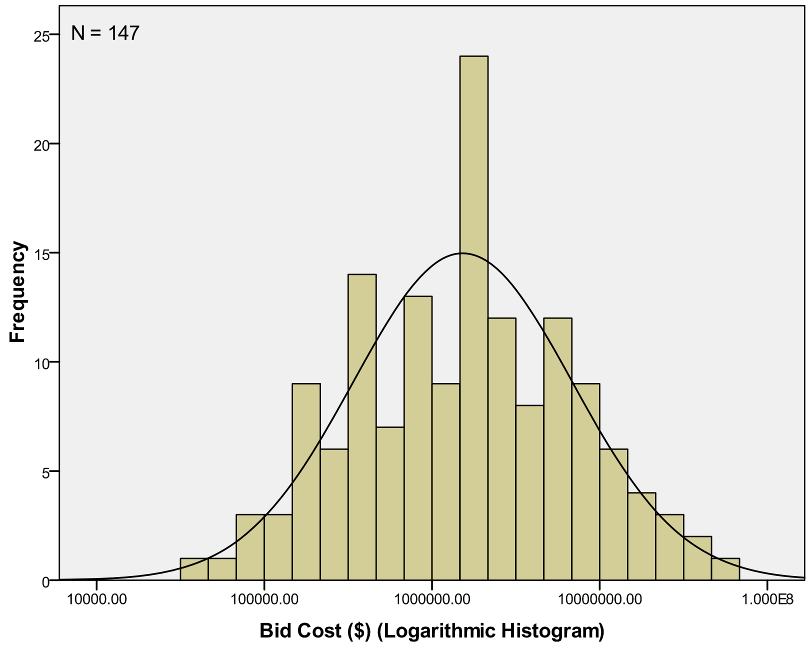


Fig. 7. Logarithmic histogram of bid cost

Fig. 7 shows the Histogram of Bid Cost for all the projects after transformation. The Histogram shows that the data are normally distributed.

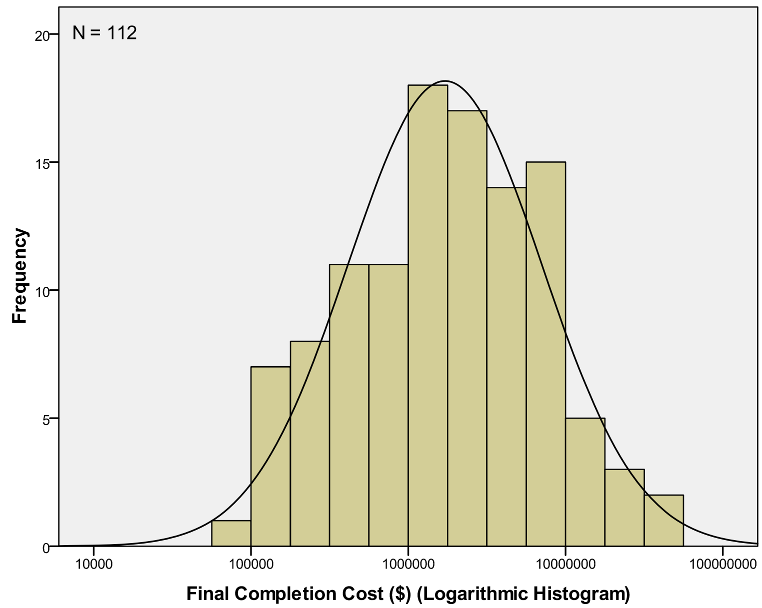


Fig. 8. Logarithmic histogram of final completion cost

The logarithmic histogram shown in Fig. 8 represents the Final Completion Cost of the projects. The Histogram shows that the data has a somehow normal-distribution.

4.2 Preliminary Analysis

To identify the items whose regression models would be developed, a preliminary analysis was conducted. First, bid item data from all 147 pdf bid documents, were manually entered into Microsoft Excel Worksheets. Next, twenty-five projects were chosen at random and the most repetitive items in the street construction projects were determined.

In addition to base bid items, this included supplemental work like utility piping, traffic signal modifications, and streetscape beautification. A total of 252 items were identified as shown in Table A-2.

From these items, only twenty were selected for regression model development. The items were selected based on the number of times they were used in the constructed street projects. It was determined that repetition represented significant tasks for comparison. In addition, the repetitive items provided an adequate data set for further analysis. The twenty items selected are shown in Table 2. (In some older projects, certain item codes and item names were not consistent with newer data. These inconsistencies have been corrected in Table 2, consistent with confirmation from CCPWD of which new item codes have replaced the older item codes no longer in use by the County.)

Table 2. Shortlisted Items selected for Further Analysis

SN	Item Code	Item Name	Unit
1	105.01	Quality Control	LS
2	107.01	Traffic Control	LS
3	109.03	Construction Conflicts and Additional Work	LS
4	109.01	Historical Owner-Caused Delay Allowance	DAY
5	109.02	Additional Amount over $500/day as determined by Bidder	DAY
6	201.01	Clearing and Grubbing	LS
7	200.01	Mobilization	LS
8	203.01	Roadway Excavation	CY
9	302.01	Type II Aggregate Base	TON
10	402.01	Plantmix Bituminous Surface	TON
11	403.01	Plantmix Bituminous Open Graded Surface (3/4")	SY
12	406.01	Prime Coat	TON
13	405.01	Tack Coat	TON
14	407.01	Seal Coat	TON
15	613.02	Concrete Sidewalk	SF
16	613.03	Concrete Valley Gutter	SF
17	613.01	Type "L" Curb & Gutter	LF
18	633.01	Reflective Pavement Markings	EA
19	633.02	Non-reflective Pavement Markers	EA
20	637.01	Dust Control	LS

where,
LS = Lump sum
CY = Cubic Yard
SF = Square Footage
LF = Linear Footage
SY = Square Yard
EA = Each

Thereafter, all the data for each of the items of Table 2 were tabulated in separate worksheets in Excel and time adjustments were done for unit price and other dollar amounts. The RS Means Cost Index was used to convert the bid costs to their 2008 equivalent costs. Table 3 shows the RS Means Cost Indices and the multiplication factor used to adjust the cost (based on Jan 1, 1993 = 100).

Table 3. RS Means Cost Indices

Year	Index	Year	Index
1991	96.8	2000	120.9
1992	99.4	2001	125.1
1993	101.7	2002	128.7
1994	104.4	2003	132.0
1995	107.6	2004	143.7
1996	110.2	2005	151.6
1997	112.8	2006	162.0
1998	115.1	2007	169.4
1999	117.6	2008	180.4

Eq. 14. is used for adjusting the bid cost.

$$\textit{Equivalent amount in 2008} = \textit{Bid Cost} * \textit{Multiplication Factor} \qquad (14)$$

4.3 Data Analysis

Total of 147 projects were used to construct regression models for twenty selected items. However, the regression models between the Total Bid Cost and Total Completion Cost was conducted for the data from112 projects. The entire step-by-step process of data analysis is described below.

4.3.1 Data Preparation

Predictive Analytics SoftWare (PASW 17), by Statistical Package for the Social Sciences Incorporated (SPSS Inc.), was used to analyze the data for each item and for construction of the regression models. An analysis was done for each item separately and a regression equation was formulated.

The variables for the models of the Unit Price Items were converted to 2008 equivalents for Unit Price and Quantity in each Bid. The variables for the models of Lump Sum Items were calculated as a Percentage of Total Bid allocated to that Item and the Total Bid Cost of the project. For the regression model to predict the Total Completion Cost, the Total Bid Cost of the Projects were used as the independent variable.

4.3.2 Construction of regression models

Different regression models such as Linear, Logarithmic, Inverse, Power and Exponential were developed and their respective R^2 values were calculated. The model with the highest R^2 and significant at alpha level 0.05 was selected to predict the dependent variables. Initially, the scatter plots for all the regression models were studied and the outliers, which can severely affect the accuracy and range of a model, are avoided. For this, a trial and error method was used by generating Box Plots for all the variables. (A Box Plot shows the degree of dispersion and skewness in the data and identifies the outlier. The outlier data points are removed and regression models are tried again to see the changes in R^2 as well as the visual appeal of the plot.) Finally, when a convenient plot, free from such outliers, was obtained, the final regression analysis was completed.

It is to be noted that all the regression models considered above are intrinsically linear. A function relating the *y* to the *x* is said to be linear if, by any means, any or both of the variables can be transformed and a linear equivalent equation can be formulated. The expected final equation is in the form $y' = \beta_0 + \beta_1 x'$, where, *x'* and *y'* are transformations of *x* and *y* respectively (Devore 1999).

Table 4 shows the forms of Intrinsically Linear Functions and transformations required to convert those equations to their linear equivalents. The linear equivalent forms are also shown in Table 4. It should be noted that for the Exponential Function, a natural log should be taken while for other functions, a log of any base can be used. For this research, only a natural log, with base *"e,"* is taken to maintain consistency.

Table 4. Intrinsically Linear Functions and Required Transformations

Function		Transformation(s)	Linear Form
Linear	$y = \beta_0 + \beta_1 x$		$y = \beta_0 + \beta_1 x$
Logarithmic		$x' = \log(x)$	$y = \beta_0 + \beta_1 x'$
Inverse	$y = \beta_0 + \beta_1 \frac{1}{x}$	$x' = \frac{1}{x}$	$y = \beta_0 + \beta_1 x'$
Power	$y = \beta_0 x^{\beta_1}$	$y' = \log(y)$ $x' = \log(x)$	$y' = \log(\beta_0) + \beta_1 x'$
Exponential	$y = \beta_0 e^{\beta_1 x}$	$y' = \ln(y)$	$y' = \ln(\beta_0) + \beta_1 x$

The term Intrinsically Linear Function was introduced because the different regression equations obtained for different items were transformed into their linear forms. Tests were conducted to check whether the assumptions of the Linear Regression Model were valid for the data.

4.3.3 Residual Analysis

Residual Analysis is used to check the assumptions of Linear Regression Model (Mendenhall and Sincich 2007). Residuals refer to the term $y - \hat{y}$, which is the difference between the true values of *y* and its corresponding predicted values. For the Residual Analysis, first the variables were transformed into their respective required forms. Then, a linear regression analysis was conducted with the transformed variables and residuals that were generated. For this research, Un-standardized Predicted Value and Standardized Residuals were studied to consider their sensitivity. From the data generated by the linear regression of the transformed variables, tests for the assumptions of the linear regression were performed. The different checks performed were as follows:

4.3.3.1 Check for Mis-specified Model

Mis-specification of the model can be checked by plotting the residuals against the independent variable. A random scatter around the zero line indicates no relation between the residual and the independent variable. If a curvilinear pattern is observed, then a polynomial of the independent variable can probably improve the model efficiency. This plot will show whether the residuals have any harmonic pattern with the independent variable that might suggest other relations than the linear one.

4.3.3.2 Check for Heteroscedasticity / Unequal Variance

In case of heteroscedasticity, relating to the sequence of random variables within the data set, the residual and predicted values of *y* shows definitive pattern. It can be studied by plotting the predicted values against the residual values. It may be observed that the value of the residuals increases with the increase of predicted values. In such a case, different transformations on the independent variables should be implemented depending upon the nature of the plot. Commonly encountered transformations may include Poisson, Binomial, and Multiplicative. In conclusion, a scatter plot is desirable to avoid any further transformations of variables.

4.3.3.3 Check for Non-normal Errors

The normality of errors underlies the assumptions of the linear regression model. Hence, the distribution of the errors can be tested by plotting a histogram of errors. Extremely skewed plots indicate the requirement for transformation of variables. The transformations in this case also resemble the transformations in the previous case. Non-normality may also be caused due to outliers.

4.3.3.4 Check for Correlated Errors

This check should be performed when data in the research correspond to different time frames. If any pattern is observed in the plot of residuals against time, a time series analysis should be done to address the problem. In such conditions, the introduction of time variables can be helpful. Here, also, a random scatter plot is useful in verifying that the linear model is sufficient for the analysis.

4.3.4 Model Validation

After all the tests were performed the regression equations obtained from the models were used to check the accuracy of the prediction. The obtained values from prediction equation were compared with the actual values for the respective projects. The nearer the predicted values to the actual values, the stronger the model was found to be.

CHAPTER 5

RESULTS/FINDINGS

To test the predictive strength of the regression model as an estimating tool, items selected from the bid documents of 147 Clark County Public Works' Street Construction Projects were analyzed using a rigorous methodology. The purpose of this analysis was to find a reliable mechanism to display the relationship between the predicted and historical data.

Below, the results of the regressions on each item are shown. For each, a table identifies the *n* value, the minimum cost, the maximum cost, the mean cost and the standard deviation. The N value represents the number of times the item is found in the bid documents of the 147 projects. A second table identifies the results of five different regression models applied to the items descriptive statics. The model having the highest R-squared value was used as the test for assumptions. The data were transformed, validated and re-plotted. The plots were assessed for aptness and the mathematical equation was noted.

5.1 Regression Models for Items with Unit Price

Unit Price is used for those items whose quantity can be accurately estimated. There were altogether twelve items that were successfully modeled for this research. Item 109.01 "Historical Owner Caused Delay Allowance" with unit of "DAY" and item 109.02 "Additional Amount over $500/day as determined by Bidder" with unit of "DAY" could not be fitted into any regression model and hence were dropped out. The regression analyses for each item are as follows,

5.1.1 Item 203.01 Roadway Excavation

Initially, there were 126 data points for this item. The unit of measurement for roadway excavation is cubic yards (CY). Fig. B- 1. shows the box plot for Quantity (CY) and Fig. B- 2. shows the box plot for Unit Price ($/CY) based on 126 data points. The initial box plots showed significant numbers of outliers. The data were examined and twelve data points were removed due to deviations from the selection criteria. (Five data points were found to have abnormal unit prices. Seven were removed due to quantity outliers. This was the highest number of data omitted among all the items regressed in this study.) The number of data points used for the roadway excavation regression model, following elimination of the deviations, was 114. The final box plots, after processing, are shown in Fig. B- 3. and Fig. B- 4.

The descriptive statistics of the roadway excavation items are shown in Table 5. A wide range in quantity, from a low value of 36 CY to a maximum value of 487,650 CY, can be seen. The mean quantity for all projects was 37,021 CY, for which a high standard deviation was seen. The range of unit price varied from $2.32/CY to $27.01/CY. The mean unit price was $9.55/CY and standard deviation was $5.48/CY.

Table 5. Descriptive statistics of Quantity and Unit Price for Roadway Excavation

	n	Minimum	Maximum	Mean	Std. Deviation
Quantity (CY)	114	36.00	487,650.00	37,021	69,543.67
Unit Price ($/CY)	114	2.32	27.01	9.55	5.48

Table 6 below shows the results of all the regression models calculated on this item. All the models were found to be significant at 95% confidence level, though they had varying R^2 values.

Table 6. Result of different regression models for Roadway Excavation

Model	R^2	Significance	Coefficient		Constant	
			Value	Significance	Value	Significance
Linear	0.108	<0.001	-2.58E-5	<0.001	10.508	<0.001
Logarithmic	0.347	<0.001	-1.865	<0.001	27.012	<0.001
Inverse	0.113	<0.001	671.273	<0.001	9.153	<0.001
Power	0308	<0.001	-0.182	<0.001	44.953	<0.001
Exponential	0.130	<0.001	-2.94E-6	<0.001	9.104	<0.001

The logarithmic model, having the highest R^2 value, at 34.7%, was chosen to transform the data and test for assumptions. Checks for mis-specified model, heteroscedasticity, non-normal and correlated errors were performed and the data were re-plotted. The random scatter around the base line in the final plot showed the aptness of the tests. The plots are shown in Fig. C- 1., Fig. D- 1., Fig. E- 1. and Fig. F- 1. respectively.

The plot in Fig. G-1. shows that almost all the data points lie between the 95% confidence interval lines. Both the predicted and the historical data points tend to cluster around the diagonal line. Hence, the logarithmic regression model was found acceptable for expressing this relational information.

The regression equation adopted for roadway excavation can be described mathematically as in Eq. 15.

$$UP_{RE} = 27.012 - 1.865 * \log(Q_{RE}) \qquad (15)$$

In this equation, the unit price of roadway excavation is shown in dollars per cubic yard, converted to the equivalent sum of 2008 dollars. The quantity for roadway excavation is given cubic yards:

UP_{RE} = Unit price of roadway excavation in 2008 in \$/CY

Q_{RE} = Quantity of roadway excavation in CY

The data used for analysis are listed in Table H-1and the resulting plot is shown in Fig. 9.

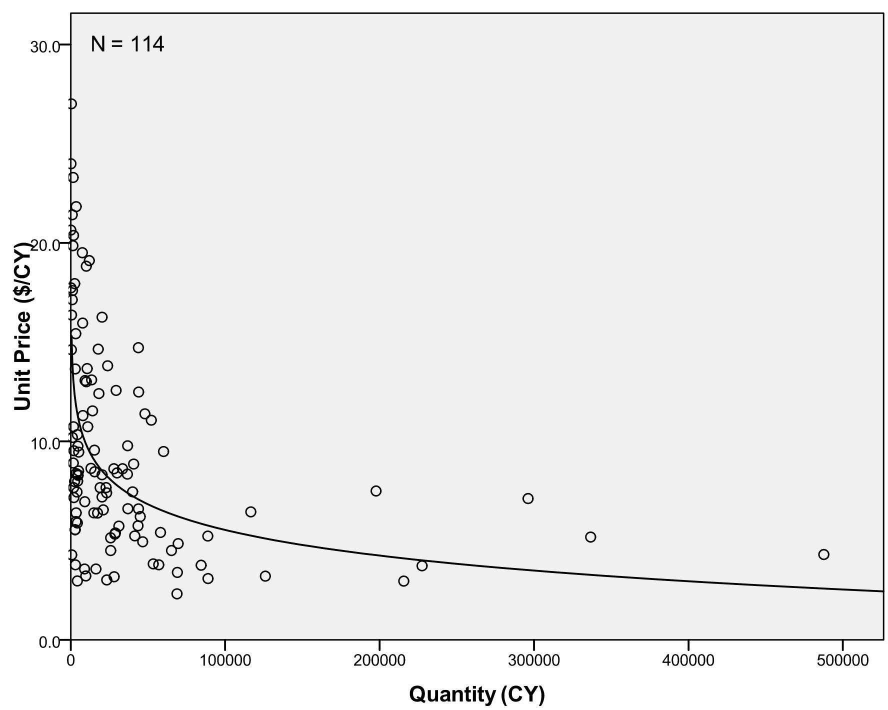


Fig. 9. Logarithmic regression model for roadway excavation

5.1.2 Item 302.01 Type II Aggregate Base

Initially, there were 123 data points for this item. The unit of measurement for roadway excavation is ton (TON). Fig. B- 5. shows the box plot for Quantity (TON) and Fig. B- 6. shows the box plot for Unit Price ($/TON) based on 123 data points. The initial box plots showed few outliers. The data were examined and three data points were removed due to deviations from the selection criteria. (Three data points were found to have abnormal unit prices.) The number of data points used for the Type II aggregate base regression model, following elimination of the deviations, was 120. The final box plots, after processing, are shown in Fig. B- 7. and Fig. B- 8 .

The descriptive statistics of the Type II aggregate base items are shown in Table 7. A wide range in quantity, from a low value of 49 TON to a maximum value of 57,909 TON, can be seen. The mean quantity for all projects was 37,020.84 TON, for which a standard deviation of 11,441 TON was seen. The range of unit price varied from $4.8/TON to $104.14/TON. The mean unit price was $34.07/TON and standard deviation was $20.24/TON.

Table 7. Descriptive Statistics of Quantity and Unit Price for Type II Aggregate Base

	n	Minimum	Maximum	Mean	Std. Deviation
Quantity (TON)	120	49.01	57,909.00	9,157.72	11,440.65
Unit Price ($/TON)	120	4.80	104.14	34.07	20.24

Table 8 below shows the results of all the regression models calculated on this item. All the models were found to be significant at 95% confidence level, though they had varying R^2 values.

Table 8. Result of Different Regression Models for Type II Aggregate Base

Model	R^2	Significance	Coefficient		Constant	
			Value	Significance	Value	Significance
Linear	0.141	<0.001	-0.001	<0.001	40.156	<0.001
Logarithmic	0.351	<0.001	-7.598	<0.001	96.776	<0.001
Inverse	0.185	<0.001	2,662.115	<0.001	30.874	<0.001
Power	0.263	<0.001	-0.193	<0.001	141.524	<0.001
Exponential	0.147	<0.001	-1.986E-5	<0.001	34.592	<0.001

The logarithmic model, having the highest R^2 value at 35.1%, was chosen to transform the data and test for assumptions. Checks for mis-specified model, heteroscedasticity, non-normal and correlated errors were performed, and the data was re-plotted. The random scatter around the base line in the final plot showed the aptness of the tests. The plots are shown in Fig. C- 2., Fig. D- 2., Fig. E- 2. and Fig. F- 2. respectively.

The plot in Fig. G-2. shows that almost all the data points lie between the 95% confidence interval lines. Both the predicted and the historical data points tend to cluster around the diagonal line. Hence, the logarithmic regression model was found acceptable for expressing this relational information..

The regression equation adopted for type II aggregate base can be described mathematically as in Eq. 16:

$$UP_{T2AB} = 96.776 - 7.598 * \log(Q_{T2AG}) \qquad (16)$$

In this equation, the unit price of Type II aggregate base is shown in dollars per ton, converted to the equivalency of 2008 dollars. The quantity for Type II aggregate base is given in tons:

UP_{T2AG} = Unit price of type II aggregate base in 2008 in \$/TON

Q_{T2AB} = Quantity of type II aggregate base in CY

The data used for analysis are listed in

Table H-2 and the resulting plot is shown in Fig. 10.

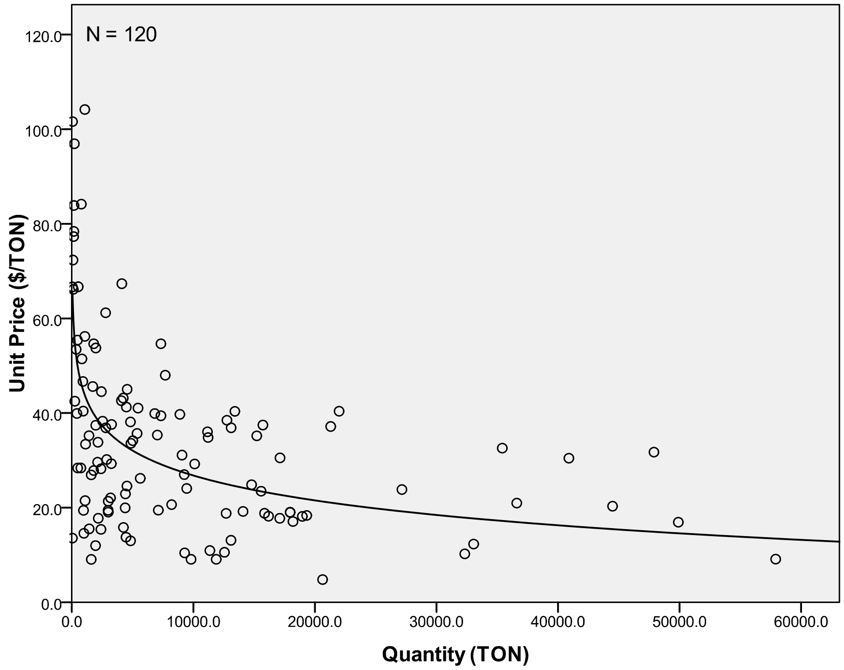


Fig. 10. Logarithmic regression model for type II aggregate base

5.1.3 Item 402.01 Plantmix Bituminous Surface

Initially, there were 137 data points for this item. The unit of measurement for plantmix bituminous surface is ton (TON). Fig. B- 9. shows the box plot for Quantity (TON) and Fig. B- 10 shows the box plot for Unit Price ($/TON) based on137 data points. The data were examined and one data point was removed due to deviations in unit price. The number of data points used for plantmix bituminous surface regression model, following elimination of the deviations, was 136. The final box plots, after processing, are shown in Fig. B- 11. and Fig. B- 12.

The descriptive statistics of the plantmix bituminous surface items are shown in Table 9. A wide range in quantity, from a low value of 62 TON to a maximum value of 67,000 TON, can be seen. The mean quantity for all projects was 15,953 TON, for which a standard deviation of 15,930 TON was seen. The range of unit price varied from $31.93/TON to $187.17/TON. The mean unit price was $51.53/TON and the standard deviation was $23.54/TON.

Table 9. Descriptive Statistics of Quantity and Unit Price for Plantmix Bituminous Surface

	n	Minimum	Maximum	Mean	Std. Deviation
Quantity (TON)	136	62.00	67,000.00	15,952.68	15,929.89
Unit Price ($/TON)	136	31.93	187.17	51.53	23.54

Table 10 below shows the results of all the regression models calculated on this item. All the models were found to be significant at 95% confidence level, though they had varying R^2 values.

Table 10. Result of Different Regression Models for Plantmix Bituminous Surface

Model	R^2	Significance	Coefficient		Constant	
			Value	Significance	Value	Significance
Linear	0.112	<0.001	-4.95E-4	<0.001	59.432	<0.001
Logarithmic	0.401	<0.001	-9.313	<0.001	134.33	<0.001
Inverse	0.474	<0.001	7,803.379	<0.001	45.864	<0.001
Power	0.449	<0.001	-0.135	<0.001	160.006	<0.001
Exponential	0.136	<0.001	-7.43E-6	<0.001	54.458	<0.001

The inverse model, having the highest R^2 value, at 47.4%, was chosen to transform the data and test for assumptions. Checks for mis-specified model, heteroscedasticity, non-normal and correlated errors were performed, and the data was re-plotted. The random scatter around the base line in the final plot showed the aptness of the tests. The plots are shown in Fig. C- 3., Fig. D- 3., Fig. E- 3. and Fig. F- 3. respectively.

The plot in Fig. G-3. shows that almost all the data points lie between the 95% confidence interval lines. Both the predicted and the historical data points tend to cluster around the diagonal line. Hence, the inverse regression model was found acceptable for expressing this relational information.

The regression equation adopted for plantmix bituminous surface can be described mathematically as in Eq. 17:

$$UP_{PBS} = 45.864 + \frac{7803.379}{Q_{PBS}} \tag{17}$$

In this equation, the unit price of plantmix bituminous surface is shown in dollars per ton, converted to the equivalency of 2008 dollars. The quantity for plantmix bituminous surface is given in ton:

UP_{PBS} = Unit price of plantmix bituminous surface in 2008 in $/TON

Q_{PBS} = Quantity of plantmix bituminous surface in TON

The data used for analysis are listed in

Table H-3 and the resulting plot is shown in

Fig. 11.

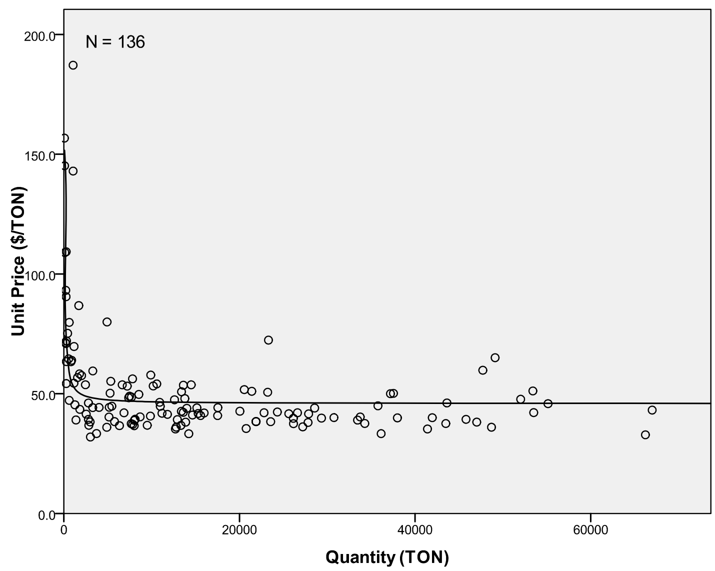


Fig. 11. Logarithmic regression model for plantmix bituminous surface

5.1.4 Item 403.01 Plantmix Bituminous Open Graded Surface (3/4")

Initially, there were 63 data points for this item. The unit of measurement for plant mix bituminous open-graded surface (3/4") is square yards (SY). Fig. B- 13. shows the box plot for Quantity (SY) and Fig. B- 14. shows the box plot for Unit Price ($/SY) based on 63 data points. The data were examined and two data points were removed due to deviations from the selection criteria. (One data point was found to have abnormal unit price. One was removed due to quantity outliers.) The number of data points used for the plantmix bituminous open-graded surface (3/4") regression model, following elimination of the deviations, was 61. The final box plots, after processing, are shown in Fig. B- 15. and Fig. B- 16.

The descriptive statistics of the plantmix bituminous open-graded surface (3/4") items are shown in Table 11. A wide range in quantity, from a low value of 578 SY to a maximum value of 214,894 SY, can be seen. The mean quantity for all projects was 41,382 SY, for which a standard deviation of 41,796 SY was seen. The range of unit price varied from $1.82/SY to $51.57/SY. The mean unit price was $8.57/SY and the standard deviation was $10.80/SY.

Table 11. Descriptive Statistics of Quantity and Unit Price for Plantmix Bituminous Open-Graded Surface (3/4" Depth)

	n	Minimum	Maximum	Mean	Std. Deviation
Quantity (SY)	61	578.00	214,894.00	41,381.81	41,795.83
Unit Price ($/SY)	61	1.82	51.57	8.57	10.80

Table 12 below shows the results of all the regression models calculated on this item. All the models were found to be significant at 95% confidence level, although they had varying R2 values.

Table 12. Result of Different Regression Models for Plantmix Bituminous Open-Graded Surface (3/4" Depth)

Model	R^2	Significance	Coefficient		Constant	
			Value	Significance	Value	Significance
Linear	0.176	0.001	-1.08E-4	0.001	13.058	<0.001
Logarithmic	0.372	<0.001	-5.331	<0.001	62.257	<0.001
Inverse	0.151	0.002	17,082.37	0.002	6.690	<0.001
Power	0.483	<0.001	-0.521	<0.001	988.464	0.166
Exponential	0.302	<0.001	-1.218E-5	<0.001	8.586	<0.001

The power model, having the highest R^2 value, at 48.3%, was chosen to transform the data and test for assumptions. Checks for mis specified model, heteroscedasticity, non-normal and correlated errors were performed, and the data was re-plotted. The random scatter around the base line in the final plot showed the aptness of the tests. The plots are shown in Fig. C- 4., Fig. D- 4., Fig. E- 4. and Fig. F- 4. respectively.

The plot in Fig. G-4. shows that almost all the data points lie between the 95% confidence interval lines. Both the predicted and the historical data points tend to cluster around the diagonal line. Hence, the power regression model was found acceptable for expressing this relational information..

The regression equation adopted for plantmix bituminous open graded surface (3/4") can be described mathematically as in Eq. 18:

$$UP_{PBOS} = 988.464 * Q_{PBOS}^{-0.521} \tag{18}$$

In this equation, the unit price of plantmix bituminous open graded surface (3/4") is shown in dollars per square yard, converted to the equivalency of 2008 dollars. The quantity for plantmix bituminous open-graded surface (3/4") is given in square yards:

UP_{PBOS} = Unit price of plantmix bituminous open-graded surface (3/4") in 2008 in $/SY

Q_{PBOS} = Quantity of plantmix bituminous open-graded surface (3/4") in SY

The data used for analysis are listed in Table H-4 and the resulting plot is shown in Fig. 12.

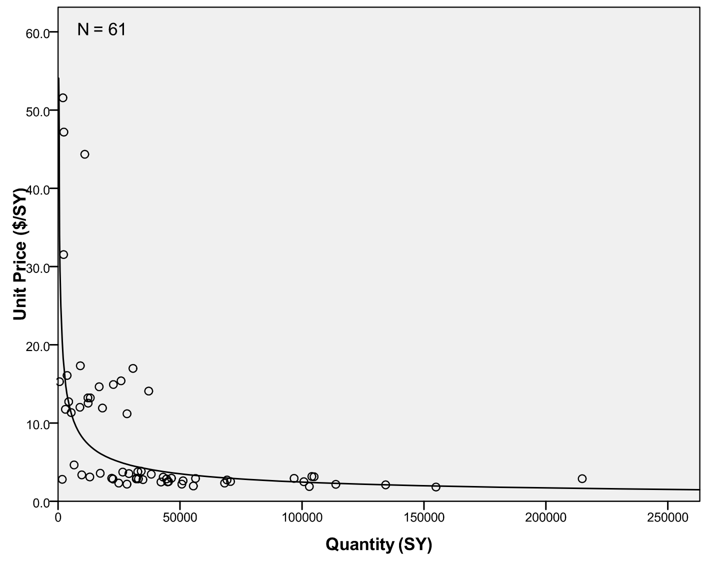


Fig. 12. Power regression model for plantmix bituminous open-graded surface (3/4" depth)

5.1.5 Item 406.01 Prime Coat

There were 62 data points for this item. The unit of measurement for prime coat is ton (TON). Fig. B- 17. shows the box plot for Quantity (TON), and Fig. B- 18. shows the box plot for Unit Price ($/TON) based on 62 data points. The data were examined, and no data points were removed due to deviations from the selection criteria.

The descriptive statistics of the prime coat items are shown in Table 13. A wide range in quantity, from a low value of 0.5 TON to a maximum value of 297 TON, can be seen. The mean quantity for all projects was 39 TON, for which a standard deviation of 59 TON was seen. The range of unit price varied from $1.19/TON to $2,301.02/TON. The mean unit price was $584.12/TON and the standard deviation was $381.03/TON.

Table 13. Descriptive Statistics of Quantity and Unit Price for Prime Coat

	n	Minimum	Maximum	Mean	Std. Deviation
Quantity (TON)	62	0.53	297.00	39.39	58.50
Unit Price ($/TON)	62	1.19	2,301.02	584.108	381.034

Table 14. Result of Different Regression Models for Prime Coat below shows the results of all the regression models calculated on this item. All the models were found to be significant at 95% confidence level, though they had varying R^2 values. The value of R^2 was 15.9% for linear model, 28.9% for logarithmic model, 18.8% for inverse model, 21.6% for power model and 30.8% for exponential model.

Table 14. Result of Different Regression Models for Prime Coat

Model	R^2	Significance	Coefficient		Constant	
			Value	Significance	Value	Significance
Linear	0.159	0.001	-2.599	0.001	686.504	<0.001
Logarithmic	0.289	<0.001	-134.441	<0.001	955.170	<0.001
Inverse	0.188	<0.001	443.400	<0.001	493.082	<0.001
Power	0.216	<0.001	-0.419	<0.001	1300.789	0.003
Exponential	0.308	<0.001	-0.013	<0.001	684.241	<0.001

The exponential model, having the highest R^2 value, at 30.8%, was chosen to transform the data and test for assumptions. Checks for mis-specified model, heteroscedasticity, non-normal and correlated errors were performed, and the data was re-plotted. The random scatter around the base line in the final plot showed the aptness of the tests. The plots are shown in Fig. C- 5., Fig. D- 5., Fig. E- 5. and Fig. F- 5. respectively.

The plot in Fig. G-5. shows that almost all the data points lie between the 95% confidence interval lines. Both the predicted and the historical data points tend to cluster around the diagonal line. Hence, the exponential regression model was found acceptable for expressing this relational information..

The regression equation adopted for prime coat can be described mathematically as in Eq. 19:

$$UP_{PC} = 684.241 * e^{-0.013 Q_{PC}} \qquad (19)$$

In this equation, the unit price of prime coat is shown in dollars per ton, converted to the equivalency of 2008 dollars. The quantity for prime coat is given in ton:

UP_{PC} = Unit price of prime coat in 2008 in \$/TON

Q_{PC} = Quantity of prime coat in TON

The data used for analysis are listed in Table H-5 and the resulting plot is shown in Fig. 13.

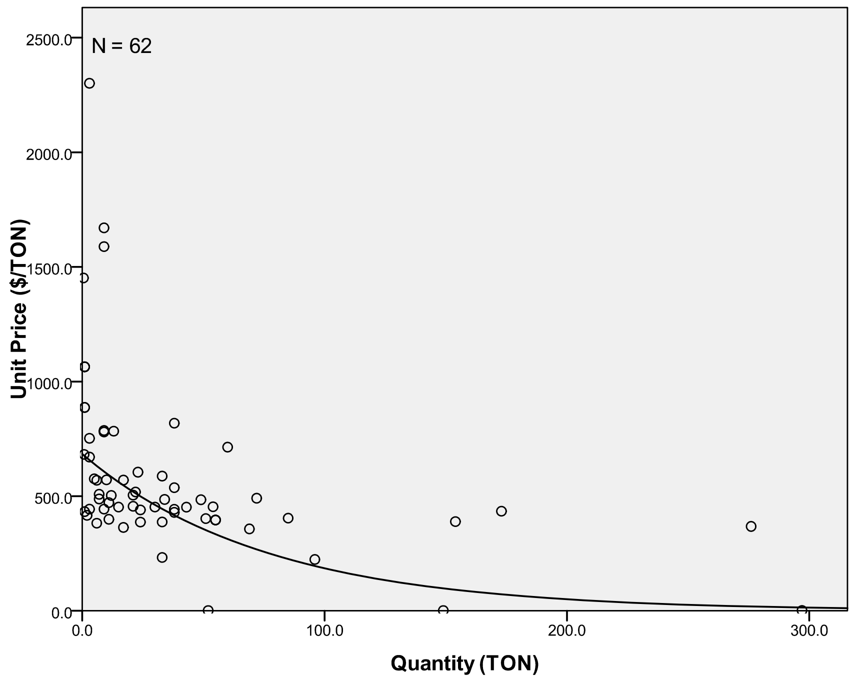


Fig. 13. Exponential regression model for prime coat

5.1.6 Item 405.01 Tack Coat

There were 38 data points for this item. The unit of measurement for tack coat is ton (TON). Fig. B- 19. shows the box plot for Quantity (TON) and Fig. B- 20. shows the box plot for Unit Price (\$/TON) based on 38 data points. The data were examined, and no data points were removed due to deviations from the selection criteria.

The descriptive statistics of the tack coat items are shown in Table 15. A wide range in quantity, from a low value of 1 TON to a maximum value of 142 TON, can be seen. The mean quantity for all projects was 39 TON, for which a standard deviation of 33 TON was seen. The range of unit price varied from $2.51/TON to $1,670.37/TON. The mean unit price was $417.84/TON and the standard deviation was $234.43/TON.

Table 15. Descriptive Statistics of Quantity and Unit Price for Tack Coat

	n	Minimum	Maximum	Mean	Std. Deviation
Quantity (TON)	38	1.00	142.00	38.87	32.62
Unit Price ($/TON)	38	2.51	1,670.37	417.84	234.43

Table 16 below shows the results of all the regression models calculated on this item. Models except power and linear were found to be significant at 95% confidence level.

Table 16. Result of Different Regression Models for Tack Coat

Model	R^2	Significance	Coefficient		Constant	
			Value	Significance	Value	Significance
Linear	0.089	0.068	-2.149	0.068	501.345	<0.001
Logarithmic	0.331	<0.001	-119.714	<0.001	802.472	<0.001
Inverse	0.695	<0.001	1070.119	<0.001	319.283	<0.001
Power	0.099	0.054	-0.248	0.054	776.663	0.024
Exponential	0.038	0.241	-0.005	0.241	429.846	<0.001

The inverse model, having the highest R^2 value, at 69.5%, was chosen to transform the data and test for assumptions. Checks for aptness of the tests are shown in Fig. C- 6., Fig. D- 6., Fig. E- 6. and Fig. F- 6. respectively and the plot of predicted value and historical value is shown in Fig. G-6 .

The regression equation adopted for tack coat can be described mathematically as in Eq. 20:

$$UP_{TC} = 319.283 + \frac{1070.119}{Q_{TC}} \tag{20}$$

In this equation, the unit price of tack coat is shown in dollars per ton, converted to the equivalency of 2008 dollars. The quantity for tack coat is given in ton:

UP_{TC} = Unit Price of tack coat in 2008 in $/TON

Q_{TC} = Quantity of tack coat in TON

The data used for analysis are listed in Table H-6 and the resulting plot is shown in Fig. 14.

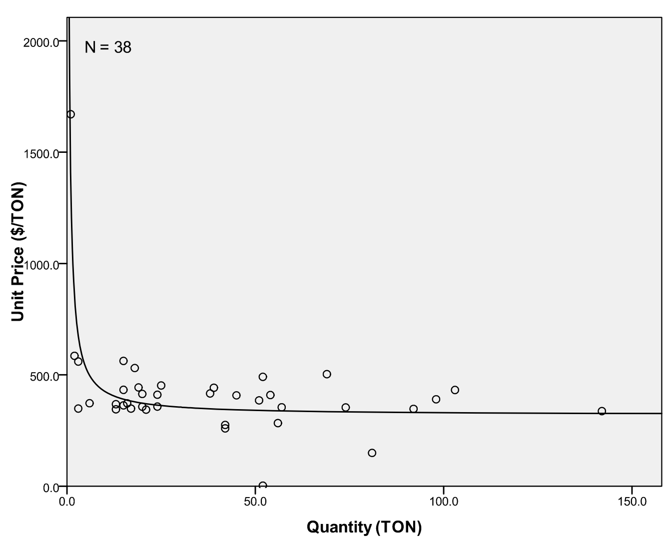


Fig. 14. Inverse regression model for tack coat

5.1.7 Item 407.01 Seal Coat

Initially, there were 65 data points for this item. The unit of measurement for seal coat is ton (TON). Fig. B- 21. shows the box plot for Quantity (TON) and Fig. B- 22. shows the box plot for Unit Price ($/TON) based on 65 data points. The data were examined, and one data point was removed due to deviation from the selection criteria. The number of data points used for the seal coat regression model, following elimination of the deviations, was 64. The final box plots, after processing, are shown in Fig. B- 23. and Fig. B- 24.

The descriptive statistics of the seal coat items are shown in Table 17. A wide range in quantity, from a low value of 0.23 TON to a maximum value of 125 TON, can be seen. The mean quantity for all projects was 23 TON, for which a standard deviation of 29 TON was seen. The range of unit price varied from $1.19/TON to $1670.37/TON. The mean unit price was $473.02/TON and the standard deviation was $258.02/TON.

Table 17. Descriptive Statistics of Quantity and Unit Price for Seal Coat

	n	Minimum	Maximum	Mean	Std. Deviation
Quantity (TON)	64	0.23	125.00	22.84	29.28
Unit Price ($/TON)	64	1.19	1,670.37	473.02	258.02

Table 18 below shows the results of all the regression models calculated on this item. All the models were found to be significant at 95% confidence level, though they had varying R^2 values.

Table 18. Result of Different Regression Models for Seal Coat

Model	R^2	Significance	Coefficient		Constant	
			Value	Significance	Value	Significance
Linear	0.155	0.001	-3.465	0.001	552.155	<0.001
Logarithmic	0.251	<0.001	-88.858	<0.001	672.509	<0.001
Inverse	0.188	<0.001	182.083	<0.001	419.006	<0.001
Power	0.152	0.001	-0.348	0.001	761.816	0.001
Exponential	0.181	<0.001	-0.019	<0.001	536.923	<0.001

The logarithmic model, having the highest R^2 value, at 25.1%, was chosen to transform the data and test for assumptions. The plots for check of aptness of the model are shown in Fig. C- 7., Fig. D- 7., Fig. E- 7. and Fig. F- 7. respectively. The plot between predicted and historical data points are shown in Fig. G-7.

The regression equation adopted for seal coat can be described mathematically as in Eq. 21:

$$UP_{SC} = 672.509 - 88.858 * \log(Q_{SC}) \tag{21}$$

In this equation, the unit price of seal coat is shown in dollars per ton, converted to the equivalency of 2008 dollars. The quantity for seal coat is given in ton:

UP_{SC} = Unit Price of seal coat in 2008 in $/TON

Q_{SC} = Quantity of seal coat in TON

The data used for analysis are listed in Table H-7 and the resulting plot is shown in Fig. 15.

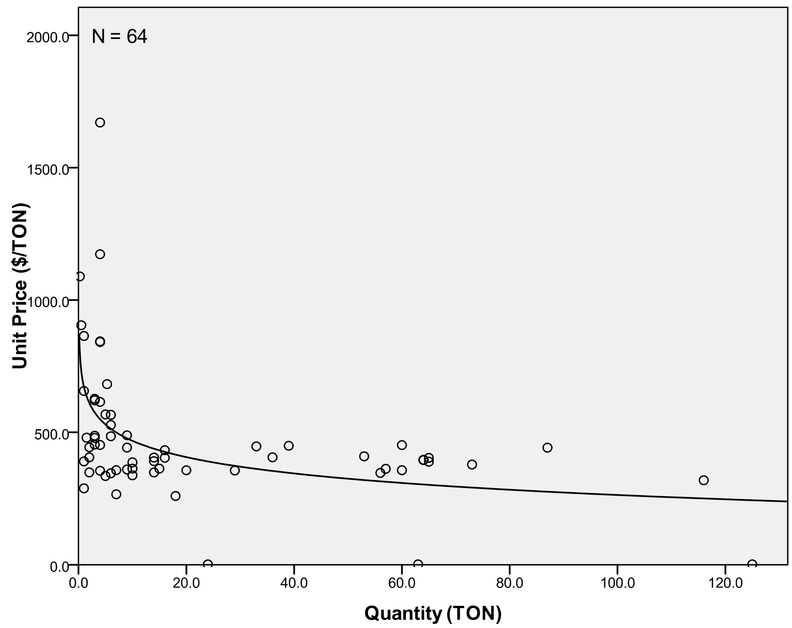


Fig. 15. Logarithmic regression model for seal coat

5.1.8 Item 613.02 Concrete Sidewalk

There were 58 data points for this item. The unit of measurement for concrete sidewalk is square foot (SF). Fig. B- 25. shows the box plot for Quantity (SF), and Fig. B- 26. shows the box plot for Unit Price ($/SF) based on 58 data points. The data were examined and no data points were removed due to deviations from the selection criteria.

The descriptive statistics of the concrete sidewalk items are shown in Table 19. A wide range in quantity, from a low value of 355 SF to a maximum value of 97,880 SF, can be seen. The mean quantity for all projects was 23,634 SF, for which a standard deviation of 23,779 SF was seen. The range of unit price varied from $2.70/SF to $11.14/SF. The mean unit price was $4.17/SF and the standard deviation was $1.82/SF.

Table 19. Descriptive Statistics of Quantity and Unit Price for Concrete Sidewalk

	n	Minimum	Maximum	Mean	Std. Deviation
Quantity (SF)	58	355.21	97,880.00	23,633.71	23,779.29
Unit Price ($/SF)	58	2.7	11.14	4.17	1.82

Table 20 below shows the results of all the regression models calculated on this item. All the models were found to be significant at 95% confidence level, though they had varying R^2 values.

Table 20. Result of Different Regression Models for Concrete Sidewalk

Model	R^2	Significance	Coefficient		Constant	
			Value	Significance	Value	Significance
Linear	0.202	<0.001	-3.435E-5	<0.001	4.985	<0.001
Logarithmic	0.529	<0.001	-1.026	<0.001	13.876	<0.001
Inverse	0.587	<0.001	3,138.540	<0.001	3.521	<0.001
Power	0.575	<0.001	-0.192	<0.001	24.132	<0.001
Exponential	0.275	<0.001	-7.193E-6	<0.001	4.646	<0.001

The inverse model, having the highest R^2 value, at 58.7%, was chosen to transform the data and test for assumptions. Checks for aptness of the tests are shown in Fig. C- 8., Fig. D- 8., Fig. E- 8. and Fig. F- 8. respectively and plot between predicted and historical data points is shown in Fig. G-8. Hence, the inverse regression model was found acceptable for expressing this relational information..

The regression equation adopted for concrete sidewalk can be described mathematically as in Eq. 22:

$$UP_{CS} = 3.521 + \frac{3138.54}{Q_{CS}} \tag{22}$$

In this equation, the unit price of concrete sidewalk is shown in dollars per square foot, converted to the equivalency of 2008 dollars. The quantity for concrete sidewalk is given in square foot:

UP_{CS} = Unit price of concrete sidewalk in 2008 in $/SF

Q_{CS} = Quantity of concrete sidewalk in SF

The data used for analysis are listed in Table H-8 and the resulting plot is shown in Fig. 16.

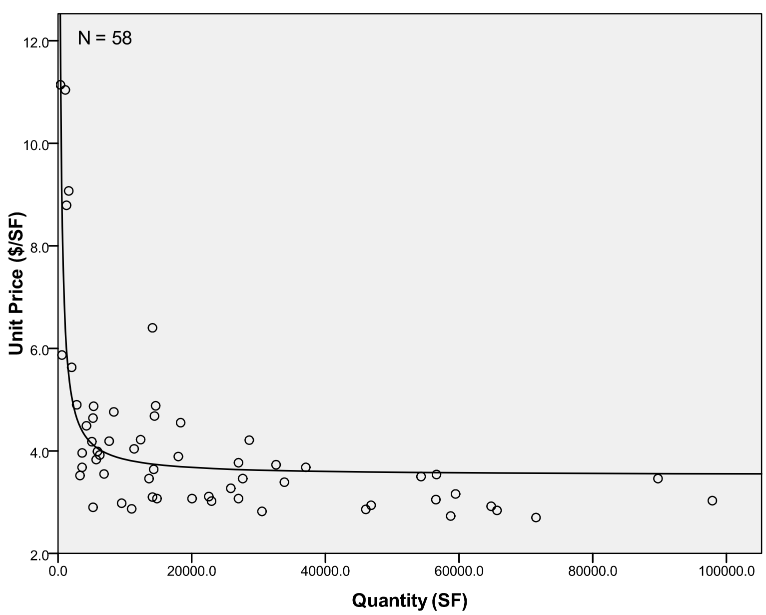


Fig. 16. Inverse regression model for concrete sidewalk

5.1.9 Item 613.03 Concrete Valley Gutter

There were 39 data points for this item. The unit of measurement for concrete valley gutter is cubic yards (CY). Fig. B- 26. shows the box plot for Quantity (SF), and Fig. B-27. shows the box plot for Unit Price ($/SF) based on 39 data points. The data were examined and no data points were removed due to deviations from the selection criteria.

The descriptive statistics of the concrete valley gutter items are shown in Table 21. A wide range in quantity, from a low value of 71 SF to a maximum value of 14,952 SF, can be seen. The mean quantity for all projects was 4,172 SF, for which a standard deviation of 3,917 SF was seen. The range of unit price varied from $2.22/SF to $16.75/SF. The mean unit price was $8.92/SF and the standard deviation was $2.58/SF.

Table 21. Descriptive Statistics of Quantity and Unit Price for Concrete Valley Gutter

	n	Minimum	Maximum	Mean	Std. Deviation
Quantity (SF)	39	71.00	14,952.00	4,171.77	3,916.76
Unit Price ($/SF)	39	2.22	16.75	8.92	2.53

Table 22 below shows the results of all the regression models calculated on this item. All the models were not found to be significant at 95% confidence level with varying R^2 values.

Table 22. Result of Different Regression Models for Concrete Valley Gutter

Model	R^2	Significance	Coefficient		Constant	
			Value	Significance	Value	Significance
Linear	0.019	0.398	-9.010E-5	0.398	9.296	<0.001
Logarithmic	0.177	0.008	-0.890	0.008	15.866	<0.001
Inverse	0.365	<0.001	673.215	<0.001	8.250	<0.001
Power	0.061	0.128	-0.065	0.128	14.201	0.004
Exponential	0.001	0.836	-2.749E-6	0.836	8.646	<0.001

The inverse model, having the highest R^2 value, at 36.5%, was chosen to transform the data and test for assumptions. Checks for mis-specified model, heteroscedasticity, non-normal and correlated errors were performed, and the data were re-plotted. The random scatter around the base line in the final plot showed the aptness of the tests. The plots are shown in Fig. C- 9., Fig. D- 9., Fig. E- 9. and Fig. F- 9. respectively.

The plot in Fig. G-9. shows that almost all the data points lie between the 95% confidence interval lines. Both the predicted and the historical data points tend to cluster around the diagonal line. Hence, the inverse regression model was found acceptable for expressing this relational information..

The regression equation adopted for concrete valley gutter can be described mathematically as in Eq. 23:

$$UP_{CVG} = 8.250 + \frac{673.215}{Q_{CVG}} \quad (23)$$

In this equation, the unit price of concrete valley gutter is shown in dollars per square foot, converted to the equivalency of 2008 dollars. The quantity for concrete valley gutter is given in square foot:

UP_{CVG} = Unit Price of concrete valley gutter in 2008 in \$/SF

Q_{CVG} = Quantity of concrete valley gutter in SF

The data used for analysis are listed in Table H-9 and the resulting plot is shown in Fig. 17.

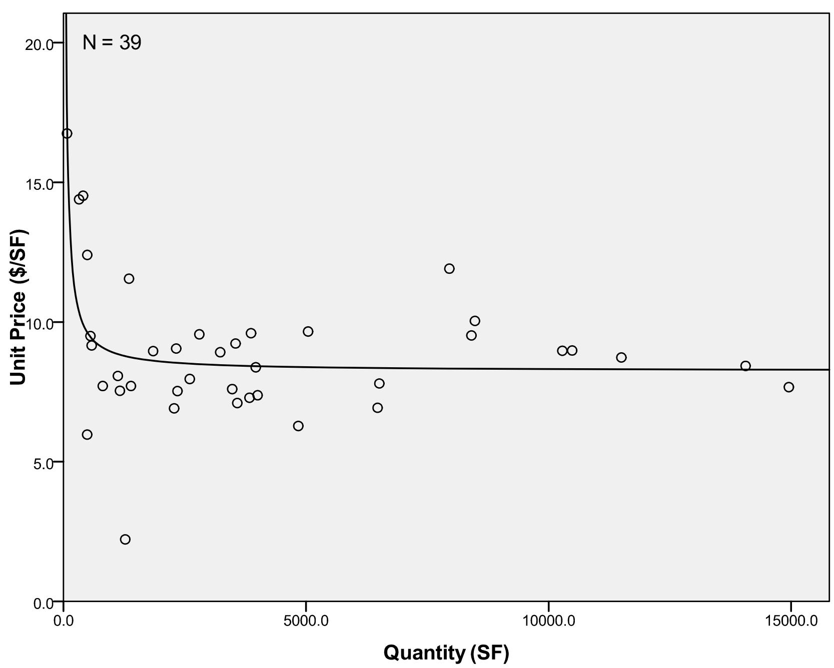


Fig. 17. Inverse regression model for concrete valley gutter

5.1.10 Item 613.01 Type "L" Curb and Gutter

Initially, there were 67 data points for this item. The unit of measurement for type "L" curb and gutter is linear foot (LF). Fig. B- 29. shows the box plot for Quantity (LF) and Fig. B- 30. shows the box plot for Unit Price ($/LF) based on 67 data points. The data were examined and two data points were removed due to deviations from the selection criteria. (One data point was found to have abnormal unit price. One was removed due to quantity outlier.) The number of data points used for the type "L" curb and gutter regression model, following elimination of the deviations, was 65. The final box plots, after processing, are shown in Fig. B- 31. and Fig. B- 32.

The descriptive statistics of the type "L" curb and gutter items are shown in Table 23. A wide range in quantity, from a low value of 85 LF to a maximum value of 18,889 LF, can be seen. The mean quantity for all projects was 5,544 LF, for which a standard deviation of 5,675 LF was seen. The range of unit price varied from $7.44/LF to $43.94/LF. The mean unit price was $14.77/LF and the standard deviation was $7.73/LF.

Table 23. Descriptive Statistics of Quantity and Unit Price for Type "L" Curb and Gutter

	n	Minimum	Maximum	Mean	Std. Deviation
Quantity (LF)	65	85.28	18,889.00	5,543.54	5,675.15
Unit Price ($/LF)	65	7.44	43.94	14.77	7.73

Table 24 below shows the results of all the regression models calculated on this item. All the models were found to be significant at 95% confidence level, though they had varying R^2 values.

Table 24. Result of Different Regression Models for Type “L” Curb and Gutter

Model	R^2	Significance	Coefficient		Constant	
			Value	Significance	Value	Significance
Linear	0.278	<0.001	-0.001	<0.001	18.758	<0.001
Logarithmic	0.634	<0.001	-4.200	<0.001	47.788	<0.001
Inverse	0.580	<0.001	2,452.801	<0.001	11.757	<0.001
Power	0.697	<0.001	-0.237	<0.001	85.989	<0.001
Exponential	0.367	<0.001	-4.432E-5	<0.001	17.125	<0.001

The power model, having the highest R^2 value, at 69.7%, was chosen to transform the data and test for assumptions. Checks for mis-specified model, heteroscedasticity, non-normal and correlated errors were performed, and the data was re-plotted. The random scatter around the base line in the final plot showed the aptness of the tests. The plots are shown in Fig. C- 10., Fig. D- 10., Fig. E- 10. and Fig. F- 10. respectively.

The plot in Fig. G-10. shows that almost all the data points lie between the 95% confidence interval lines. Both the predicted and the historical data points tend to cluster around the diagonal line. Hence, the power regression model was found acceptable for expressing this relational information.

The regression equation adopted for type “L” curb and gutter can be described mathematically as in Eq. 24:

$$UP_{TLCG} = 85.989 * Q_{TLCG}^{-0.237} \tag{24}$$

In this equation, the unit price of type “L” curb and gutter is shown in dollars per linear foot, converted to the equivalency of 2008 dollars. The quantity for type “L” curb and gutter is given in linear feet:

UP_{TLCG} = Unit price of type "L" curb and gutter in 2008 in $/LF

Q_{TLCG} = Quantity of type "L" curb and gutter in LF

The data used for analysis are listed in

Table H-10 and the resulting plot is shown in Fig. 18.

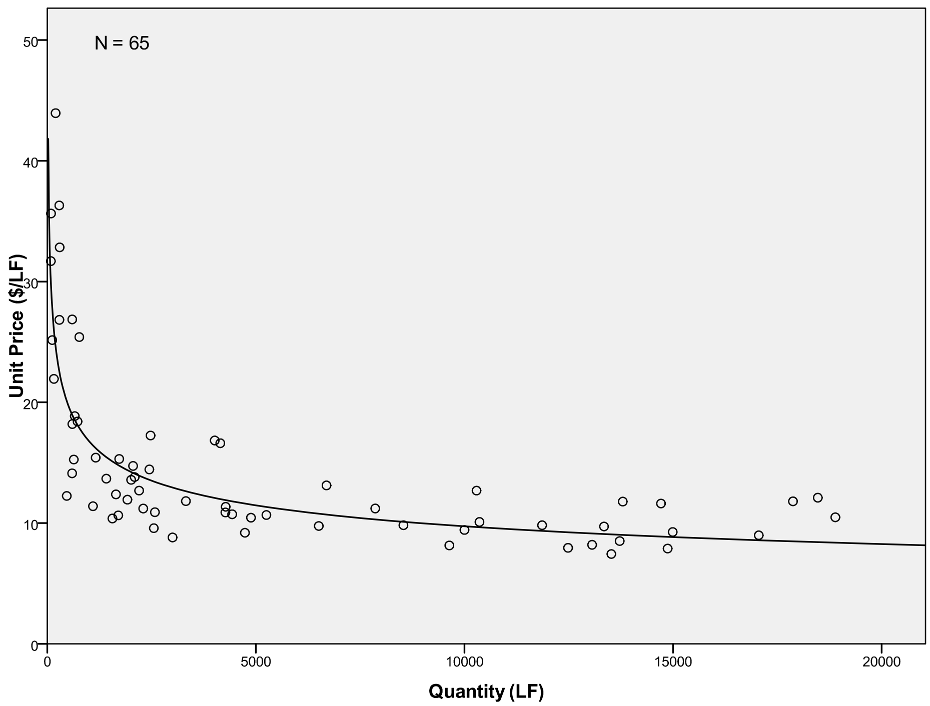


Fig. 18. Power regression model for type "L" curb and gutter

5.1.11 Item 633.01 Reflective Pavement Markers

Initially, there were 110 data points for this item. The unit of measurement for reflective pavement markers is each (EA). Fig. B- 33. shows the box plot for Quantity (EA) and Fig. B- 34. shows the box plot for Unit Price ($ EA) based on 110 data points. The data were examined and four data points were removed due to deviations from the selection criteria. (Two data points were found to have abnormal unit prices. Two were removed due to quantity outliers.) The number of data points used for the reflective pavement markers regression model, following elimination of the deviations, was 106. The final box plots, after processing, are shown in Fig. B- 35. and Fig. B- 36.

The descriptive statistics of the reflective pavement markers items are shown in Table 25. A wide range in quantity, from a low value of 16 to a maximum value of 6,204, can be seen. The mean quantity for all projects was 1,429, for which a standard deviation of 1,139 was seen. The range of unit price varied from $1.57 EA to $7.37 EA. The mean unit price was $3.81 EA and the standard deviation was $0.86 EA.

Table 25. Descriptive Statistics of Quantity and Unit Price for Reflective Pavement Markers

	n	Minimum	Maximum	Mean	Std. Deviation
Quantity (EA)	106	16.00	6204.00	1,429.30	1,138.61
Unit Price ($ EA)	106	1.57	7.37	3.81	0.86

Table 26 below shows the results of all the regression models calculated on this item. All the models were found to be significant at 95% confidence level, though they had varying R^2 values.

Table 26. Result of Different Regression Models for Reflective Pavement Markers

Model	R^2	Significance	Coefficient		Constant	
			Value	Significance	Value	Significance
Linear	0.043	0.033	-1.572E-4	0.033	4.039	<0.001
Logarithmic	0.079	0.004	-0.208	0.004	5.234	<0.001
Inverse	0.070	0.006	57.425	0.006	3.729	<0.001
Power	0.076	0.004	-0.059	0.004	5.541	<0.001
Exponential	0.061	0.010	-5.423E-5	0.010	4.007	<0.001

The logarithmic model, having the highest R^2 value, at 7.9%, was chosen to transform the data and test for assumptions. Checks for mis-specified model, heteroscedasticity, non-normal and correlated errors were performed, and the data was re-plotted. The random scatter around the base line in the final plot showed the aptness of the tests. The plots are shown in Fig. C- 11., Fig. D- 11., Fig. E- 11. and Fig. F- 11. respectively.

The plot in Fig. G-11. shows that almost all the data points lie between the 95% confidence interval lines. Both the predicted and the historical data points tend to cluster around the diagonal line. Hence, the logarithmic regression model was found acceptable for expressing this relational information.

The regression equation adopted for reflective pavement markers can be described mathematically as in Eq. 25:

$$UP_{RPM} = 5.234 - 0.208 * \log(Q_{RPM}) \tag{25}$$

In this equation, the unit price of reflective pavement markers is shown in dollars each, converted to the equivalency of 2008 dollars. The quantity for reflective pavement markers is given in numbers:

UP_{RPM} = Unit price of reflective pavement markers in 2008 in \$/EA

Q_{RPM} = Quantity of reflective pavement markers in numbers

The data used for analysis are listed in Table H-11 and the resulting plot is shown in Fig. 19.

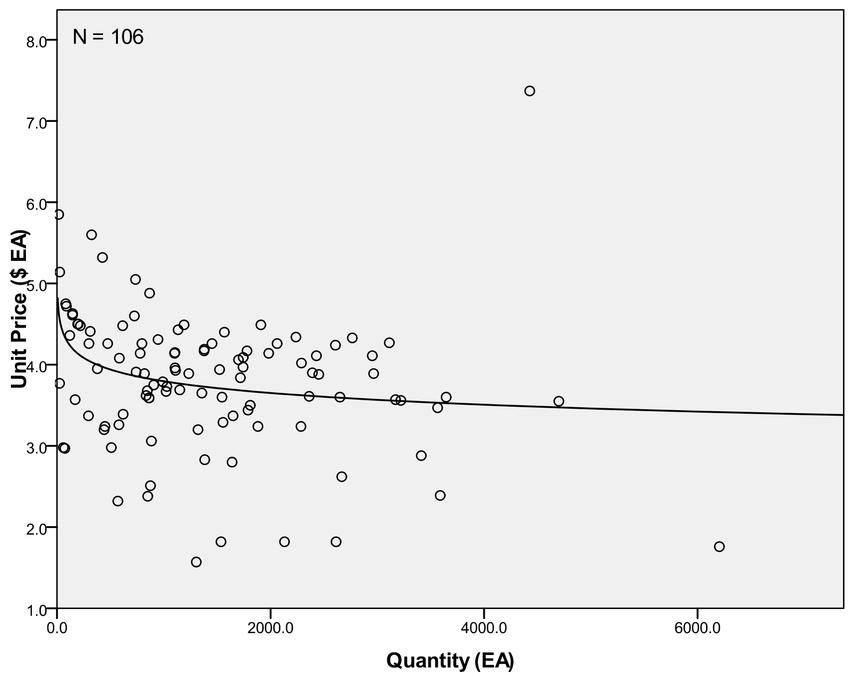


Fig. 19. Logarithmic regression model for reflective pavement markers

5.1.12 Item 633.02 Non-reflective Pavement Markers

Initially, there were 110 data points for this item. The unit of measurement for non-reflective pavement markers is each (EA). Fig. B- 37. shows the box plot for Quantity (EA) and Fig. B- 38. shows the box plot for Unit Price ($ EA) based on 110 data points. The data were examined and three data points were removed due to deviations from the selection criteria. (Two data points were found to have abnormal unit prices. One was removed due to quantity outlier.) The number of data points used for the non-reflective pavement markers regression model, following elimination of the deviations, was 107. The final box plots, after processing, are shown in Fig. B- 39. and Fig. B- 40.

The descriptive statistics of the non reflective pavement markers items are shown in Table 27. A wide range in quantity, from a low value of 42 to a maximum value of 16,477, can be seen. The mean quantity for all projects was 3,667, for which a standard deviation of 2,966 was seen. The range of unit price varied from $1.07 EA to $6.91 EA. The mean unit price was $2.22 EA and the standard deviation was $0.76 EA.

Table 27. Descriptive Statistics of Quantity and Unit Price for Non-Reflective Pavement Markers

	n	Minimum	Maximum	Mean	Std. Deviation
Quantity (EA)	107	42.00	16,477.00	3,667.18	2,965.99
Unit Price ($ EA)	107	1.07	6.91	2.22	0.76

Table 28 below shows the results of all the regression models calculated on this item. All the models, except linear, were found to be significant at 95% confidence level, though they had varying R^2 values.

Table 28. Result of Different Regression Models for Non-Reflective Pavement Markers

Model	R^2	Significance	Coefficient		Constant	
			Value	Significance	Value	Significance
Linear	0.017	0.178	-3.362E-5	0.178	2.340	<0.001
Logarithmic	0.042	0.035	-0.136	0.035	3.271	<0.001
Inverse	0.043	0.031	51.886	0.031	2.157	<0.001
Power	0.071	0.005	-0.069	0.005	3.623	<0.001
Exponential	0.049	0.022	-2.212E-5	0.022	2.295	<0.001

The power model, having the highest R^2 value, at 7.1%, was chosen to transform the data and test for assumptions. Checks for mis-specified model, heteroscedasticity, non-normal and correlated errors were performed, and the data was re-plotted. The random scatter around the base line in the final plot showed the aptness of the tests. The plots are shown in Fig. C- 12., Fig. D- 12., Fig. E- 12. and Fig. F- 12. respectively.

The plot in Fig. G-12. shows that almost all the data points lie between the 95% confidence interval lines. Both the predicted and the historical data points tend to cluster around the diagonal line. Hence, the power regression model was found acceptable for expressing this relational information.

The regression equation adopted for non-reflective pavement markers can be described mathematically as in Eq. 26:

$$UP_{NRPM} = 3.623 * Q_{NRPM}^{-0.069} \qquad (26)$$

In this equation, the unit price of non-reflective pavement markers is shown in dollars each, converted to the equivalency of 2008 dollars. The quantity for non-reflective pavement markers is given in numbers:

UP_{NRPM} = Unit price of non reflective pavement markers in 2008 in $/EA

Q_{NRPM} = Quantity of non reflective pavement markers in numbers

The data used for analysis are listed in Table H-12 and the resulting plot is shown in Fig. 20.

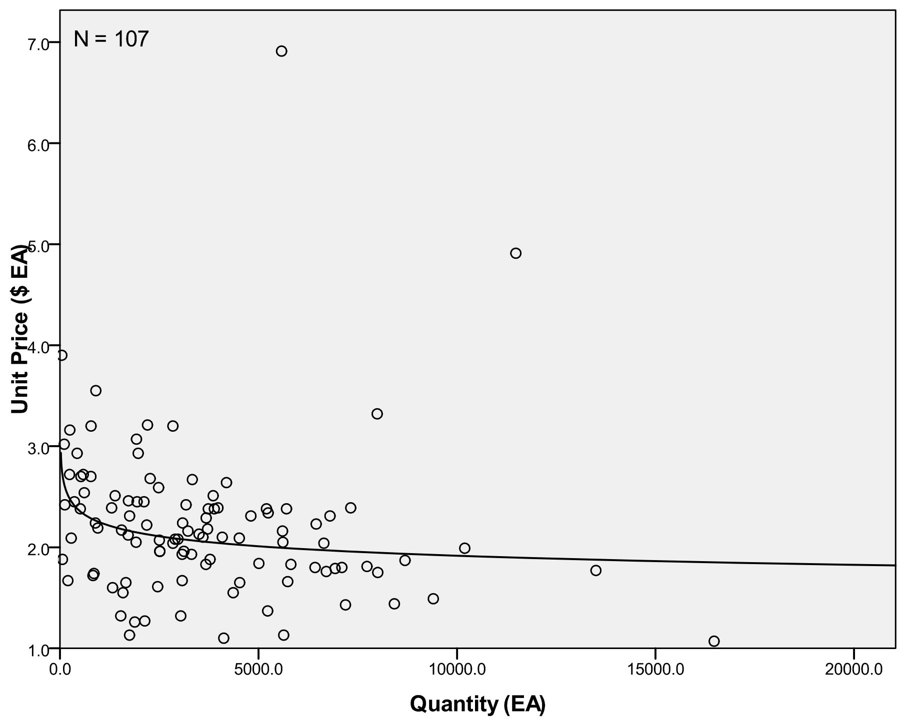


Fig. 20. Power regression model for non reflective pavement markers

5.2 Regression Models for Lump-sum Items

Typically, lump sum applies to items for which a quantity is not easily identified, cannot be known with certainty, or for which quantity is not relevant to the pricing. There were altogether 5 items that were successfully modeled for this research. "Item 200.01 Mobilization" could not be fitted into any regression model and hence was removed from the analysis. The regression analyses for each item are as follows,

5.2.1 Item 105.01 Quality Control

Initially, there were 84 data points for this item. Fig. B- 41. shows the box plot for percentage of total bid assigned to the item and Fig. B- 42. shows the box plot for total bid cost of the project ($) based on 84 data points. The data were examined, and six data points were removed due to deviations from the selection criteria. (Three data points were found to have abnormal percent of total bid cost. Three were removed due to total bid cost outliers.) The number of data points used for the quality control regression model, following elimination of the deviations, was 78. The final box plots, after processing, are shown in Fig. B- 43. and Fig. B- 44.

The descriptive statistics of the quality control are shown in Table 29. A wide range in percentage of total bid assigned to the item, from a low value of 0.25 to a maximum value of 13.37, can be seen. The mean percent for all projects was 3.84, for which a standard deviation of 2.47 was seen. The range of total bid cost varied from $147,446 to $31,363,171. The mean bid cost was $6,135,726 and the standard deviation was $7,273,189.

Table 29. Descriptive Statistics of Percentage of Total Bid and Total Bid for Quality Control

	n	Minimum	Maximum	Mean	Std. Deviation
% of Total Bid	78	0.25	13.37	3.84	2.47
Total Bid ($)	78	147,445.76	31,363,171.36	6,135,725.81	7,273,188.81

Table 30 below shows the results of all the regression models calculated on this item. All the models were found to be significant at 95% confidence level, though they had varying R^2 values.

Table 30. Result of Different Regression Models for Quality Control

Model	R^2	Significance	Coefficient		Constant	
			Value	Significance	Value	Significance
Linear	0.106	0.004	-1.106E-7	<0.001	4.519	0.349
Logarithmic	0.169	<0.001	-0.749	<0.001	14.995	<0.001
Inverse	0.108	0.003	623,760.648	0.003	3.317	<0.001
Power	0.097	0.005	-0.179	0.005	43.229	0.287
Exponential	0.078	0.013	-2.982E-8	0.013	3.630	<0.001

The logarithmic model, having the highest R^2 value, at 16.9%, was chosen to transform the data and test for assumptions. Checks for aptness of the tests are shown in Fig. C- 13., Fig. D- 13., Fig. E- 13. and Fig. F- 13. respectively.The plot in Fig. G-13.

shows that almost all the data points lie between the 95% confidence interval lines. Both the predicted and the historical data points tend to cluster around the diagonal line. Hence, the quality control regression model was found acceptable for expressing this relational information.

The regression equation adopted for quality control can be described mathematically as in Eq. 27:

$$P_{QC} = 14.995 - 0.749 * \log(TBC) \tag{27}$$

where,

P_{QC} = Percentage of total bid cost assigned to quality control

TBC = Total bid cost of the project in 2008 in $

The data used for analysis are listed in Table H-13 and the resulting plot is shown in Fig. 21.

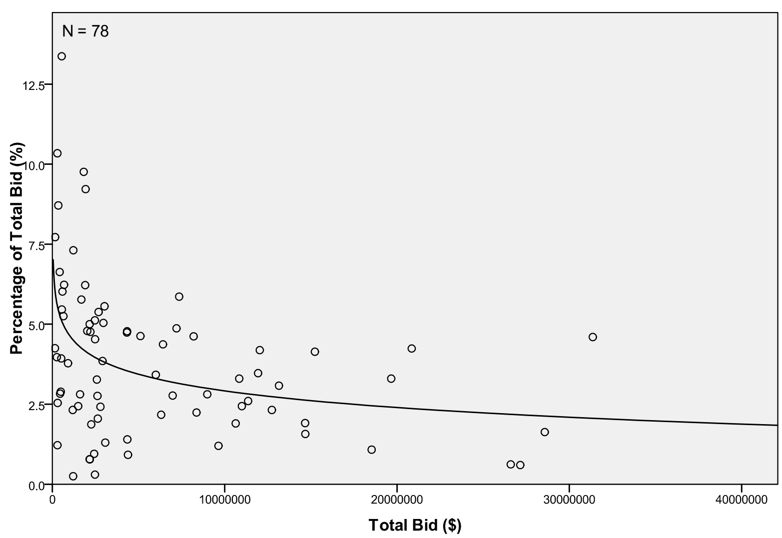


Fig. 21. Logarithmic regression model for quality control

5.2.2 Item 107.01 Traffic Control

Initially, there were 136 data points for this item. Fig. B- 45. shows the box plot for percentage of total bid assigned to the item and Fig. B- 46. shows the box plot for total bid cost of the project ($) based on 136 data points. The data were examined, and two data points were removed due to deviations from the selection criteria. (One data point was found to have abnormal percent of total bid cost. One was removed due to total bid cost outlier.) The number of data points used for the traffic control regression model, following elimination of the deviations, was 114. The final box plots, after processing, are shown in Fig. B- 47. and Fig. B- 48.

The descriptive statistics of the traffic control are shown in Table 31. A wide range in percentage of total bid assigned to the item, from a low value of 0.07 to a maximum value of 12.8, can be seen. The mean percent for all projects was 2.98, for which a standard deviation of 2.46 was seen. The range of total bid cost varied from $70,546 to $48,921.137. The mean bid cost was $4,976,406 and the standard deviation was $7,676,464.

Table 31. Descriptive Statistics of Percentage of Total Bid and Total Bid for Traffic Control

	n	Minimum	Maximum	Mean	Std. Deviation
% of Total Bid	134	0.07	12.80	2.98	2.46
Total Bid ($)	134	70,545.52	48,921,137.36	4,976,405.86	7,676,464.13

Table 32 below shows the results of all the regression models calculated on this item. All the models were found to be significant at 95% confidence level, though they had varying R^2 values.

Table 32. Result of Different Regression Models for Traffic Control

Model	R^2	Significance	Coefficient		Constant	
			Value	Significance	Value	Significance
Linear	0.098	<0.001	-1.002E-7	<0.001	3.478	<0.001
Logarithmic	0.210	<0.001	-0.802	<0.001	14.659	<0.001
Inverse	0.119	<0.001	430,463.774	<0.001	2.456	<0.001
Power	0.203	<0.001	-0.280	<0.001	129.451	0.136
Exponential	0.176	<0.001	-4.550E-8	_	2.752	<0.001

The logarithmic model, having the highest R^2 value, at 21%, was chosen to transform the data and test for assumptions. Checks for mis-specified model, heteroscedasticity, non-normal and correlated errors were performed, and the data was re-plotted. The random scatter around the base line in the final plot showed the aptness of the tests. The plots are shown in Fig. C- 14., Fig. D- 14., Fig. E- 14. and Fig. F- 14. respectively.

The plot in Fig. G-14. shows that almost all the data points lie between the 95% confidence interval lines. Both the predicted and the historical data points tend to cluster around the diagonal line. Hence, the logarithmic regression model was found acceptable for expressing this relational information.

The regression equation adopted for traffic control can be described mathematically as in Eq. 26:

$$P_{TC} = 14.659 - 0.802 * \log(TBC) \tag{28}$$

where,

P_{TC} = Percentage of total bid cost assigned to traffic control

TBC = Total bid cost of the project in 2008 in $

The data used for analysis are listed in Table H-14and the resulting plot is shown in Fig. 22.

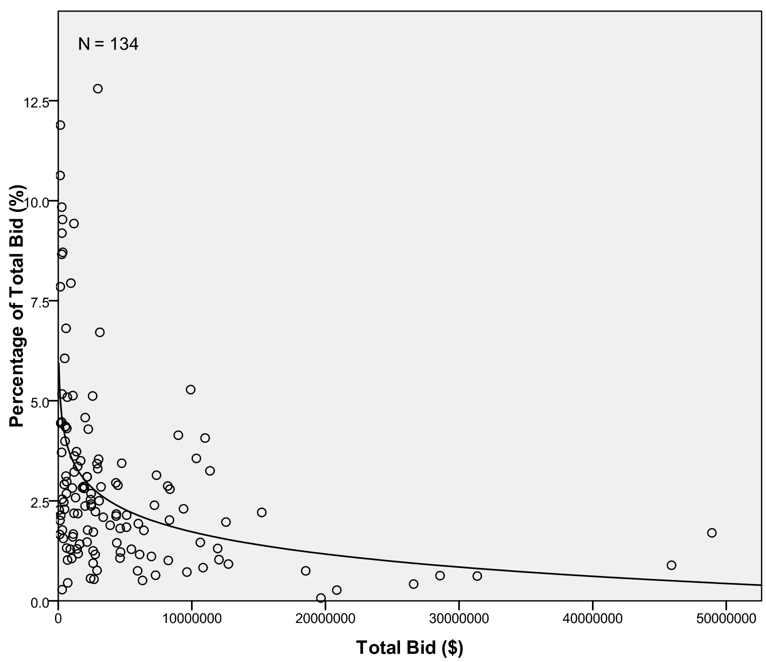


Fig. 22. Logarithmic regression model for traffic control

5.2.3 Item 109.03 Construction Conflicts and Additional Work Items

Initially, there were 145 data points for this item. Fig. B- 49. shows the box plot for percentage of total bid assigned to the item, and Fig. B- 50. shows the box plot for total bid cost of the project ($) based on 145 data points. The data were examined, and one data point was removed due to deviations from the selection criteria. Another point was removed due to total bid cost outliers. The number of data points used for the construction conflicts and additional works regression model, following elimination of the deviations, was 143. The final box plots, after processing, are shown in Fig. B- 51. and Fig. B- 52.

The descriptive statistics of the construction conflicts and additional work items are shown in Table 33. A wide range in percentage of total bid assigned to the item, from a low value of 0.49 to a maximum value of 13.56, can be seen. The mean percent for all projects was 4.41 for which a standard deviation of 2.79 was seen. The range of total bid cost varied from $70,546 to $48,921. The mean bid cost was $5,473,017 and the standard deviation was $8,380,900.

Table 33. Descriptive Statistics of Percentage of Total Bid and Total Bid for Construction Conflicts and Additional Work Items

	n	Minimum	Maximum	Mean	Std. Deviation
% of Total Bid	143	0.49	13.56	4.41	2.79
Total Bid ($)	143	70,545.52	48,921,137.36	5,473,017.41	8,380,899.67

Table 34 below shows the results of all the regression models calculated on this item. All the models were found to be significant at 95% confidence level, though they had varying R2 values.

Table 34. Result of Different Regression Models for Construction Conflicts and Additional Work Items

Model	R^2	Significance	Coefficient		Constant	
			Value	Significance	Value	Significance
Linear	0.195	<0.001	-1.473E-7	<0.001	5.218	<0.001
Logarithmic	0.314	<0.001	-1.087	<0.001	20.297	<0.001
Inverse	0.192	<0.001	633,177.801	<0.001	3.659	<0.001
Power	0.436	<0.001	-0.291	<0.001	256.485	0.016
Exponential	0.405	<0.001	-4.816E-8	-	4.750	<0.001

The power model, having the highest R^2 value, at 43.6%, was chosen to transform the data and test for assumptions. Checks for misspecified model, heteroscedasticity, non-normal and correlated errors were performed, and the data was re-plotted. The random scatter around the base line in the final plot showed the aptness of the tests. The plots are shown in Fig. C- 15., Fig. D- 15., Fig. E- 15. and Fig. F- 15. respectively.

The plot in Fig. G-15. shows that almost all the data points lie between the 95% confidence interval lines. Both the predicted and the historical data points tend to cluster around the diagonal line. Hence, the power regression model was found acceptable for expressing this relational information.The regression equation adopted for construction conflicts and additional work items can be described mathematically as in Eq. 29:

$$P_{CCAW} = 256.485 * TBC^{-0.291} \quad (29)$$

where,

P_{CCAD} = Percentage of total bid cost assigned to construction conflicts and additional works

TBC = Total bid cost of the project in 2008 in $

The data used for analysis are listed in Table H-15 and the resulting plot is shown in Fig. 23.

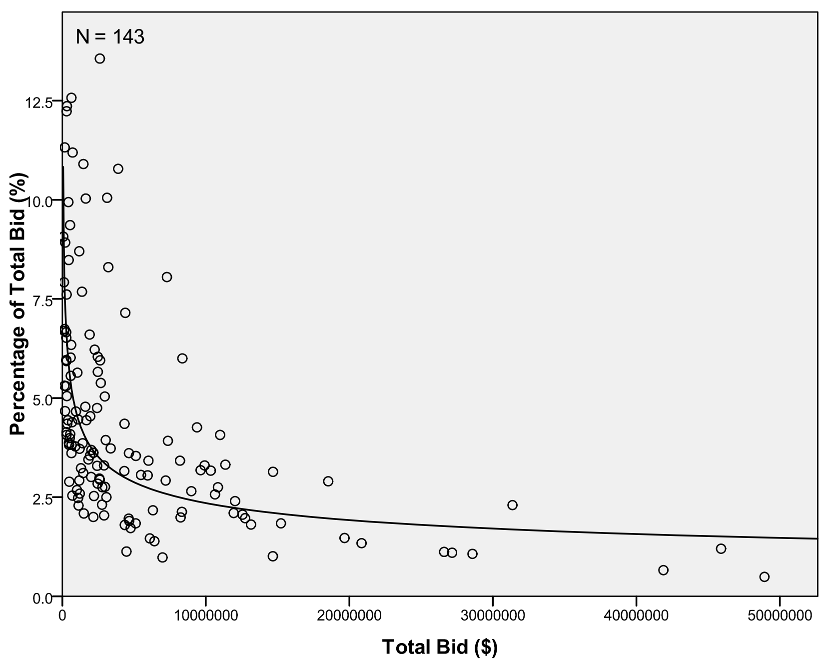


Fig. 23. Power regression model for construction conflicts and additional work items

5.2.4 Item 201.01 Clearing and Grubbing

Initially, there were 71data points for this item. Fig. B- 53. shows the box plot for percentage of total bid assigned to the item and Fig. B- 54. shows the box plot for total bid cost of the project ($) based on 71 data points. The data were examined and seven data points were removed due to deviations from the selection criteria. Four data points were found to have abnormal percent of total bid cost. Three were removed due to total bid cost outliers. The number of data points used for the clearing and grubbing regression model, following elimination of the deviations, was 64. The final box plots, after processing, are shown in Fig. B- 55. and Fig. B- 56.

The descriptive statistics of the clearing and grubbing are shown in Table 35. A wide range in percentage of total bid assigned to the item, from a low value of 0.04 to a maximum value of 5.95, can be seen. The mean percent for all projects was 1.22, for which a standard deviation of 1.5 was seen. The range of total bid cost varied from $135,716 to $26,601.186. The mean bid cost was $5,104,792 and the standard deviation was $5,447,626.

Table 35. Descriptive Statistics of Percentage of Total Bid and Total Bid for Clearing and Grubbing

	n	Minimum	Maximum	Mean	Std. Deviation
% of Total Bid	64	0.04	5.95	1.22	1.50
Total Bid ($)	64	135,716.15	26,601,185.65	5,104,792.07	5,447,626.25

Table 36 below shows the results of all the regression models calculated on this item. All the models were found to be significant at 95% confidence level, though they had varying R^2 values.

Table 36. Result of Different Regression Models for Clearing and Grubbing

Model	R^2	Significance	Coefficient		Constant	
			Value	Significance	Value	Significance
Linear	0.117	0.006	-9.450E-8	0.006	1.706	<0.001
Logarithmic	0.226	<0.001	-0.552	<0.001	9.387	<0.001
Inverse	0.212	<0.001	513,139.68	<0.001	0.772	<0.001
Power	0.319	<0.001	-0.567	<0.001	2,581.65	0.525
Exponential	0.161	0.001	-9.508E-8	0.001	0.960	<0.001

The power model, having the highest R^2 value, at 31.9%, was chosen to transform the data and test for assumptions. Checks for mis-specified model, heteroscedasticity, non-normal and correlated errors were performed, and the data was re-plotted. The random scatter around the base line in the final plot showed the aptness of the tests. The plots are shown in Fig. C- 16., Fig. D- 16., Fig. E- 16. and Fig. F- 16. respectively.

The plot in Fig. G-16. shows that almost all the data points lie between the 95% confidence interval lines. Both the predicted and the historical data points tend to cluster around the diagonal line. Hence, the power regression model was found acceptable for expressing this relational information.

The regression equation adopted for clearing and grubbing can be described mathematically as in Eq. 30:

$$P_{CG} = 2{,}581.659 * TBC^{-0.567} \tag{30}$$

where,

P_{CG}= Percentage of total bid cost assigned to clearing and grubbing

TBC = Total bid cost of the project in 2008 in $

The data used for analysis are listed in Table H-16 and the resulting plot is shown in Fig. 24.

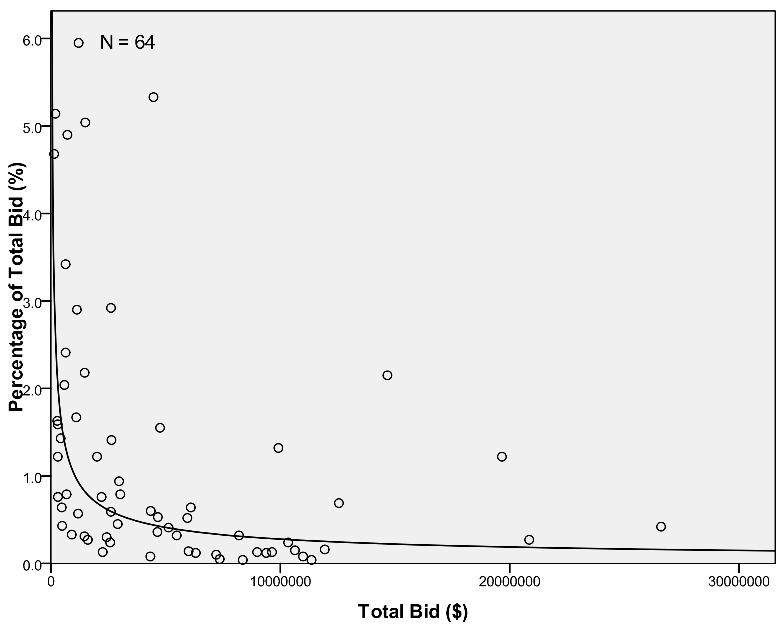


Fig. 24. Power regression model for clearing and grubbing

5.2.5 Item 637.01 Dust Control

There were 44 data points for this item. Fig. B- 57. shows the box plot for percentage of total bid assigned to the item and Fig. B- 58. shows the box plot for total bid cost of the project ($) based on 44 data points. The data were examined, and no data points were removed due to deviations from the selection criteria.

The descriptive statistics of the dust control are shown in Table 37. A wide range in percentage of total bid assigned to the item, from a low value of 0.03 to a maximum value of 2.8, can be seen. The mean percent for all projects was 0.64, for which a standard deviation of 0.62 was seen. The range of total bid cost varied from $258,100 to $48,921,137. The mean bid cost was $6,707,618 and the standard deviation was $9,243,544.51.

Table 37. Descriptive Statistics of Percentage of Total Bid and Total Bid for Dust Control

	n	Minimum	Maximum	Mean	Std. Deviation
% of Total Bid	44	0.03	2.80	0.64	0.62
Total Bid ($)	44	258,100.47	48,921,137.36	6,707,618.48	9,243,544.51

Table 38 below shows the results of all the regression models calculated on this item. All the models were found to be significant at 95% confidence level, though they had varying R^2 values.

Table 38. Result of Different Regression Models for Dust Control

Model	R^2	Significance	Coefficient		Constant	
			Value	Significance	Value	Significance
Linear	0.085	0.055	-1.956E-8	-	0.771	<0.001
Logarithmic	0.270	<0.001	-0.245	<0.001	4.297	<0.001
Inverse	0.362	<0.001	410,297.82	<0.001	0.354	0.001
Power	0.254	<0.001	-0.385	<0.001	133.501	0.517
Exponential	0.148	0.010	-4.203E-8	0.010	0.557	<0.001

The inverse model, having the highest R^2 value, at 36.2%, was chosen to transform the data and test for assumptions. Checks for aptness of the tests are shown in Fig. C- 17., Fig. D- 17., Fig. E- 17. and Fig. F- 17. respectively. The plot in Fig. G-17. shows that almost all the data points lie between the 95% confidence interval lines. Both the predicted and the historical data points tend to cluster around the diagonal line. Hence, the inverse regression model was found acceptable for expressing this relational information. The regression equation adopted for dust control can be described mathematically as in Eq. 31:

$$P_{DC} = 0.354 + \frac{410{,}297.827}{TBC} \tag{31}$$

where,

P_{DC} = Percentage of total bid cost assigned to dust control

TBC = Total bid cost of the project in 2008 in $

The data used for analysis are listed in Table H-17 and the resulting plot is shown in Fig. 25.

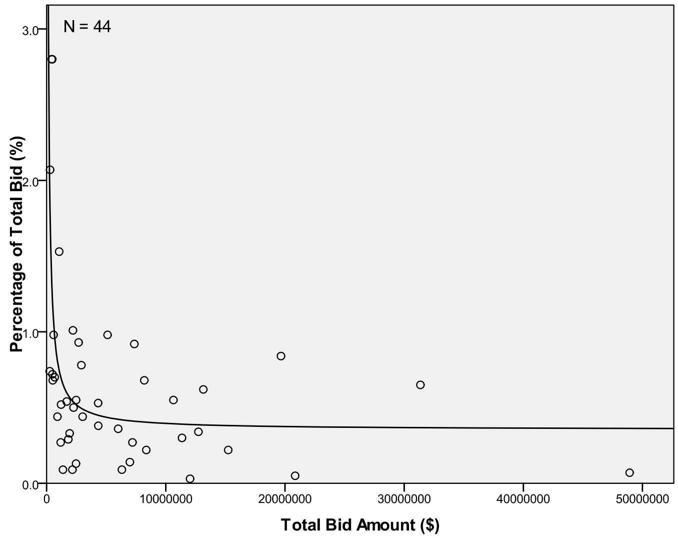


Fig. 25. Inverse regression model for dust control

5.3 Regression Model for Total Completion Cost

There were 112 data points for this item. Fig. B- 59. shows the box plot for total bid cost ($) and total completion cost ($) based on 112 data points. The data were examined, and no data points were removed due to deviations from the selection criteria.

The descriptive statistics of the total bid cost and total completion cost are shown in Table 39. A wide range in total bid cost, from a low value of $74,779 to a maximum value of $41,111,111, can be seen. The mean bid cost was $3,920,476, for which a standard deviation of $5,905,363 was seen. The range of total completion cost varied from $74,779 to $42,965,986. The mean completion cost was $4,072,838and the standard deviation was $6,196,127.

Table 39. Descriptive Statistics of Total Bid Cost and Total Completion Cost

	n	Minimum	Maximum	Mean	Std. Deviation
Total Bid Cost ($)	112	74,779.30	41,111,111.00	3,920,476.10	5,905,363.62
Total Completion Cost ($)	112	74,779.30	42,965,986.46	4,072,838.19	6,196,127.36

Table 40 below shows the results of all the regression models calculated on this item. All the models were found to be significant at 95% confidence level, though they had varying R^2 values.

Table 40. Result of Different Regression Models for Total Completion Cost

Model	R^2	Significance	Coefficient		Constant	
			Value	Significance	Value	Significance
Linear	0.997	<0.001	1.048	<0.001	-34,716.80	0.036
Logarithmic	0.548	<0.001	3,220,610.69	<0.001	42,015,730.95	<0.001
Inverse	0.135	<0.001	-9.59569E11	<0.001	5,577,610.97	<0.001
Power	0.997	<0.001	0.993	<0.001	1.157	<0.001
Exponential	0.560	<0.001	1.7947E-7	<0.001	845,459.84	<0.001

The linear model and power model had the same R^2 value. But, for simplicity, the linear model, having the R^2 value, at 99.7%, was chosen to test for assumptions. Checks for mis-specified model, heteroscedasticity, non-normal and correlated errors were performed, and the data was re-plotted. The random scatter around the base line in the final plot showed the aptness of the tests. The plots are shown in Fig. C- 18., Fig. D- 18., Fig. E- 18. and Fig. F- 18. respectively.

The plot in Fig. G-18. shows that almost all the data points lie between the 95% confidence interval lines. Both the predicted and the historical data points tend to cluster around the diagonal line. Hence, the linear regression model was found acceptable for expressing this relational information.

The regression equation adopted for total completion cost can be described mathematically as in Eq. 32:

$$TCC = -34,716.80 + 1.048 * TBC \tag{32}$$

where,

TCC = Total completion cost of the project in 2008 in $

TBC = Total bid cost of the project in 2008 in $

The data used for analysis are listed in Table A-1 and the resulting plot is shown in Fig. 26.

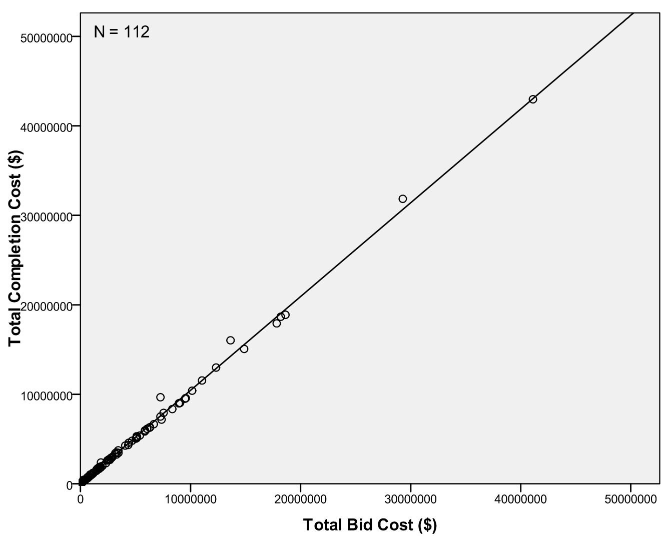


Fig. 26. Linear regression model for total completion cost

5.4 Summary of Results

A summary of all the regression analysis done for all the items considered is listed in Table 41. In the table, N is the sample size of the corresponding regression. R^2 is the value of R^2 for that regression model. β_0 and β_1 are the constant and coefficient terms in the equations respectively. Use of these coefficients in different regression models are as shown in Eq. 4, Eq. 5, Eq. 6, Eq. 7 and Eq. 8. Model is the regression model chosen from among the five discussed in Chapter 3.3.2 with the highest R^2 for particular case.

Table 41. Summary of Regression Analysis

Item Code	Item Name	Unit	N	R^2	β_0	β_1	Model
105.01	Quality Control	LS	78	16.9	14.995	-0.749	Logarithmic
107.01	Traffic Control	LS	134	21	14.659	-0.802	Logarithmic
109.03	Construction Conflicts and Additional Work Items	LS	143	43.6	256.485	-0.291	Power
201.01	Clearing and Grubbing	LS	64	31.9	2581.659	-0.567	Power
203.01	Roadway Excavation	CY	114	34.7	27.012	-1.865	Logarithmic
302.01	Type II Aggregate Base	TON	120	35.1	96.776	-7.598	Logarithmic
402.01	Plantmix Bituminous Surface	TON	136	47.4	45.864	7803.379	Inverse
403.01	Plantmix Bituminous Open-Graded Surface (3/4")	SY	61	48.3	988.464	-0.521	Power
406.01	Prime Coat	TON	62	30.8	684.241	-0.013	Exponential
405.01	Tack Coat	TON	38	69.5	319.283	1070.119	Inverse
407.01	Seal Coat	TON	64	25.1	672.509	-88.858	Logarithmic
613.02	Concrete Sidewalk	SF	58	58.7	3.521	3138.54	Inverse
613.03	Concrete Valley Gutter	SF	39	36.5	8.25	673.215	Inverse
613.01	Type "L" Curb & Gutter	LF	65	69.7	85.989	-0.237	Power
633.01	Reflective Pavement Markings	EA	106	7.9	5.234	-0.208	Logarithmic
633.02	Non reflective Pavement Markers	EA	107	7.1	3.623	-0.069	Power
637.01	Dust Control	LS	44	36.2	0.354	410297.8	Inverse

5.5 Model Validation

The validation of the regression models were tested through the scatter plots of predicted values versus historical, observed values for each item. This section shows the variation of the predicted values from the observed values. Table 42 lists the variations for each item.

Table 42. Summary of Prediction Errors

Item Code	Observations	Frequency of Observations (Percentage of Total)			
		Error -20% ~ +20%	Error -50% ~ +50%	Error -75% ~ +75%	Error Over +/- 75%
105.01	78	17 (21.79%)	49 (62.82%)	58 (74.36%)	20 (25.64%)
107.01	134	33 (28.95%)	71 (62.28%)	94 (82.46%)	20 (17.54%)
109.03	143	55 (38.46%)	113 (79.02%)	125 (87.41%)	18 (12.59%)
201.01	64	6 (9.38%)	19 (29.69%)	34 (53.13%)	30 (46.88%)
203.01	114	31 (27.19%)	85 (74.56%)	95 (83.33%)	19 (16.67%)
302.01	120	34 (28.33%)	88 (73.33%)	98 (81.67%)	22 (18.33%)
402.01	136	90 (66.18%)	133 (97.79%)	136 (100%)	0 (0%)
403.01	61	19 (31.15%)	50 (81.97%)	57 (93.44%)	4 (6.56%)
406.01	62	56 (90.32%)	58 (93.55%)	59 (95.16%)	3 (4.84%)
405.01	38	24 (63.16%)	35 (92.11%)	35 (92.11%)	3 (7.89%)
407.01	64	24 (37.5%)	51 (79.69%)	58 (90.63%)	6 (9.38%)
613.02	58	37 (63.79%)	57 (98.28%)	58 (100%)	0 (0%)
613.03	39	29 (74.36%)	37 (94.87%)	38 (97.44%)	1 (2.56%)
613.01	65	65 (100%)	65 (100%)	65 (100%)	0 (0%)
633.01	106	79 (74.53%)	97 (91.51%)	101 (95.28%)	5 (4.72%)
633.02	107	63 (58.88%)	85 (79.44%)	94 (87.85%)	13 (12.15%)
637.01	44	7 (15.91%)	21 (47.73%)	31 (70.45%)	13 (29.55%)

It was observed that more than 50% of the values lie within the range of ± 20% error range for the following items: 402.01 Plantmix Bituminous Surface, 406.01 Prime Coat, 405.01 Tack Coat, 613.02 Concrete Sidewalk, 613.03 Concrete Valley Gutter, 613.01 Type "L" Curb & Gutter, 633.01 Reflective Pavement Markings, 633.02 Non -Reflective Pavement Markers. For Item 613.01 Type "L" Curb & Gutter, 100% values lie within the 20% interval range.

When this range was widened to ± 50%, more than 50% of the values were found to lie within the range for almost all the items except for 201.01 Clearing and Grubbing and 637.01 Dust Control. It was observed that the variations were higher in the lump-sum items than in the unit price items. The probable reasons are discussed in Chapter 5.5 Study Limitations.

5.6 Study Limitations

The limitations of this study are the following:

- The study deals only with street construction projects undertaken by the Public Works Department, Clark County, Nevada, from 1991 through 2006. Hence, the models may not be relevant to other types of projects or to projects contracted by a different authority.
- This study relates the bid cost to only one variable; quantity, in the case of unit-price items, and percentage of bid cost, in case of lump-sum items. Real-world bidding takes into account various other factors which have not been incorporated into the model. For example, Item 107.01 Traffic Control does not only depend on the total bid cost of the project. It also depends upon the traffic density of the street, alternatives available, numbers of junctions to be

controlled, extent of the work and more. Therefore, this study suggests that a more accurate model can be obtained from multivariate regression models, and incorporating all these variables, whereas univariate regression models were utilized for the study undertaken for this thesis. Low R^2 values in some regression models strongly suggest this conclusion is true.

- The bid price for any item can also be remarkably affected by unbalanced bidding. When a contractor senses underestimation or overestimation of any material quantity, he can prepare a bid in such a way that maximizes his profit by anticipating possible future change orders for that item. But, since this model considers only quantity and total bid cost as factors, such unbalanced bidding creates outliers in the model that result in distortions from reality.
- Costs from different timeframes were transformed to a single date datum using RS Means Cost Indices. Since these indices are very vague in scope, they may not exactly reflect the cost inflation in particular areas of study for particular items.
- Costs of items also fluctuate highly in some time periods because of commodity price fluctuations, an energy crisis or other unusual conditions. This study lacks sufficient controls to account for these variables.

CHAPTER 6

COMPUTER MODEL

6.1 Introduction

An application was developed in Visual Basic. NET Framework 3 to incorporate all the methodology followed in this study. All the data used in this study were managed in a Microsoft Access (.mdb) database, which served as a backend. This application contains the engine which can build all the regression models (Linear, Logarithmic, Inverse, Power and Exponential) for a given data set. Then, it can choose from among these models, the best model which fits the particular data set. This selection is done based on the R^2 values of the models. This selection can also be done manually for each item.

Initially list of all the items, along with quantities, are entered into the system. Then, this application builds regression models from available data set and predicts the unit price or lump sum amount for every item entered. Thereafter, these individual items are summed up to get the total bid cost which is again used to predict total completion cost. The main advantage of this application is that the regression models are generated in real time and as the data increases, models adjust themselves switching between models depending upon latest R^2 value.

6.2 Features of the application

Following are some of the useful features of this application,

- Minimal training and ease of use
- Significant knowledge or prior experience about cost estimating is not necessary
- Minimal input information

- Recently estimated (not completed) as well as historical projects are stored in the system, which can be retrieved at any time
- Choice of regression models is done by the system. Hence, even if the best fit model changes with addition of new data, the system can automatically switch to the best one
- Works for both unit-price and lump-sum items
- Total Completion Cost is also predicted along with Total Bid Cost

6.3 Database Structure

All the tables used in the database along with their relation to each other are shown in Fig. 27. The boxes represent the tables and texts inside the boxes represent the fields in the table. Here, “1” and infinity sign in the lines representing the relations show that a data unique in one table (occurs only one time), repeatedly occurs in other table (many times). So, the relation is called “One-to-many”. By doing this, redundancy of data can be controlled. For example, all the data related to an item are stored in table “tblItems” and only its unique key, the “Item Code” field, is referred in other tables (Eg., Tables “tblNewData” and “tblData”). Whenever information on particular item is required, it is retrieved from “tblItems” by tracking its “Item Code”.

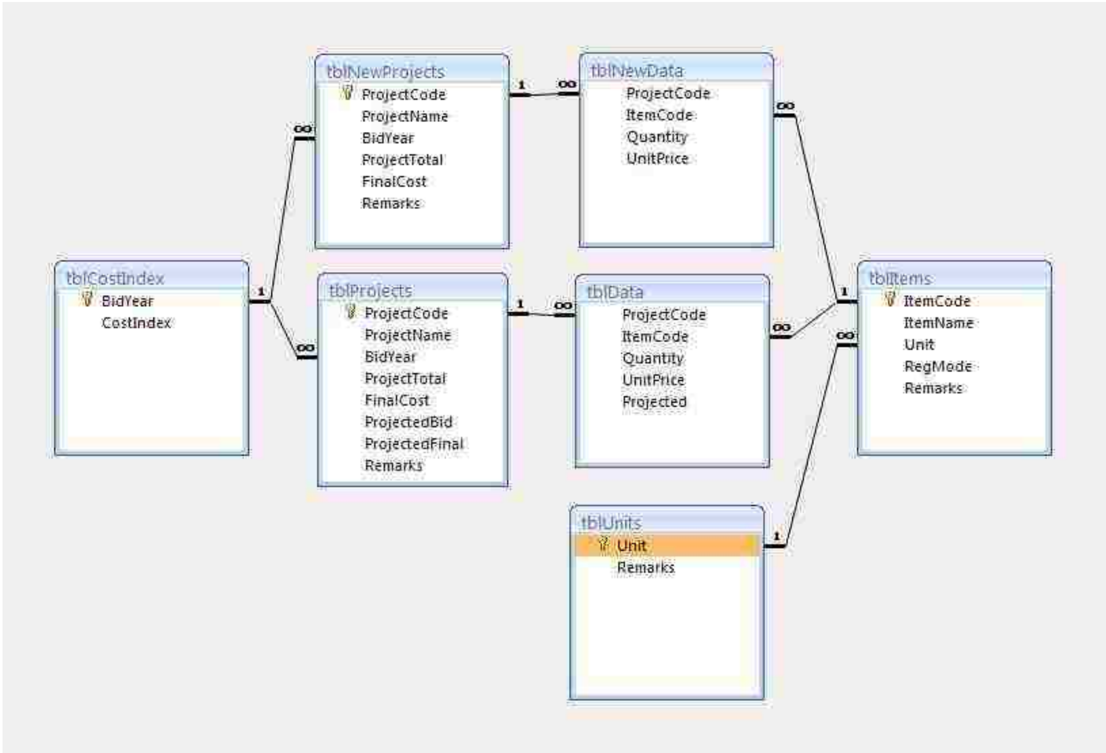


Fig. 27. Entity relationship diagram

6.4 Demonstration

The working mechanism of the system has been explained side by side with the demonstration of the application. Validations done for the calculations done by the system are also discussed. The first form in the application encountered by the user is shown in Fig. 28.

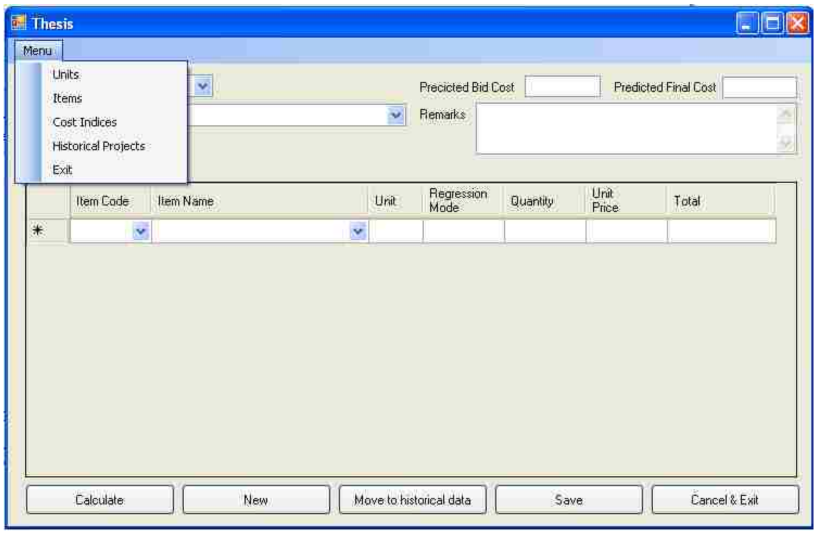


Fig. 28. Main application form

But, the start is from the basics for building up the system. Initially, all the units that are supposed to be used in the estimate should be entered into the system. It can be done by using the form shown in Fig. 29. The user can view the available units, add new units, edit existing units or delete undesired units from the system using this form.

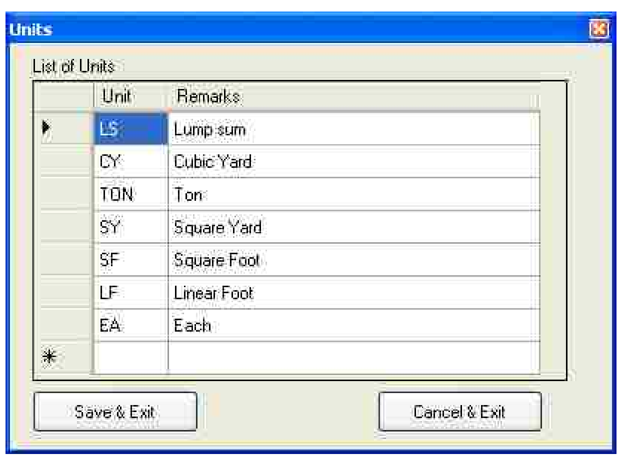


Fig. 29. Form for managing estimate units utilized

Then, all the cost indices to be used by the system should be entered. Fig. 30. shows the form for manipulating the cost indices. The user can add, edit, delete or view cost indices through this form.

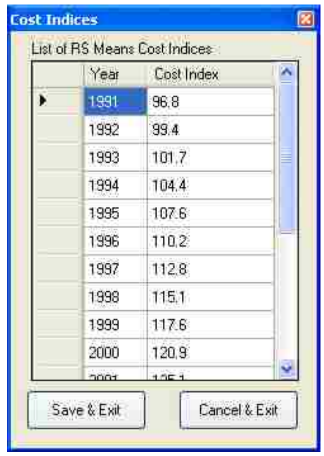
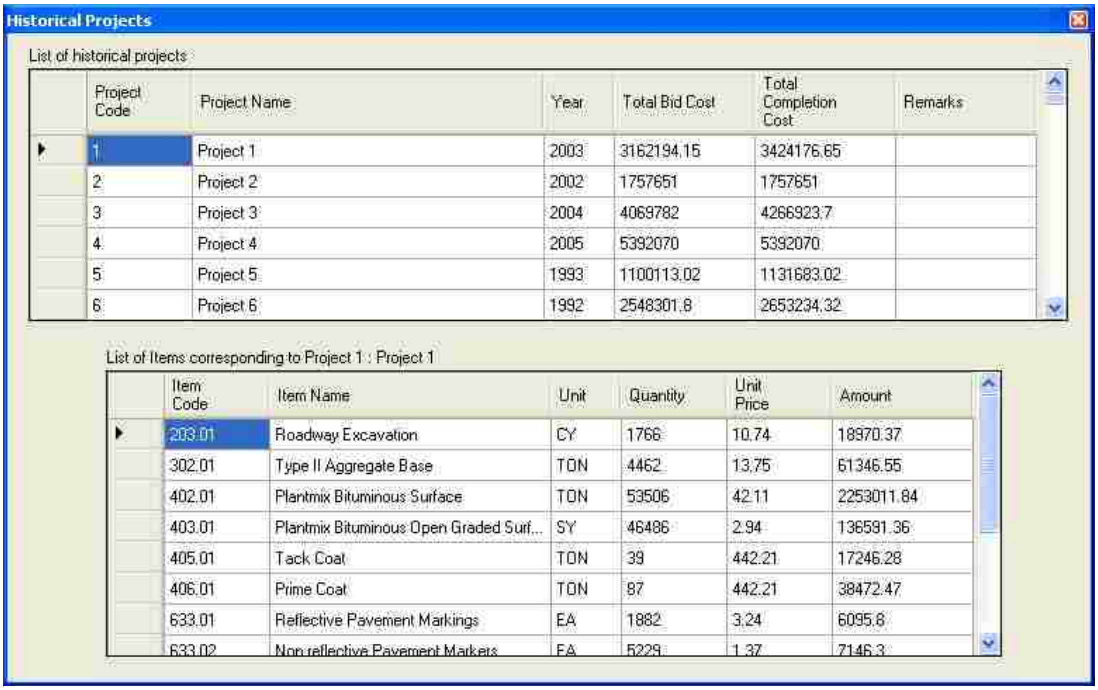


Fig. 30. Cost indices' management form

Fig. 31. shows the form for viewing data of historical projects stored in database that are used for building regression models. The upper table lists the available projects with corresponding name, year, total bid cost, total completion cost and remarks, if any. The lower table populates with items present in a project clicked in the upper list. Since the data are historical, editing cannot be done on this form.



Historical Projects

List of historical projects

Project Code	Project Name	Year	Total Bid Cost	Total Completion Cost	Remarks
1	Project 1	2003	3162194.15	3424176.65	
2	Project 2	2002	1757651	1757651	
3	Project 3	2004	4069782	4266923.7	
4	Project 4	2005	5392070	5392070	
5	Project 5	1993	1100113.02	1131683.02	
6	Project 6	1992	2548301.8	2653234.32	

List of Items corresponding to Project 1 : Project 1

Item Code	Item Name	Unit	Quantity	Unit Price	Amount
203.01	Roadway Excavation	CY	1766	10.74	18970.37
302.01	Type II Aggregate Base	TON	4462	13.75	61346.55
402.01	Plantmix Bituminous Surface	TON	53506	42.11	2253011.84
403.01	Plantmix Bituminous Open Graded Surf...	SY	46486	2.94	136591.36
405.01	Tack Coat	TON	39	442.21	17246.28
406.01	Prime Coat	TON	87	442.21	38472.47
633.01	Reflective Pavement Markings	EA	1882	3.24	6095.8
633.02	Non reflective Pavement Markers	EA	5229	1.37	7146.3

Fig. 31. Historical database of available projects' form

Items that are to be regressed can be managed from a form as shown in Fig. 32. The table above the graph lists the available items in the database. It shows the item codes, name of the items, number of occurrence of the item in available historical projects, regression mode specified and remarks, if any. Items can be added, removed or edited from this form. Unit can be chosen from the available list of units and regression mode can also be specified for each item. Available options for regression modes are "Auto", "Linear", "Logarithmic", "Inverse", "Power", "Exponential" and "None." Items will be regressed using the model specified in this table.

The graph below the table shows the scatter plot of the historical data and regression curve corresponding to the one chosen in checkboxes at the side. These checkboxes can be used to view the different regression curves for the same data. The coefficients of equation and the R^2 value for the equation are also shown above the checkboxes.

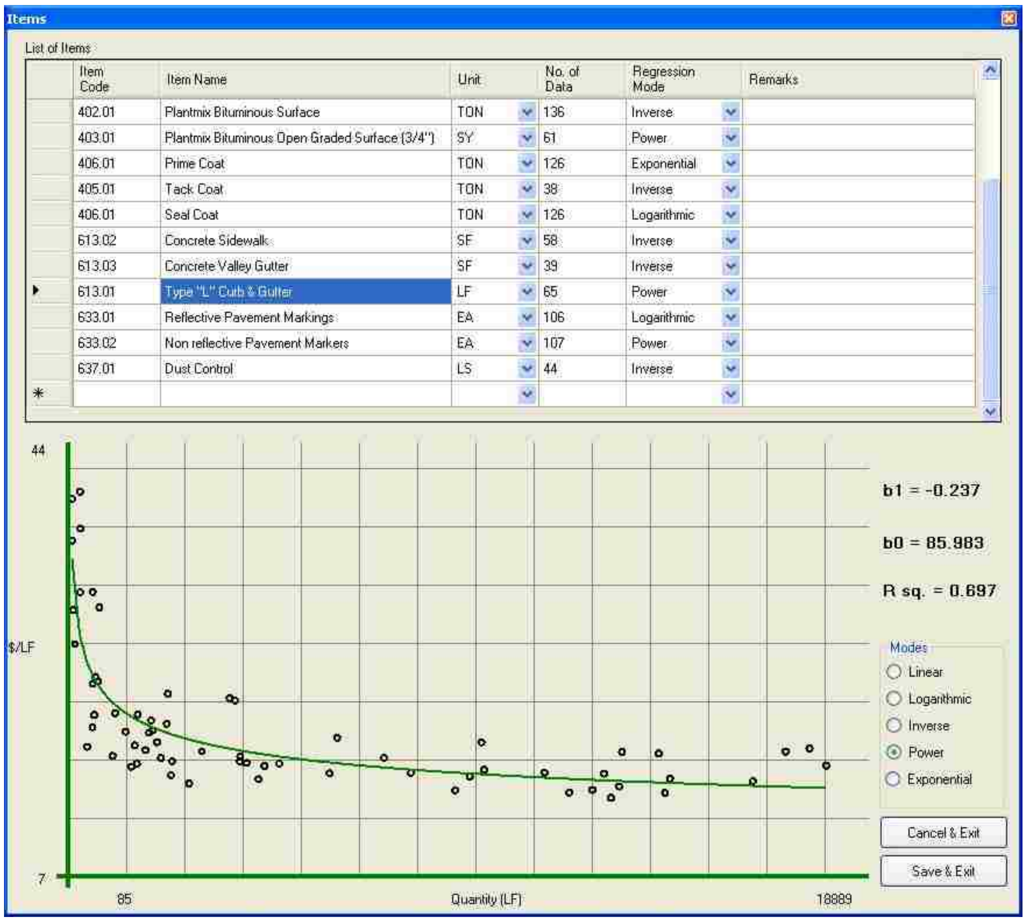


Fig. 32. Managing system item's form

If the user chooses "Auto" in regression mode, then the system will check all the models and use the model with highest R^2 for prediction purpose. When more data is added to the system, the best model representing the data may change. In that case, the system will handle this change automatically. If the user chooses "None" in regression mode, the system will not predict any value and the user will have to enter the value. This will be helpful in case of items with less data where regression is not desired.

The validity of the system in constructing the regression model was checked by comparing the coefficients of equation and R^2 value with those in Chapter 5.4.

For estimating the cost of a new street construction project, the form shown in Fig. 33. is used. If there are more than one new projects to be estimated in the same time, estimates can be saved and later retrieved using project code or project name. Items for the new project can be chosen from the list. Fig. 33. shows an example project with four items. Among these four, two are unit priced items while two are lump sum. Unit price for the items are directly predicted using the model but for lump sum items, amount cannot be calculated unless the total bid cost is unknown.

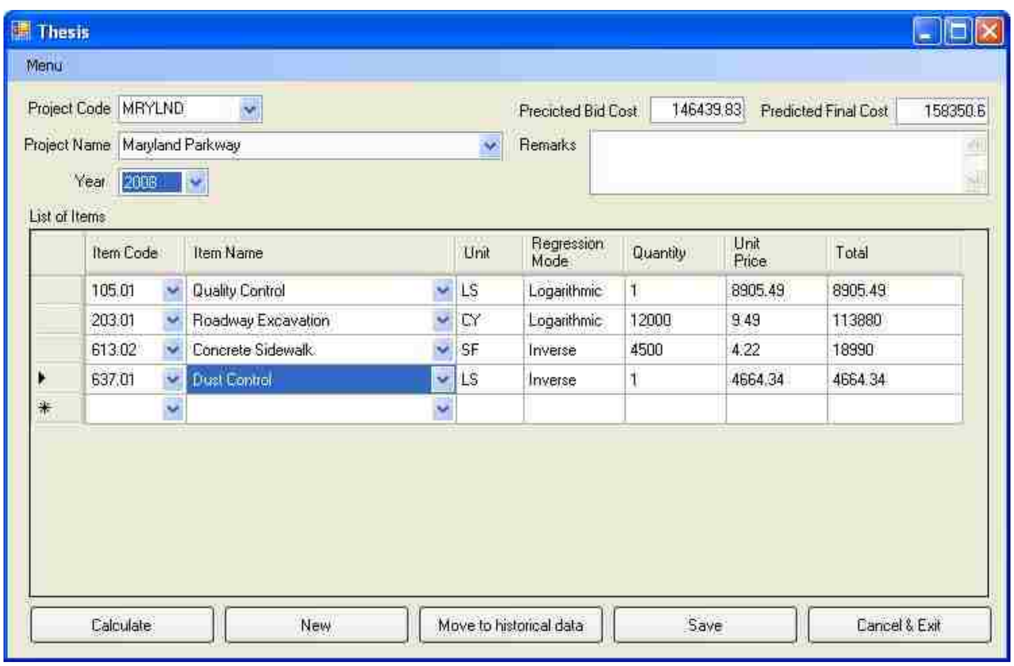


Fig. 33. New street construction project estimating form

Hence, an iterative process is run to obtain exact bid cost and percentage of bid cost. Initially, the sum of the items with unit price is assumed to be the total bid cost of the project and percentage of bid cost for each lump sum items are predicted based on it and corresponding equivalent amount are calculated. Then, a new bid cost is obtained by adding amounts for all the items (unit-price and lump-sum). This bid cost is again used to predict the percentage of bid cost for each lump-sum item. And again, a new sum is obtained. This process goes on till the exact bid cost matching the predicted percentage of bid cost for each lump-sum item is obtained.

Thereafter, the obtained total bid cost is used to predict the completion cost. The calculations done by the system were verified by hand calculations.

6.5 Limitations/Recommendations

Following are some limitations of this application and recommendations for future development of the application,

- Regression models should not only have a good R^2 but also be significant within 95% confidence level. But, the significance of the models have not been tested or calculated in this application.
- Outliers can dramatically alter the nature of equation in any prediction model. This application does not have any provisions of checking the outliers in any data set.
- This application only does univariate regression whereas a good model would have consisted of multiple variables. This is also the limitation of this entire study.

- To enable this application to predict cost of the entire project, all the items should have significant numbers of data points. Regression done with only a few data points may be misleading. This factor has not been considered in the application.
- Projects in different locations can also be predicted using relevant location factors. There is no provision for change in location in this application.
- Similarly, extension of this application can be done for different project types such as water supply, flood control, and utilities. Same applications can be used for different types of projects by simply changing the data in the database and using the same model.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

This thesis focused on proving the hypothesis stated in Chapter 1.3 Scope and Objectives. The first research hypothesis states that, for bid items with unit prices, there is a relationship between the estimated quantity and the unit price of bid item. Twelve such items with different units were considered and regression models were developed. The average R^2 value was found to be 39.2% with a range from 7.1% to 69.7%. All of the regression models were statistically significant with a 95% confidence level. Hence, the null hypothesis that there is no relationship between the estimated quantity and the unit price of a bid can be rejected. From the obtained equations, it is deduced that as an estimated quantity increases, the unit price for that bid item decreases.

The second research hypothesis states that, for lump-sum items, there is a relationship between the percentage of bid cost assigned to the item and the total bid cost of the project. Five such items were analyzed and an average R^2 value of 29.92% was obtained. The maximum R^2 value was found to be 43.6% and the minimum value was found to be 16.9%. All the models were statistically significant with a confidence level of 95%. Thus, the null hypothesis that there is no relationship between the percentage of bid cost assigned to an item and the total bid cost of the project can be rejected. It was also observed that as the total bid cost of the project increases, bidders bid a lesser percentage of the total cost of the project for lump-sum items.

The third, and final, research hypothesis states that there is a relationship between the bid cost and the final completion cost of the project and the total bid cost of contractor may use to predict the final completion cost of the project. A regression model was developed with an R^2 value of 99.7%. The slope coefficient was significant within a 95%

confidence interval. Therefore, the null hypothesis that there is no relationship between the total bid cost and the total completion cost of a project can be rejected. This implies that the total completion cost actually can be predicted from the total bid cost of a project.

In an effort to prove these research hypotheses, 17 regression models were developed for different items, except for total bid cost and total completion cost. The average R^2 value of the regression models for these items was 36.5%. This strongly suggests that the pattern of bidding in the Public Works Department, Clark County, Nevada, can be statistically analyzed and a model can be formulated for predicting values for future projects. This study is expected to be helpful to the Public Works Department for estimating future new street construction projects. In addition, such models might be created for different types of public works projects not examined by this study such as water supply, flood control, and utilities.

Finally, multivariate models incorporating more relevant variables are recommended for future study. Integrating more variables will improve R^2 values and, hence, provide more accurate predictions. More data should be collected and models should be developed for all items that appear within the bid item lists for County street construction projects. Only then can this approach to estimating be of practical use in real time.

APPENDIX A

DATA DESCRIPTION AND ANALYSIS

Table A-1. List of all the Projects with Corresponding Year, Total Estimated Amount, Total Bid Amount and Final Completion Cost (*n* = 147)

SN	Year	Estimated Cost	Bid Cost	Completion Cost
1	2003	3,415,366.00	3,162,194.15	3,424,176.65
2	2002	1,983,628.25	1,757,651.00	1,757,651.00
3	2004	3,735,566.25	4,069,782.00	4,266,923.70
4	2005	4,477,303.90	5,392,070.00	5,392,070.00
5	1993	1,352,728.30	1,100,113.02	1,131,683.02
6	1992	2,137,024.32	2,548,301.80	2,653,234.32
7	2003	4,220,572.55	4,389,372.21	4,588,763.23
8	1994	1,361,843.50	1,162,025.05	1,162,025.05
9	2002	1,614,114.90	1,607,900.00	
10	1993	174,281.20	153,363.40	147,363.40
11	1998	70,261.00	94,074.32	
12	1999	505,873.20	415,012.86	415,513.02
13	1999	12,891,606.43	9,568,470.38	9,568,470.38
14	1995	2,504,202.15	2,320,138.45	2,320,138.45
15	1996	5,438,577.50	5,034,450.72	5,049,132.22
16	1997	872,521.50	917,381.00	917,381.00
17	2000	8,084,460.25	7,265,265.00	9,669,959.71
18	1992	93,055.00	63,108.10	
19	2004	3,182,825.70	3,451,154.00	3,451,154.00
20	1998	1,973,999.00	1,681,215.53	1,681,215.53
21	2006	1,537,718.96	1,979,979.00	
22	1993	445,332.50	393,254.50	393,254.50
23	1994	254,739.10	225,247.81	
24	1996	710,008.40	672,179.06	672,179.06
25	1992	77,854.40	74,779.30	74,779.30
26	1993	120,334.50	112,104.50	136,633.75
27	2004	906,864.25	967,090.00	981,512.53
28	2003	5,297,194.00	5,107,209.00	5,308,115.32
29	1993	3,747,196.75	3,436,160.01	3,733,620.01
30	1995	4,125,003.39	4,345,730.68	4,345,730.68
31	1997	1,722,126.50	1,816,269.47	1,816,269.47
32	1997	1,647,472.40	1,517,517.00	1,670,715.66
33	2002	7,296,854.00	5,138,230.65	5,215,706.87
34	1998	1,323,239.90	1,381,848.75	
35	1993	4,944,876.00	4,695,369.52	4,811,213.97
36	2005	495,377.50	570,000.00	570,000.00
37	1992	3,866,935.70	3,276,066.04	3,276,066.04
38	2002	405,395.00	346,295.00	364,963.39

SN	Year	Estimated Cost	Bid Cost	Completion Cost
39	2004	319,902.00	353,971.65	
40	2002	421,620.00	415,567.18	461,669.51
41	1997	189,445.00	202,184.73	202,184.73
42	1997	555,385.00	446,896.22	446,896.22
43	1996	177,678.40	167,815.27	164,542.23
44	1996	367,254.40	359,861.14	359,861.05
45	1997	1,717,499.50	1,729,715.39	1,729,715.39
46	1999	1,873,357.00	1,579,186.97	1,632,923.45
47	1996	4,636,988.25	6,055,923.75	6,141,018.66
48	2001	1,555,044.40	1,499,000.00	1,549,777.31
49	1998	1,065,631.70	954,908.59	
50	2002	425,946.60	301,749.25	301,749.25
51	1993	151,195.50	150,050.00	150,050.00
52	1995	832,749.25	774,858.49	777,843.33
53	2005	279,630.00	241,700.00	243,000.00
54	2000	799,076.21	806,404.00	
55	2003	320,125.00	375,991.00	
56	1998	1,995,793.00	1,989,641.05	1,989,641.05
57	1992	882,997.00	778,080.00	
58	2000	350,285.00	366,554.00	426,078.00
59	2005	914,946.00	885,850.50	1,036,466.88
60	2001	523,631.25	374,042.73	
61	1997	6,129,563.31	5,866,866.00	5,966,866.00
62	1991	89,351.00	88,327.00	
63	1999	1,874,474.25	1,817,614.45	1,921,329.57
64	1993	274,248.50	258,091.70	426,938.86
65	1999	1,232,098.60	1,046,233.13	1,046,233.13
66	2000	1,265,652.60	1,356,378.93	
67	1998	1,323,239.00	1,381,848.75	
68	2000	1,888,846.35	1,983,741.02	
69	2005	9,796,186.00	12,326,412.67	12,987,732.21
70	1993	2,243,165.00	1,806,688.15	1,806,688.15
71	2005	7,926,540.95	7,553,178.60	7,926,701.51
72	1993	442,340.95	536,054.75	536,054.75
73	1993	100,596.75	107,063.55	117,101.05
74	1999	198,512.70	197,014.00	197,014.00
75	1993	2,706,396.45	2,627,448.15	2,764,727.98
76	1993	745,350.00	687,626.00	687,626.00
77	2001	2,182,802.90	1,858,981.95	2,382,022.35
78	2005	2,529,108.30	2,540,000.00	2,641,177.02
79	2004	1,479,421.30	1,515,611.20	1,561,274.51

SN	Year	Estimated Cost	Bid Cost	Completion Cost
80	2003	1,589,350.90	1,409,939.00	1,449,438.00
81	2004	8,801,240.00	9,048,811.75	9,034,558.28
82	2003	1,843,635.80	4,618,921.00	
83	2000	8,709,787.00	7,367,367.00	7,172,867.00
84	2001	9,413,156.19	8,346,355.73	8,346,355.73
85	1994	656,591.00	684,233.49	735,600.37
86	1999	2,562,894.97	1,999,948.00	
87	1998	3,081,011.00	2,798,757.60	
88	2005	10,818,069.70	11,048,109.00	11,544,642.93
89	2002	11,458,909.50	10,868,888.00	
90	2003	715,222.15	661,724.00	721,724.00
91	2006	29,000,000.00	37,609,459.35	
92	2005	355,230.50	393,083.00	393,083.00
93	1995	153,325.20	168,698.15	170,521.62
94	2001	6,284,268.96	5,100,904.95	5,100,904.95
95	1991	1,747,077.15	1,675,870.41	1,827,378.01
96	2000	236,309.50	229,633.77	233,186.13
97	1992	3,685,530.55	2,823,247.33	2,895,681.63
98	1996	2,759,927.85	2,904,680.26	3,011,822.60
99	1997	198,603.75	197,979.30	197,979.30
100	1997	443,612.50	397,692.20	397,692.20
101	1992	192,789.20	163,547.62	219,647.62
102	1999	1,802,464.00	1,703,442.00	1,739,342.89
103	2000	22,838,534.71	17,827,513.00	17,923,543.83
104	1995	3,397,192.50	3,268,335.60	3,507,120.62
105	2005	2,406,730.65	2,445,170.00	2,608,872.99
106	1998	2,369,841.00	2,775,317.72	2,874,819.55
107	2004	6,498,269.50	6,661,744.20	6,661,744.20
108	2004	8,565,363.70	9,507,073.00	9,516,598.29
109	1995	2,424,647.50	2,766,942.05	2,863,780.85
110	2000	1,633,231.60	1,654,691.88	1,654,691.88
111	1992	903,590.00	802,643.05	834,479.05
112	1999	80,940.00	103,843.62	103,840.87
113	2003	174,790.00	188,854.00	252,159.00
114	1997	49,930.00	44,110.50	
115	1996	1,842,921.10	1,813,132.11	1,813,132.11
116	1994	7,350,797.35	7,266,000.00	7,511,557.25
117	2001	30,921,281.00	21,749,072.82	
118	2001	15,408,375.75	13,635,579.25	16,031,708.06
119	1992	682,391.00	604,559.55	604,559.55
120	1992	583,165.00	560,434.34	

SN	Year	Estimated Cost	Bid Cost	Completion Cost
121	2002	6,311,121.50	5,847,510.00	5,847,510.00
122	2002	1,952,902.60	1,765,948.21	
123	2004	1,646,912.98	1,447,468.00	1,447,468.00
124	2002	1,590,259.80	976,235.00	
125	1999	6,822,574.50	6,281,914.72	6,281,914.72
126	2005	8,405,268.63	8,938,552.79	8,992,145.18
127	1998	67,834,675.50	66,394,772.56	
128	2003	854,348.50	862,405.00	
129	2005	45,704,556.30	41,111,111.00	42,965,986.46
130	1997	30,217,905.36	29,988,000.00	
131	1998	30,748,162.70	29,284,650.12	31,841,241.52
132	1996	868,430.50	997,380.05	
133	1995	2,560,981.50	2,666,042.97	2,666,042.97
134	2000	1,244,183.00	1,126,904.59	1,219,752.15
135	1999	1,919,308.90	1,682,066.79	1,721,116.19
136	1996	5,292,554.75	6,316,316.00	6,316,316.00
137	1998	394,927.00	394,422.35	
138	1996	399,872.20	393,086.72	
139	1993	1,498,391.50	1,474,874.35	1,595,270.15
140	1995	1,687,674.90	2,008,567.45	
141	2002	17,978,073.13	14,875,945.50	15,068,612.29
142	2000	18,587,275.52	18,199,683.95	18,670,793.33
143	1999	24,407,587.15	18,627,063.31	18,883,709.07
144	2004	9,290,661.75	10,144,655.70	10,397,995.70
145	1999	11,869,596.00	12,077,777.00	
146	2005	198,980.00	245,730.00	
147	1994	581,740.25	654,191.42	736,450.08

Table A-2. List of all items identified from 25 Randomly-Selected Projects

Construction Conflicts and additional works	Metal Fabrications (Handrail)
Traffic Control	6' High Chain Link Fence w/ Ext Arm & Barbed Wire
Mobilization	Drilled Pier 36" Diameter
Plantmix Bituminous Surface	3' Concrete Cutoff Wall
Roadway Excavation	4" Service Conduit and Wire Special Detour
Type II Aggregate Base	Special Detour
Plantmix Bituminous Open-Graded Surface (3/4 inch)	Cold Polymer Pavement Striping
Traffic Signal Underground	Relocate 4" Barbed Wire Fence
Traffic Sign Modification	Sign (Ground Mounted)
Clearing & Grubbing	Asphalt Concrete Median Island
Traffic Signal System	24" Corrugated Metal Pipe
250 Watt HPS Street Light Assembly	400W HPS Double Mast Arm Streetlight Assembly
Dust Control	Service Pedestal
Bridge Structure	3/4" Open Graded Surface
Non reflective Pavement Markers	4' AC Sidewalk
Concrete Sidewalk	18" R.C.P (2000-D)
Concrete Valley Gutter	24" White Cold Polymer Stripe
18" RCP Class III	60" Flat Top Manhole (30" Opening)
Tack Coat	60" Eccentric Manhole (30" Opening)
24 "L" Type Curb & Gutter	Adjust Sewer Manhole Grade Rings
Traffic Signal Modifications	12" White Cold Polymer Stripe
Removal of Structures and obstructions	18" P.V.C (C-905)
Allowance for on site material testing for quality control	Yellow Cold Polymer (Misc)
Prime Coat	4" Wide White Painted Pavement Marking
Landscape Restoration	Concrete Barrier Rail, Type A
Historic Owner-caused delay allowance	Traffic Signal Poles with Luminaries and underground
Cold planings (3/4" Depth)	Select Borrow Embankment
Type A Curb	250W HPS Decorative Street light Assembly (Single Arm)
Dust Palliative	NDOT Type 2 Drop Inlet
250W HPS Double Mast Arm Streetlight Assembly	12" Type "C" Drop Inlet
Construction Survey	60" Type 1A Manhole
Vertically Adjust Water Valve Box	18" R.C.P Class II

4" Type A Drop Inlet	200W HPS St. Light Assembly (20')
Cold Polymer Pavement Markings	Miscellaneous Asphalt Paving
4" Concrete Sidewalk	48" Eccentric Storm Drain M.H
Adjust Water Valve	19" x 30" R.C.P Class IV
Channel Excavation	Extruded Track-on Curb
48-inch Reinforced Concrete Pipe D-1350	30" R.C.P Class IV
72- inch Chain Link Fence	Pavement Replacement
Cutoff Wall	Type B Modified Concrete barrier Rail
Permanent signs (Ground Mounted)(Metal Supports)	Type A Concrete Barrier Rail
24-inch Reinforced Concrete Pipe D-1350	Variable Message Sign Foundation and Barrier
Relocate Water Meter	Drop Inlet (NDOT) Type II Modified
cold plane	Reinforced Concrete Pipe (2000-D) 43 x 68-inch H.E.
36" RCP Class III	Portland Cement Concrete Pavement
Track on concrete median island	Drop Inlet (NDOT) Type 2
30" RCP Class III	Reinforced Concrete Pipe (2000-D) 19 x 30-inch H.E.
Relocate Chainlink Fence	Reinforced Concrete Pipe (2000-D) 18-inch
18" R.C.P (1350-D)	Recompact Existing Type II
Clearing and Grubbing	Surveying
Type I Film for Crosswalk and Stop Bars (White)	Rem/Salvage Streetlight Assembly
Vertical Adj Sewer Manhole	Pavement Reinforcing Fabric
24" R.C.P Class IV	Supplemental Type II
18" R.C.P Class IV	Remove Sidewalk
Reflective Pavement Marker	Wheel chair Ramp
Remove Concrete Curb & Gutter	Extruded Tack-on Median Island
Sound Wall	Relocate Fire Hydrant
Remove A.C Pavement	Concrete Block Ret wall
Reconstruct Driveway	Wash Erosion Protect
Adjust Sewer Manhole	Rel. Water Cath. Prot. Test Sta
Residential Driveway	250W HPS Fixture
Concrete Headwall	Rel St Lt Pole & Install 250W
125 AMPService Pedestal	Commercial Driveway
Galvanized Guardrail-Triple Corrugation	Crack Sealant
"L" Type Curb & Gutter	Footing Cap
#2 THW Wire	Remove Median Island
#4 THW Wire	Collars, Grd Rings and Adj MH
#6 THW Wire	Replace Exist. School Flasher
10' * 4' Box Convert DR-1	Remove Valley Gutter
10' * 4' Box Convert DR-2	48" RCP (Class IV)

10' * 4' Box Convert DR-3	Polymer Legends (Arrows)
18-inch Corrugated Metal Pipe (16 Gage)	Conn. & Incidentals
2" Scheduled 40 PVC Conduit	Rem. And Recon Wall w/like Matl
250 W HPS Streetlight Assembly Clark County area shaded drawing 313 with Safety Base	7" Type "A" Drop Inlet
250 W HPS Streetlight Assembly NDOT Type 7 with Safety Base	Pothole
3" Schedule 40 PVC Conduit	Golf Course Landscape Restor.
6' * 3' Reinforced Concrete Box	Concrete Headwall Extension
Boring for conduit installation under US-95 (4 locations)	6" Type "A" Special Inlet
Borrow Embankment	48" Storm Drain Inlet
Bridge Structure I-2339	1200 mm RCP Storm Drain Pipe (Class III)
Class B Concrete Curb and Gutter, Type L	Heavy Grouted Riprap
Concrete Barrier Rail, Type FA (Modified)	Lower 24" Water w/ Steel Casing
Concrete Headwall Type B	Lower 16" Water w/ Steel Casing
Epoxy paint striping (8-inch solid white)	1500 mm RCP Strom Drain Pipe (Class III)
Impact attenuator (65 mph)	Triple 2400 mm x 1200 mm RCB Strom Drain, ASTM C850
Permanent Overhead sign support structures	Modified Storm Drain Manhole
Riprap (300)	Tack on Median Island
Selected Borrow Embankment	Plantmix Bituminous Open Grade (20 mm)
Type I Class B Aggregate Base	Relocate Anode Station
Type I Temporary Pavement Markings	90" RCP Storm Drain Pipe (Class III)
NDOT Type 3 Drop Inlet (Modified)	96" RCP Storm Drain Pipe (Class II)
400 Watt HPS Street Light Assembly	Scarify and recompact Base/Subbase
12" Water Main Relocation	66" RCP Storm Drain Pipe (Class IV)
Class B Concrete Median Island	Remove and Pulverize existing AC Pavement
Permanent Pavement Marking Film (Varies)(Type 4)	4" Interconnect Conduit and Wire
19-inch x 30-inch HE Reinforced Concrete Pipe D-2000	Traffic Signal Construction
Concrete Barrier Rail Transition and V.M.S Sign Foundation	Trench Drain
72-inch Manhole Type 1	Yellow Reflective Paint
Type L Curb and Gutter	Type III Junction Structure
Reconstruct Fence	Tack on Concrete Median Surface
Permanent Pavement Marking Film (Type 3) (4 inch)	Type II Junction Structure
Crack Seal	Concrete Footing Cap (Type B)

Concrete Commercial Driveway	Cold Milling
72-inch Manhole Type 1A	NDOT Type III Modified Drop Inlet (40 Feet Long)
Padmount Service Pedestal	White Cold Polymer Film Type I (Stop Bars, Crosswalks, Chevrons)
3" PVC Conduit (for TCT System)	NDOT Type III Modified Drop Inlet (35 Feet Long)
8" Water Main Relocation	Concrete Bus Turn out
2" PVC Conduit (for TCT System)	60" Drop Structure
8' x 5' RCB	School Flasher Pair
6' x 5' RCB	Cold Polymer Legend Type I "ARROW"
Modified Type D Drop Inlet(15.7')	60" RCP Storm Drain Pipe (Class II)
54" Equivalent (43" x 68") HE RCP Class III	Precast Manhole Riser (48")
6" scarify and recompact subgrade	Concrete Footing Cap (Type A)
42" RCP Class III	400 Watt Signal Pole Assembly
RCB Manhole Riser	Cold Polymer Legend Type I "ONLY""BUSES"
Modified Type II Manhole	Concrete Retaining Wall
42" Equivalent (34" x 53") HE RCP Class III	Type CM Drop Inlet (14.5 Feet Long)
Junction Structure Type C (>33")	Type I Junction Structure
12' x 7' to 8' x 5' Transition Structure	Install 72 inch Chain Link Fence
Junction Structure Type B (Max 33")	Type CM Drop Inlet (2.5 Feet Long)
Drilled Pier 60" Diameter	Type DM Drop Inlet (19.5 Feet Long)
Modular Block Retaining Wall	Special Residential Driveway Modification
Concrete Bridge Deck	200 AMP Service Pedestal
Concrete Abutments Wingwalls/ Columns	60" RCP Storm Drain Pipe (Class III)
Concrete Pile Caps Footings	Type CM Drop Inlet (17 Feet Long)

APPENDIX B

BOX PLOTS

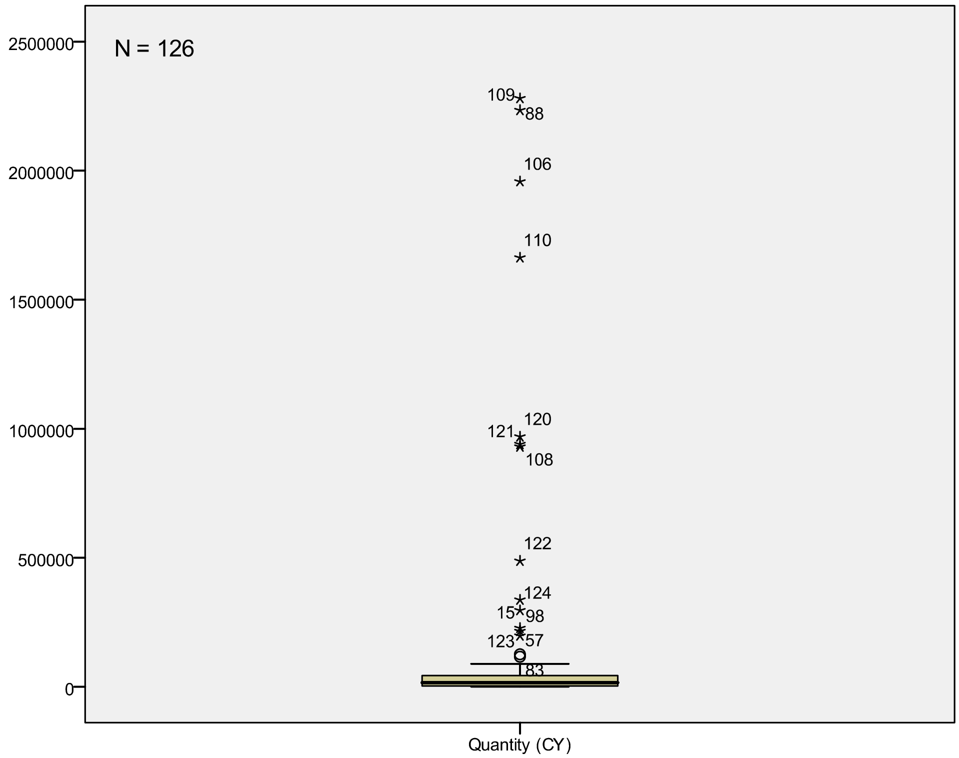


Fig. B- 1. Box plot for quantity in CY for roadway excavation before processing

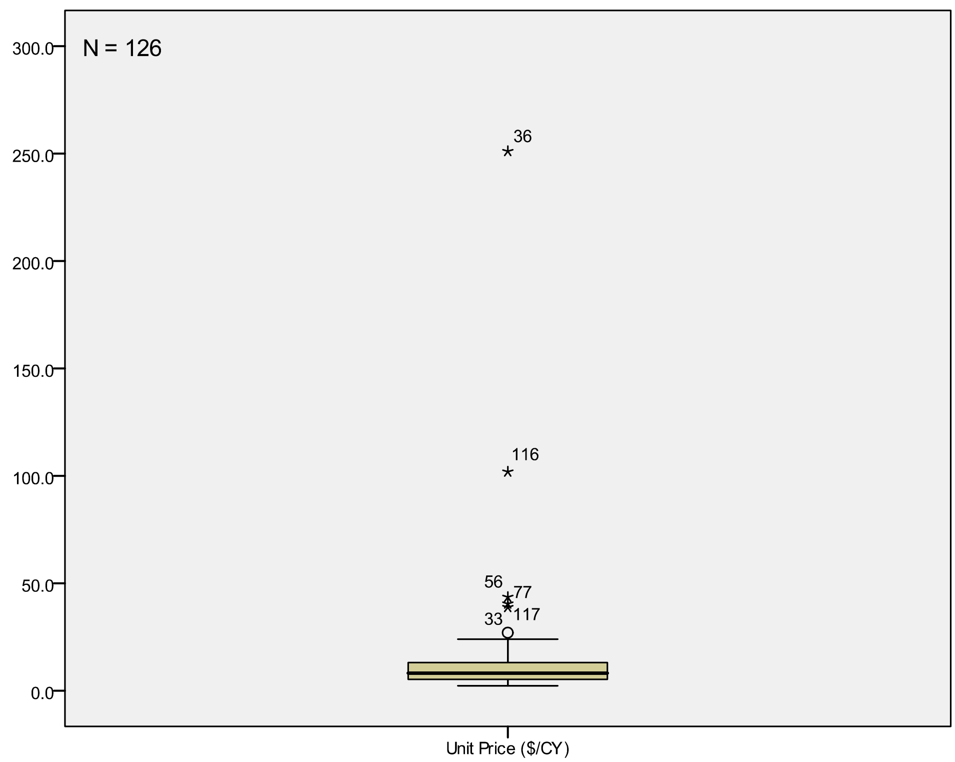


Fig. B- 2. Box plot for unit price in $/CY for roadway excavation before processing

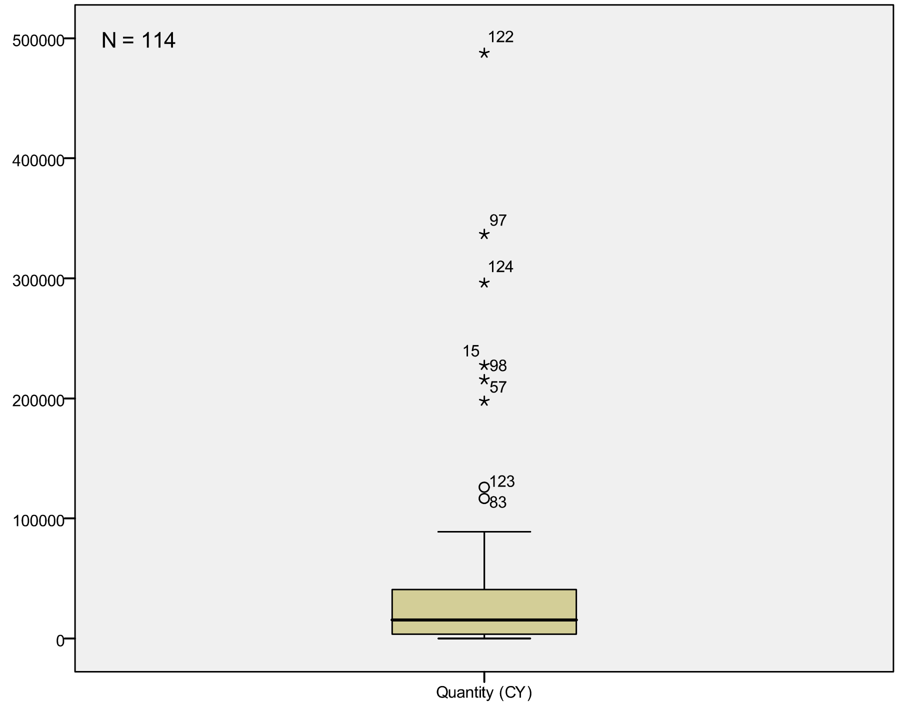


Fig. B- 3. Box plot for quantity in CY for roadway excavation after processing

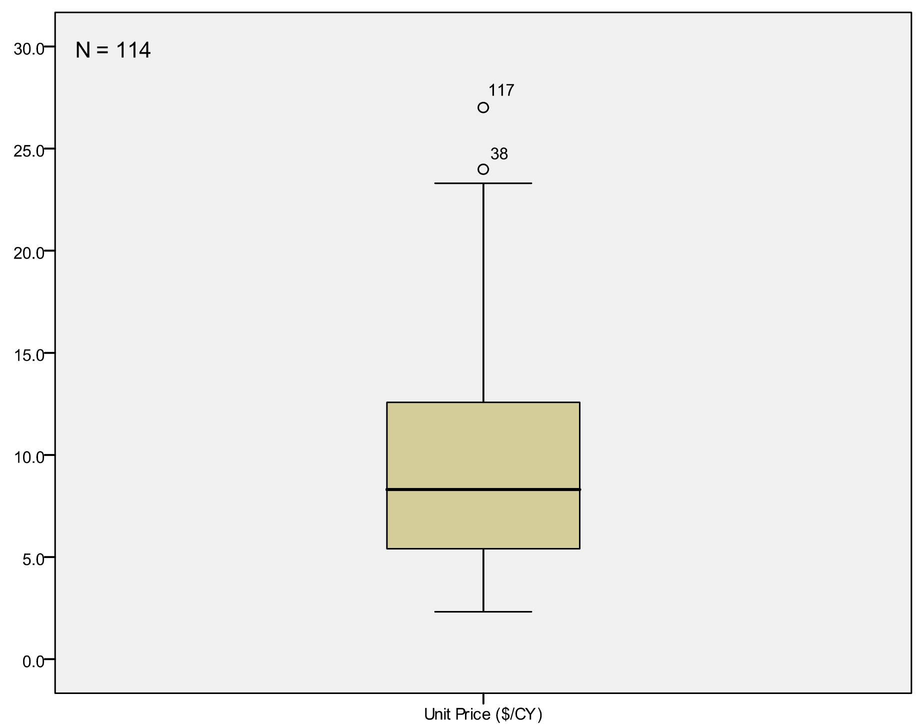


Fig. B- 4. Box plot for unit price in $/CY for roadway excavation after processing

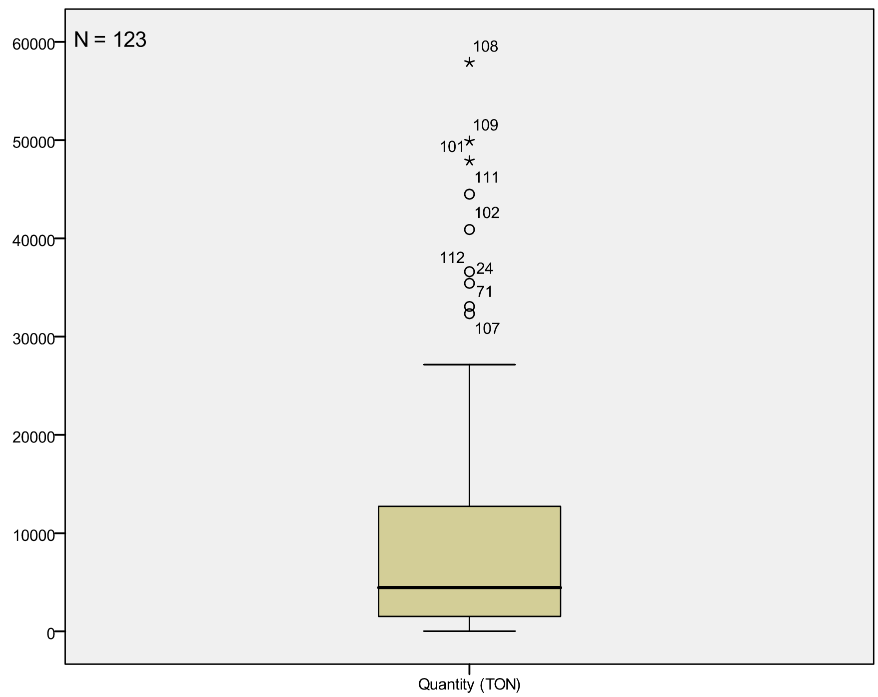


Fig. B- 5. Box plot for quantity in TON for type II aggregate base before processing

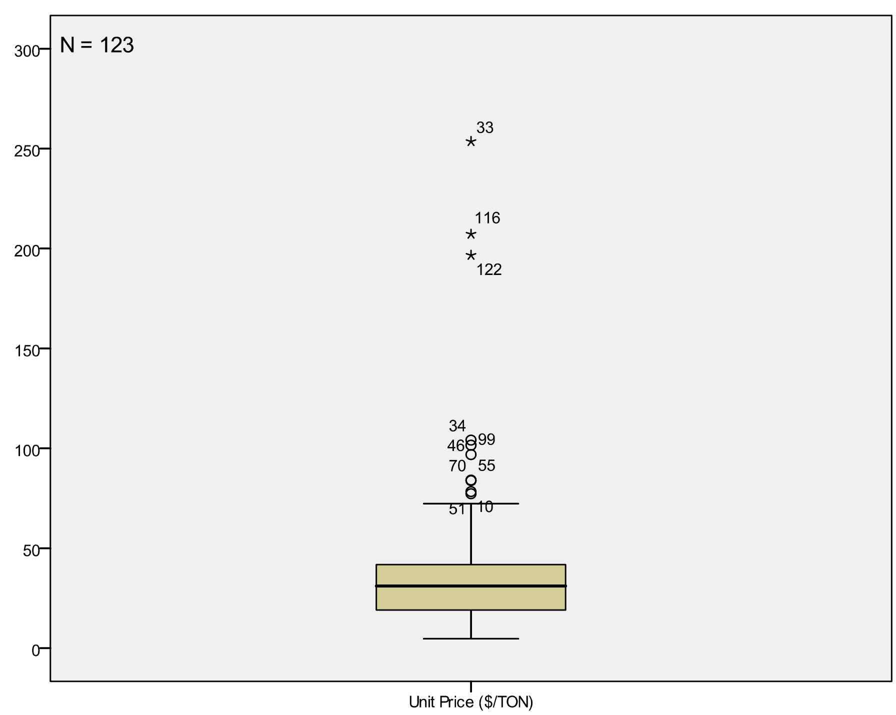


Fig. B- 6. Box plot for unit price in $/TON for type II aggregate base before processing

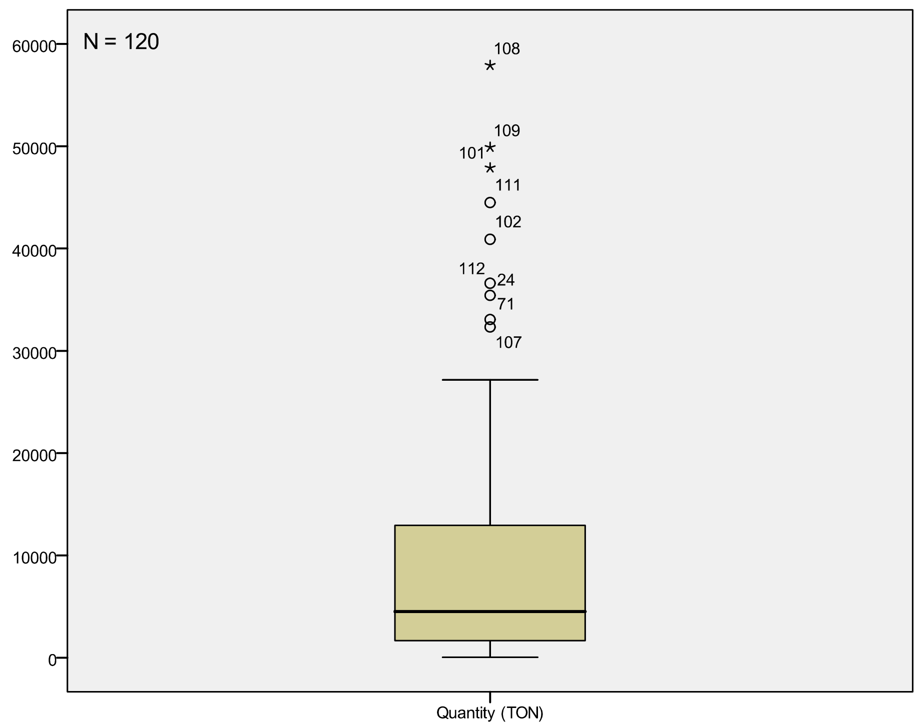


Fig. B- 7. Box plot for quantity in TON for type II aggregate base after processing

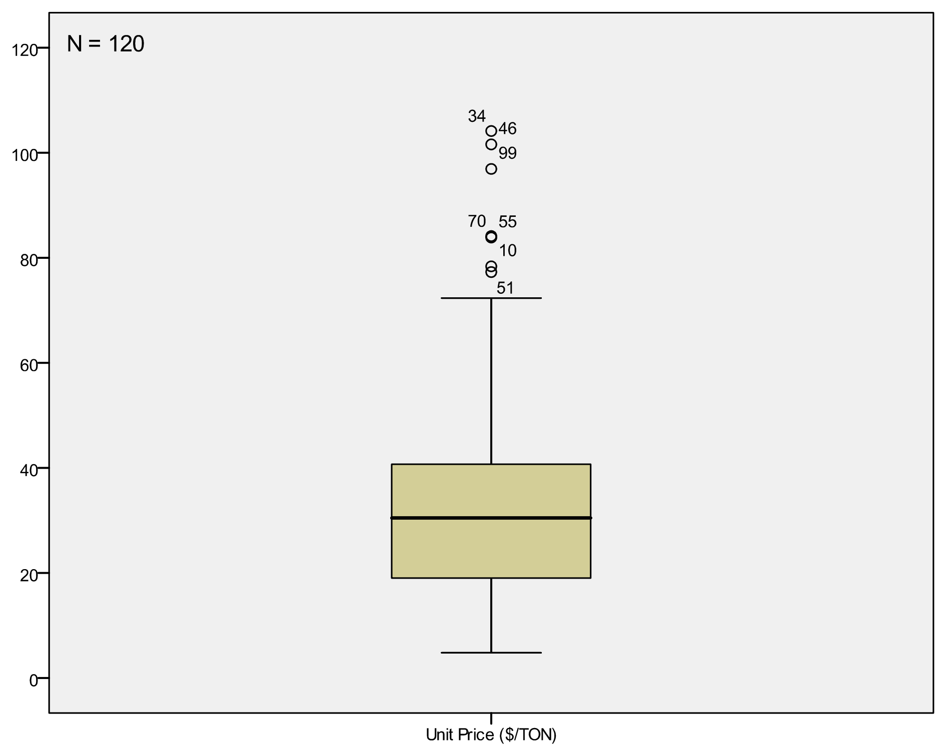


Fig. B- 8. Box plot for unit price in $/TON for type II aggregate base after processing

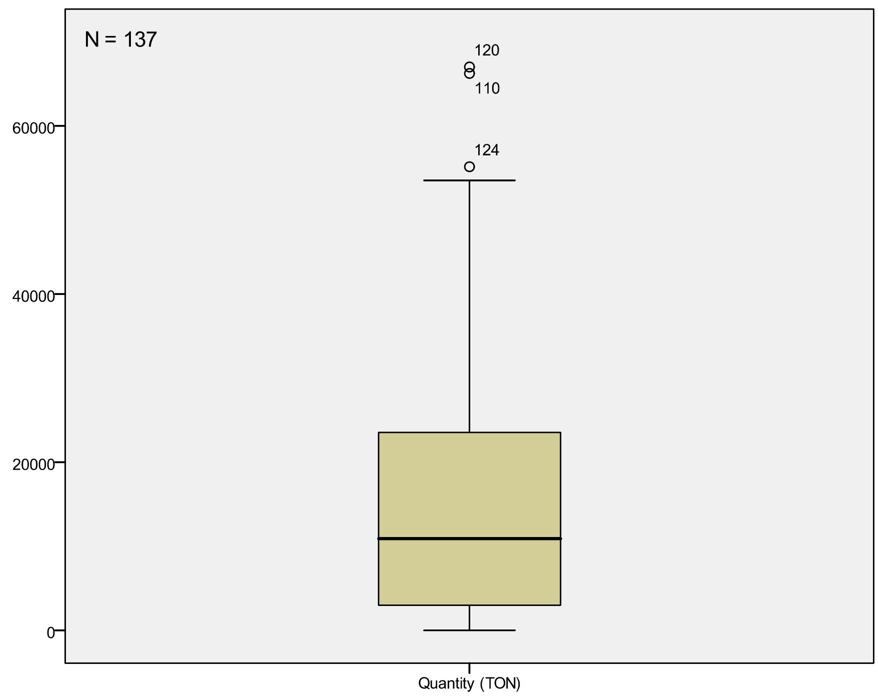


Fig. B- 9. Box plot for quantity in TON for plantmix bituminous surface before processing

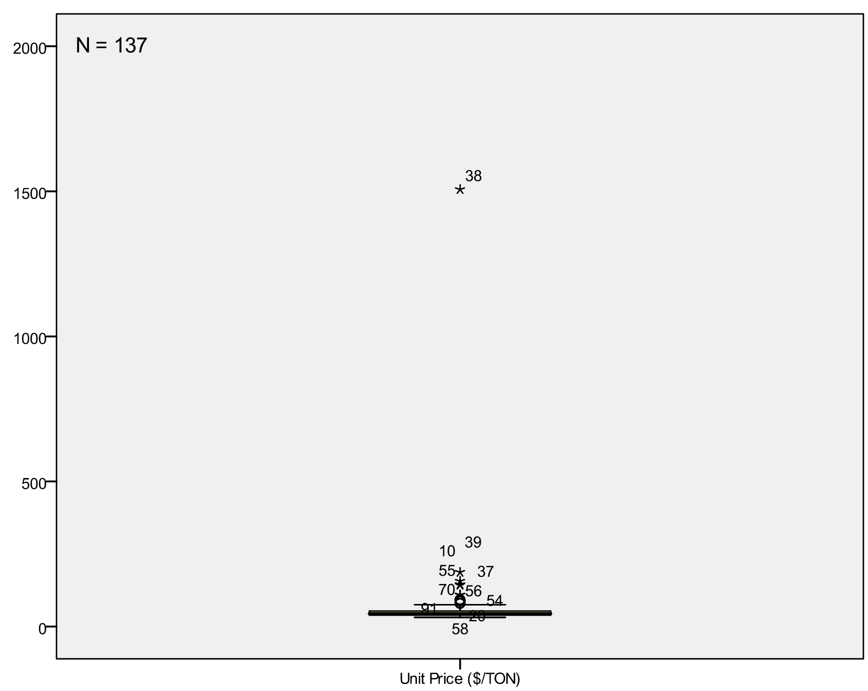


Fig. B- 10. Box plot for unit price in $/TON for plantmix bituminous surface before processing

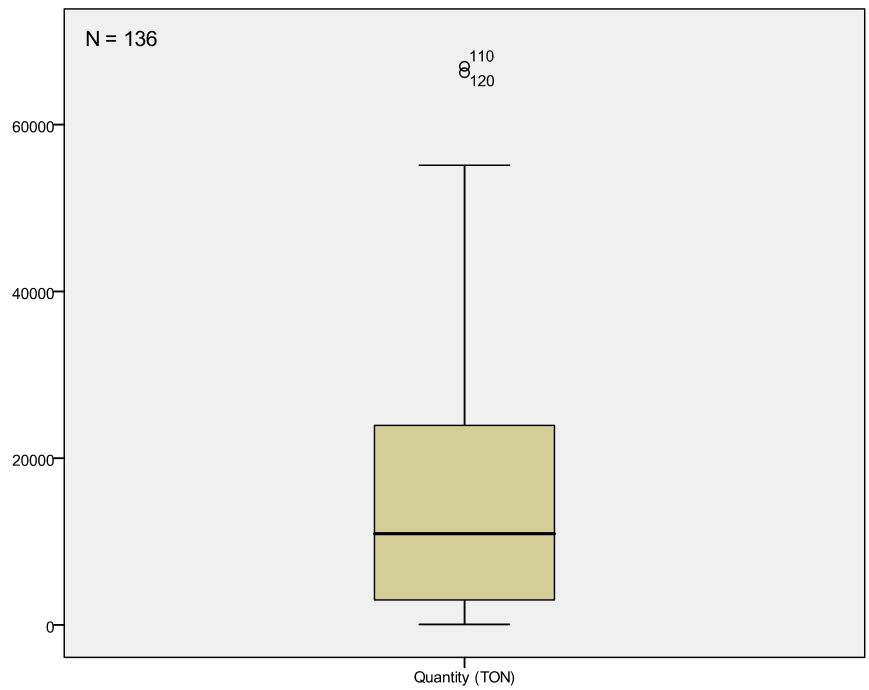


Fig. B- 11. Box plot for quantity in TON for plantmix bituminous surface after processing

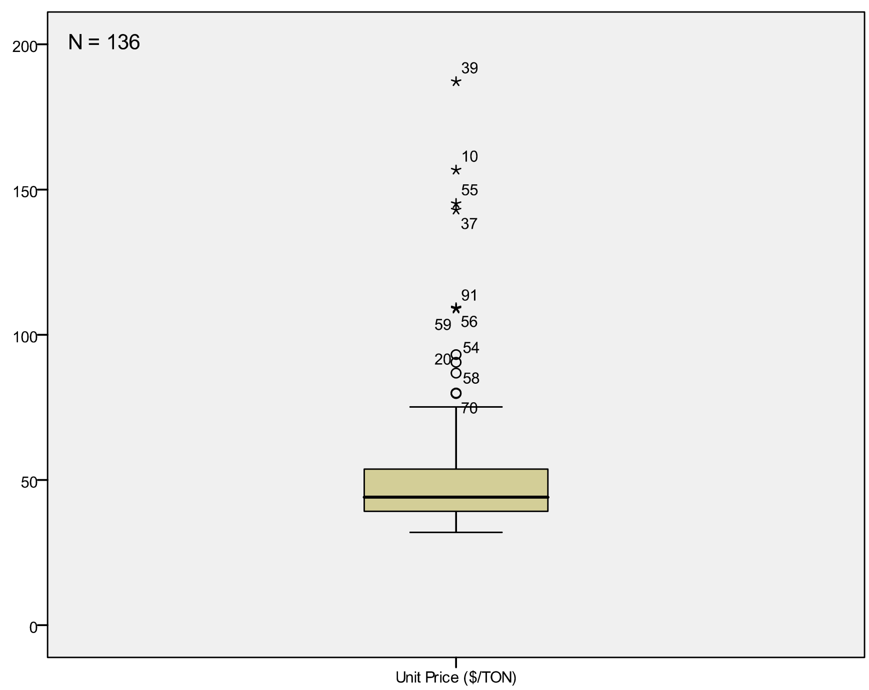


Fig. B- 12. Box plot for unit price in $/TON for plantmix bituminous surface after processing

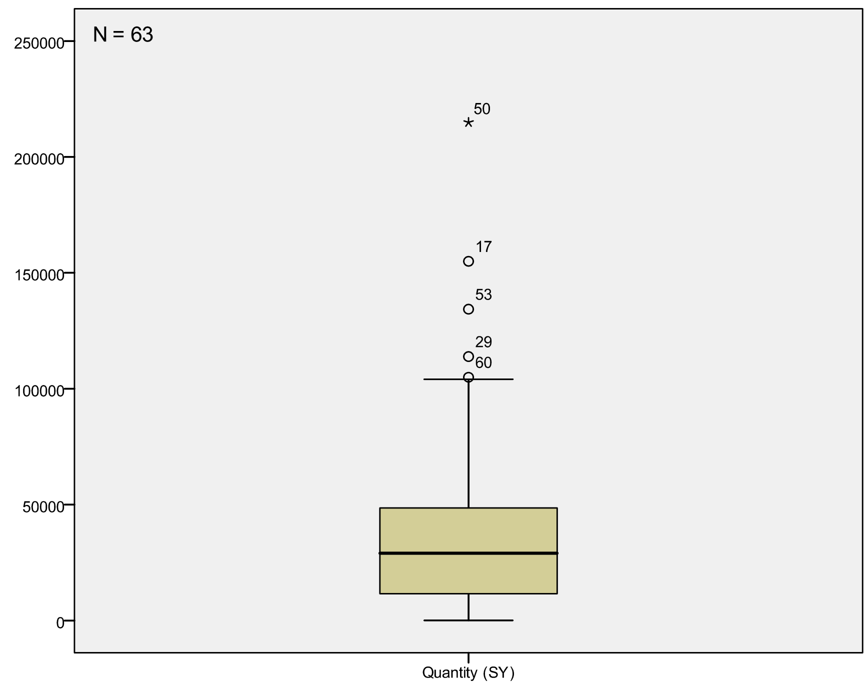


Fig. B- 13. Box plot for quantity in SY for plantmix bituminous open-graded surface (3/4" depth) before processing

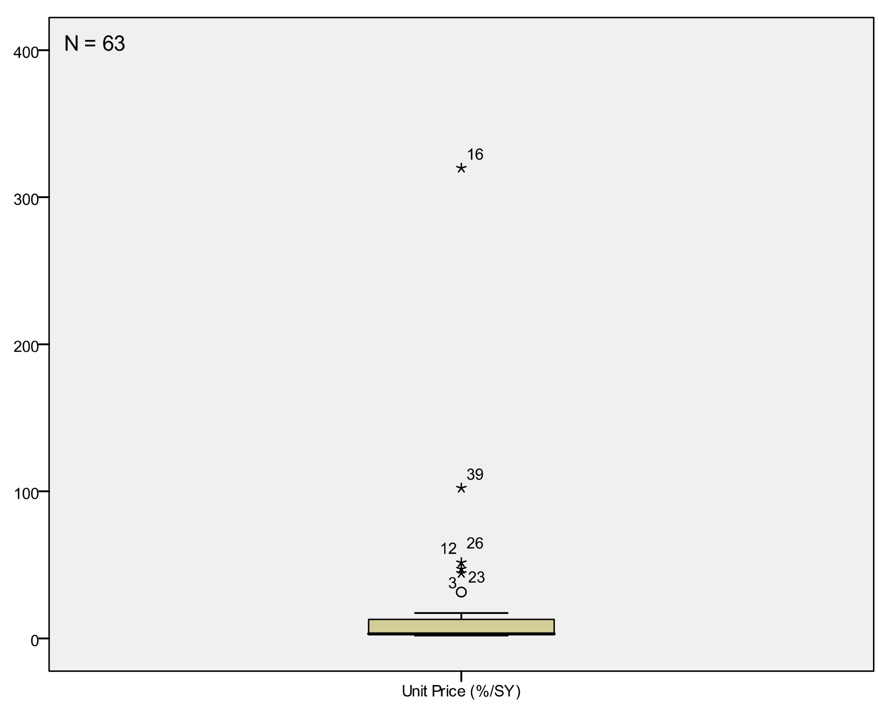


Fig. B- 14. Box plot for unit price in $/SY for plantmix bituminous open-graded surface (3/4" depth) before processing

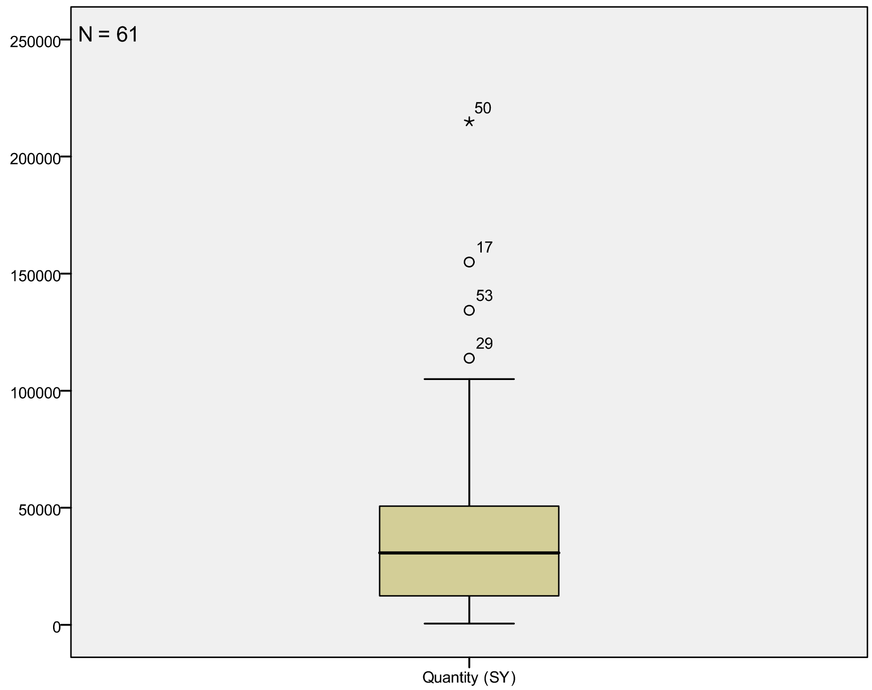


Fig. B- 15. Box plot for quantity in SY for plantmix bituminous open-graded surface (3/4" depth) after processing

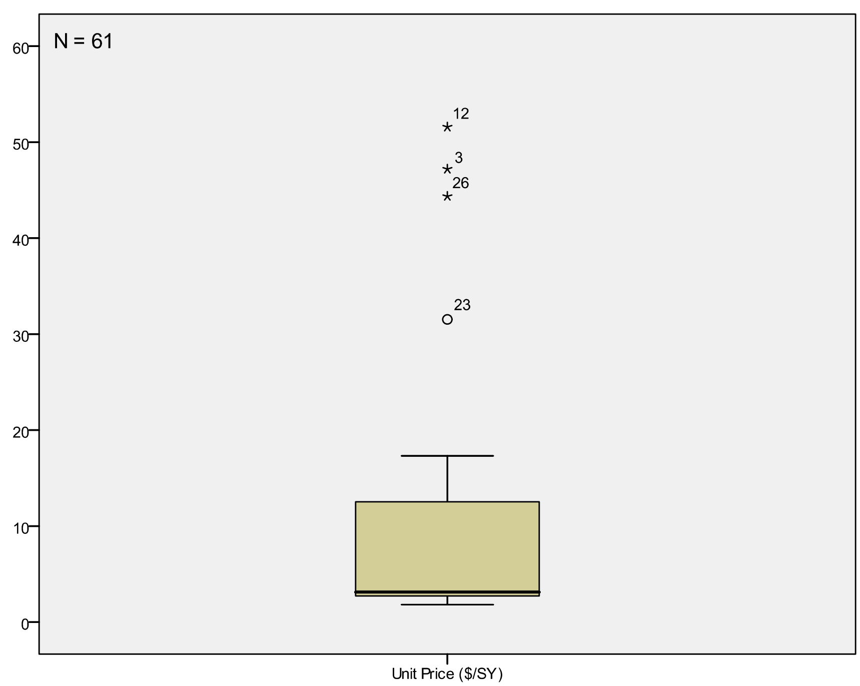


Fig. B- 16. Box plot for unit price in $/SY for plantmix bituminous open-graded surface (3/4" depth) after processing

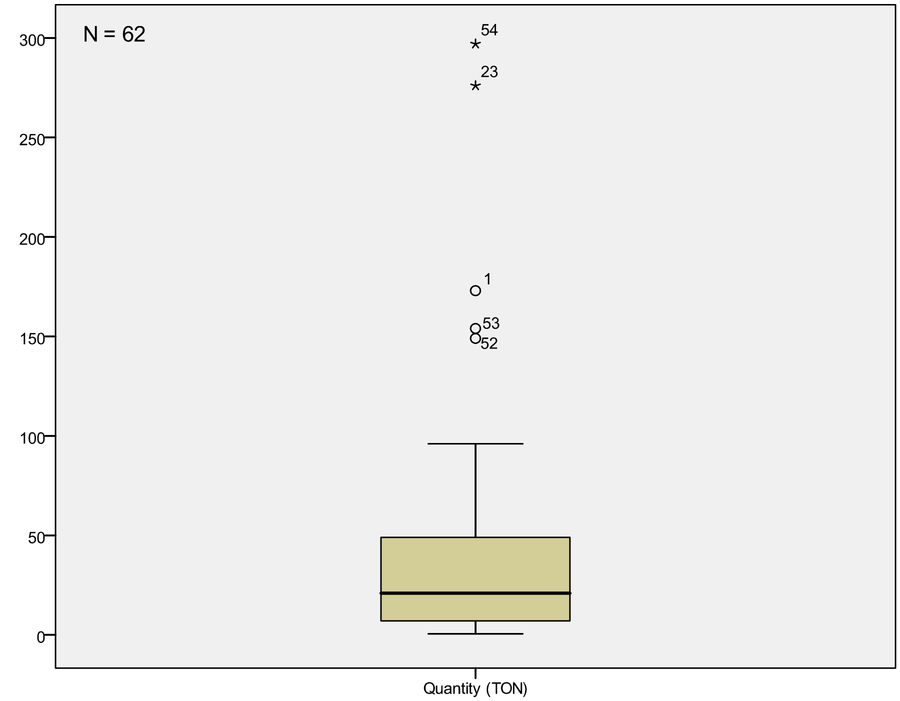


Fig. B- 17. Box plot for quantity in TON for prime coat

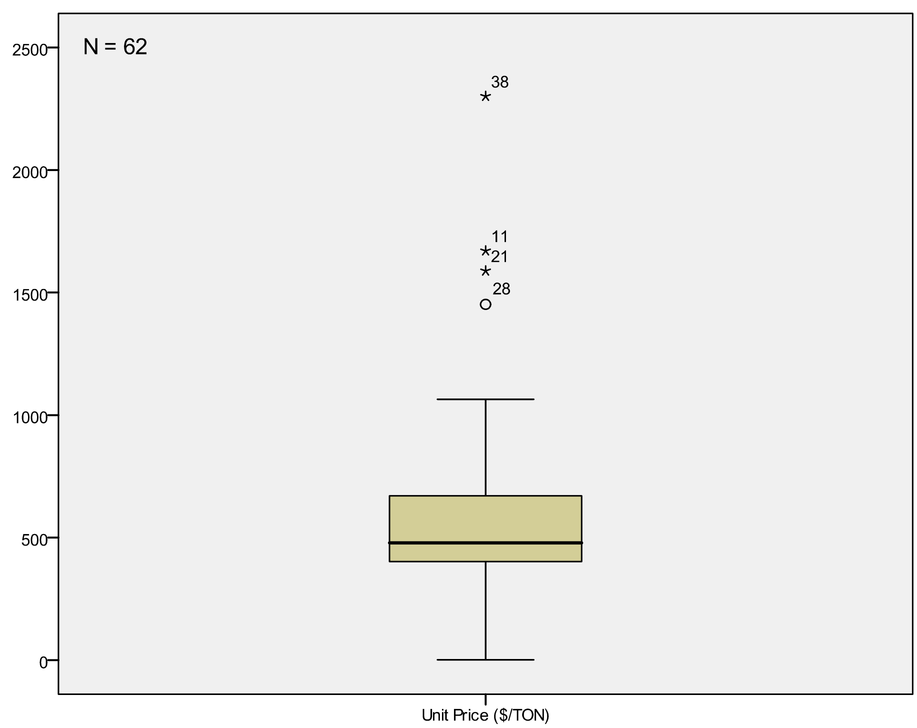


Fig. B- 18. Box plot for unit price in $/TON for prime coat

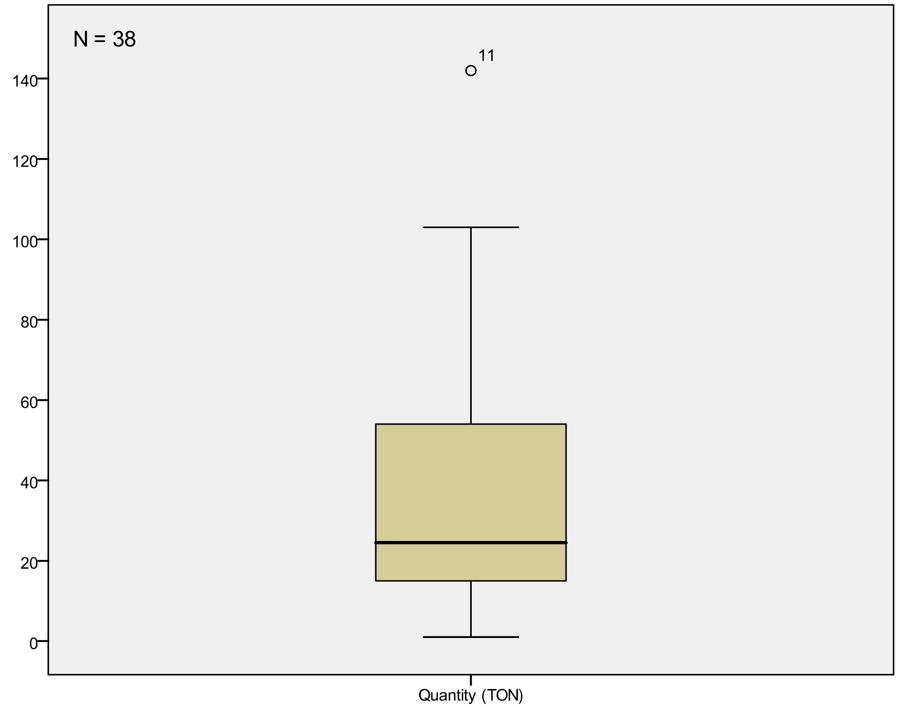


Fig. B- 19. Box plot for quantity in TON for tack coat

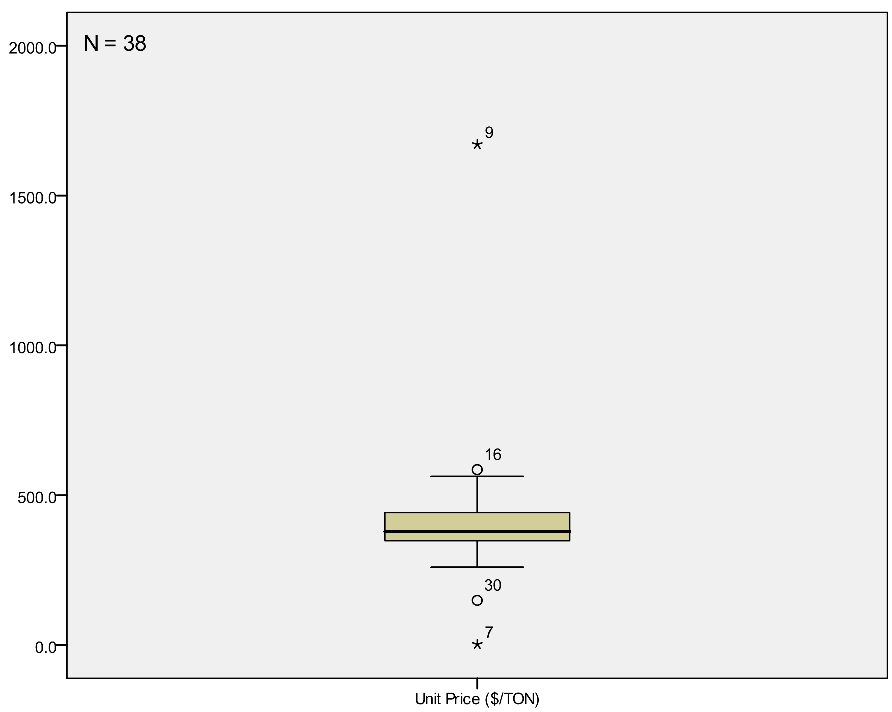


Fig. B- 20. Box plot for unit price in $/TON for tack coat

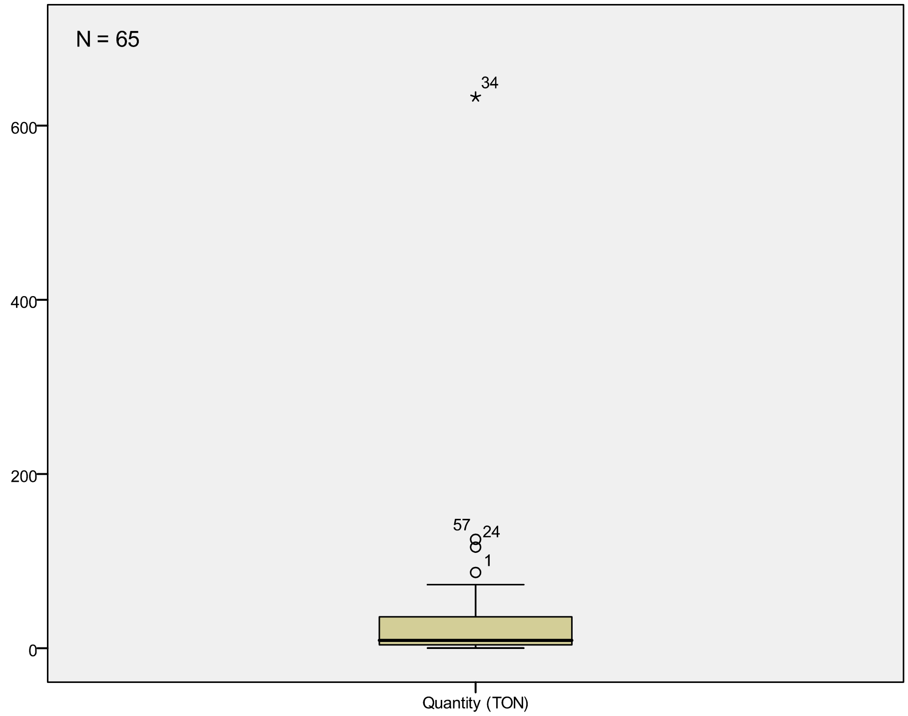


Fig. B- 21. Box plot for quantity in TON for seal coat before processing

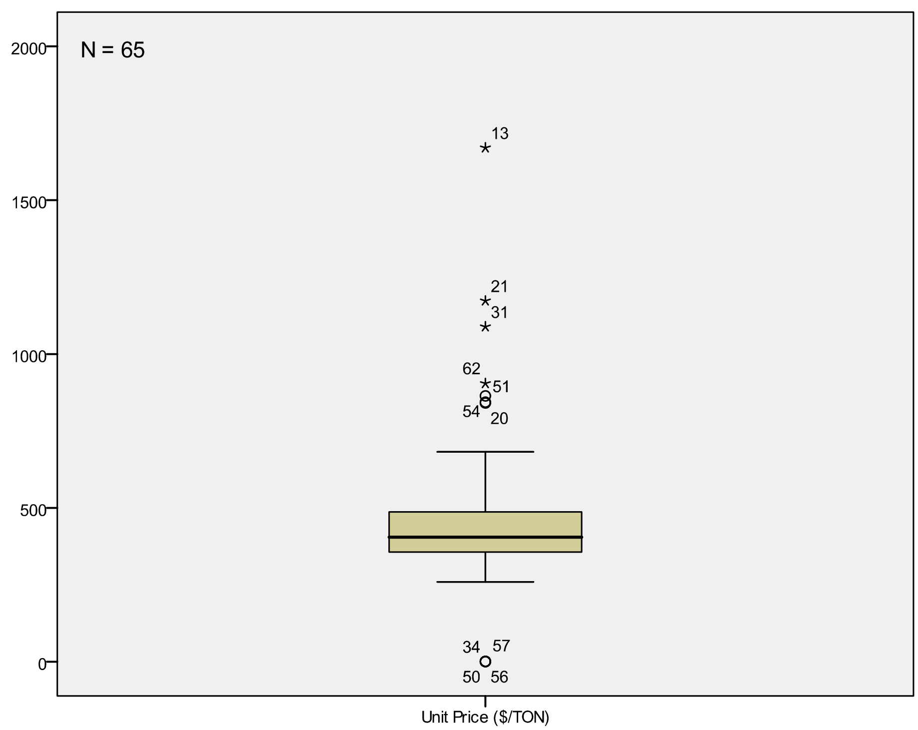


Fig. B- 22. Box plot for unit price in $/TON for seal coat before processing

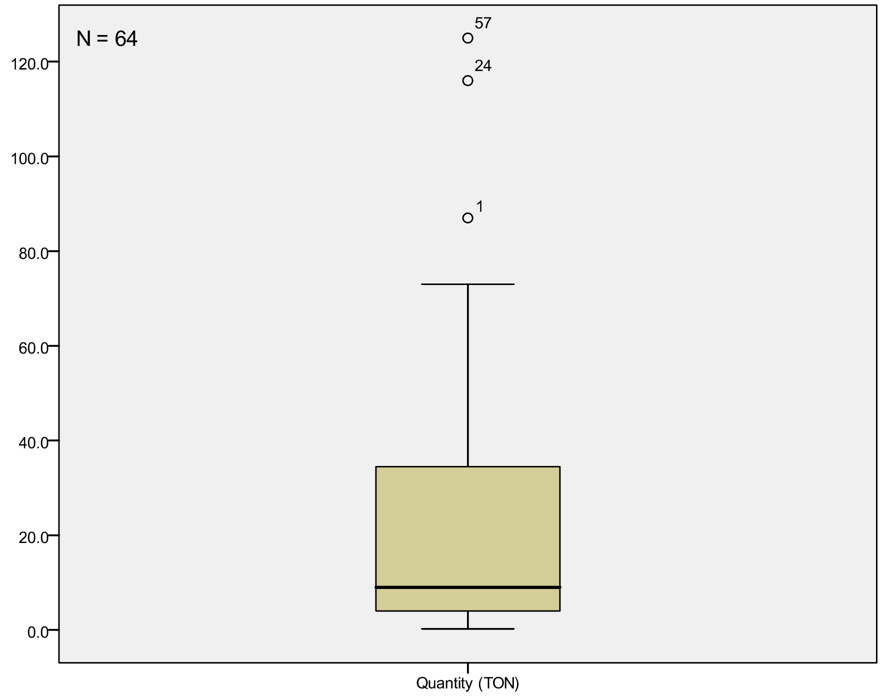


Fig. B- 23. Box plot for quantity in TON for seal coat after processing

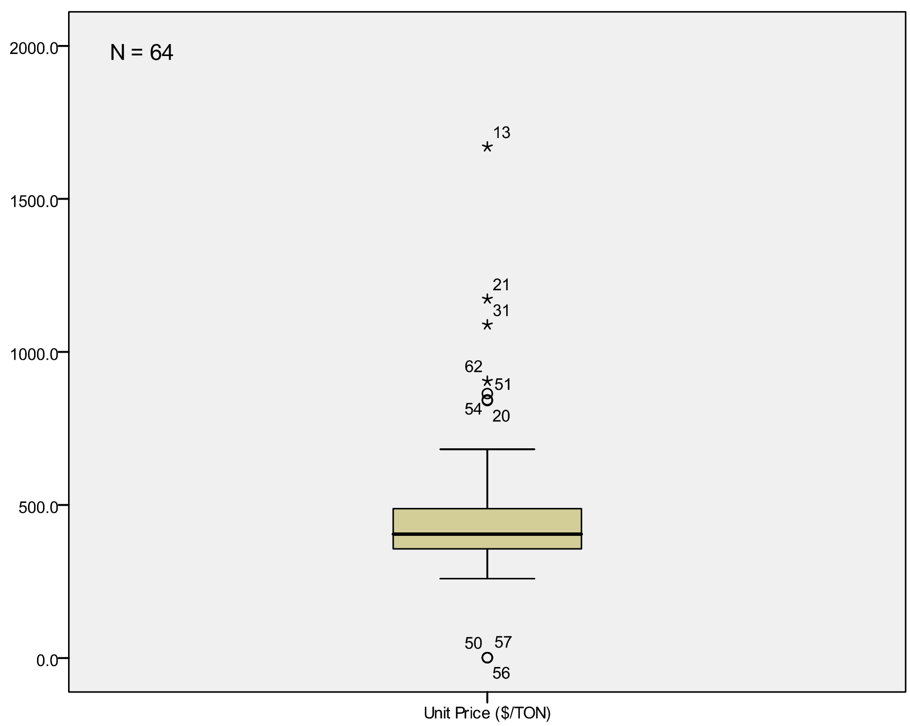


Fig. B- 24. Box plot for unit price in $/TON for seal coat after processing

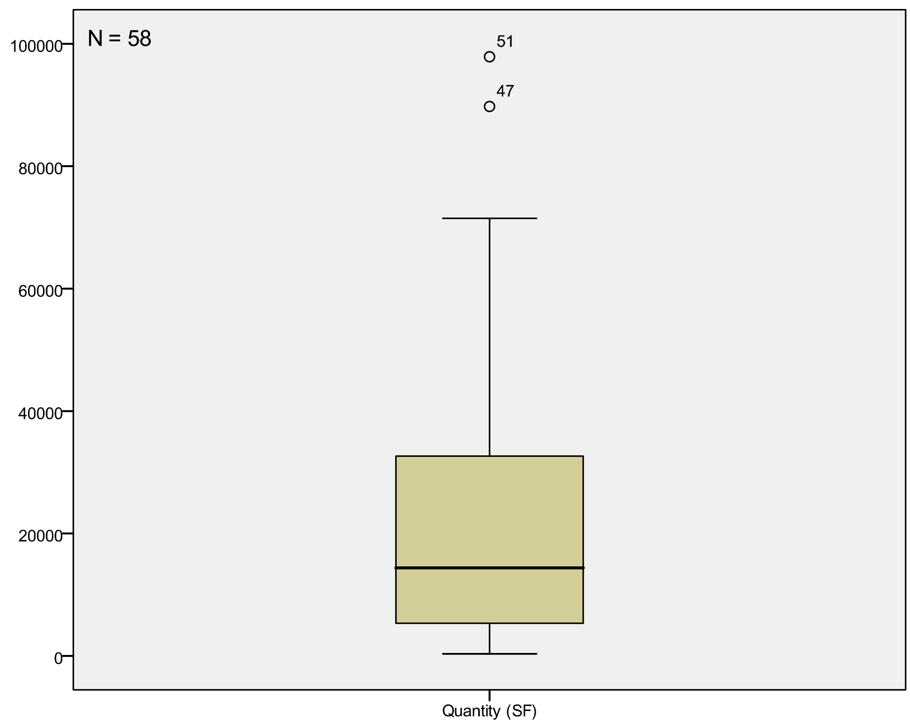


Fig. B- 25. Box plot for quantity in TON for concrete sidewalk

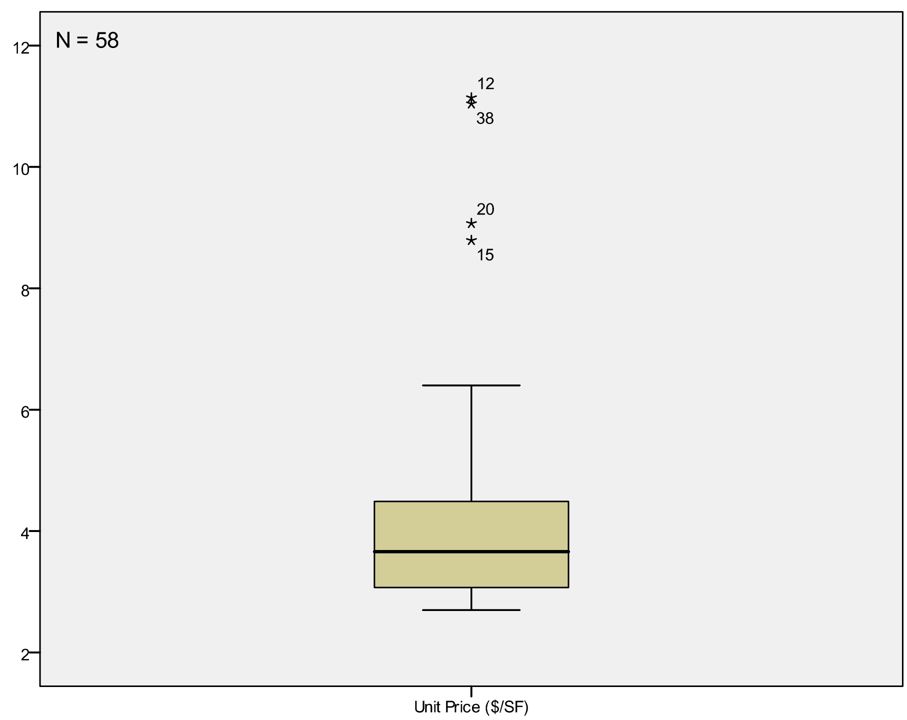


Fig. B- 26. Box plot for unit price in $/SF for concrete sidewalk

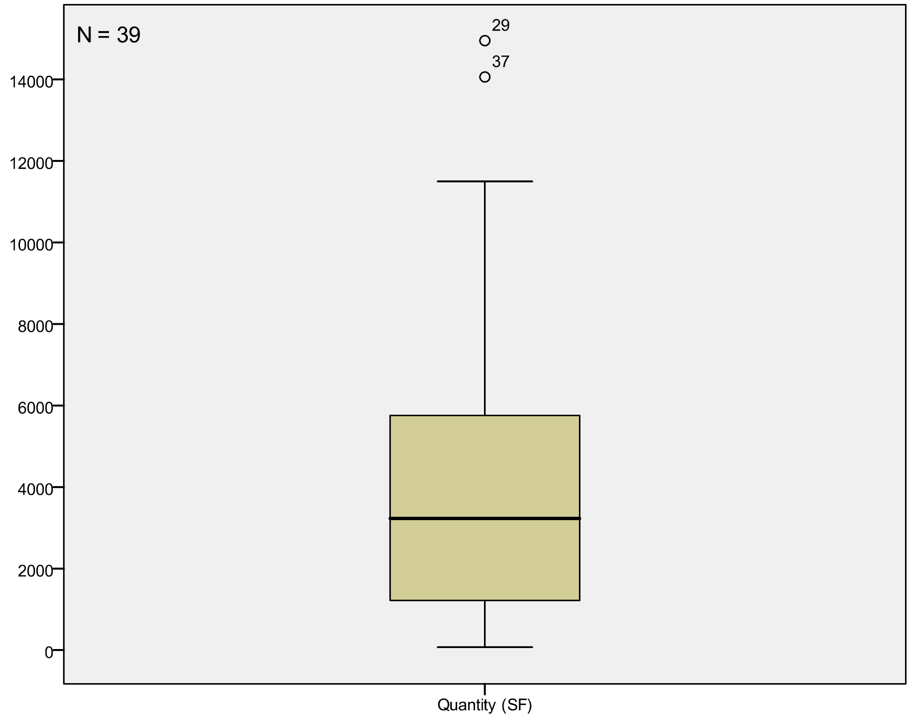


Fig. B- 27. Box plot for quantity in SF for concrete valley gutter

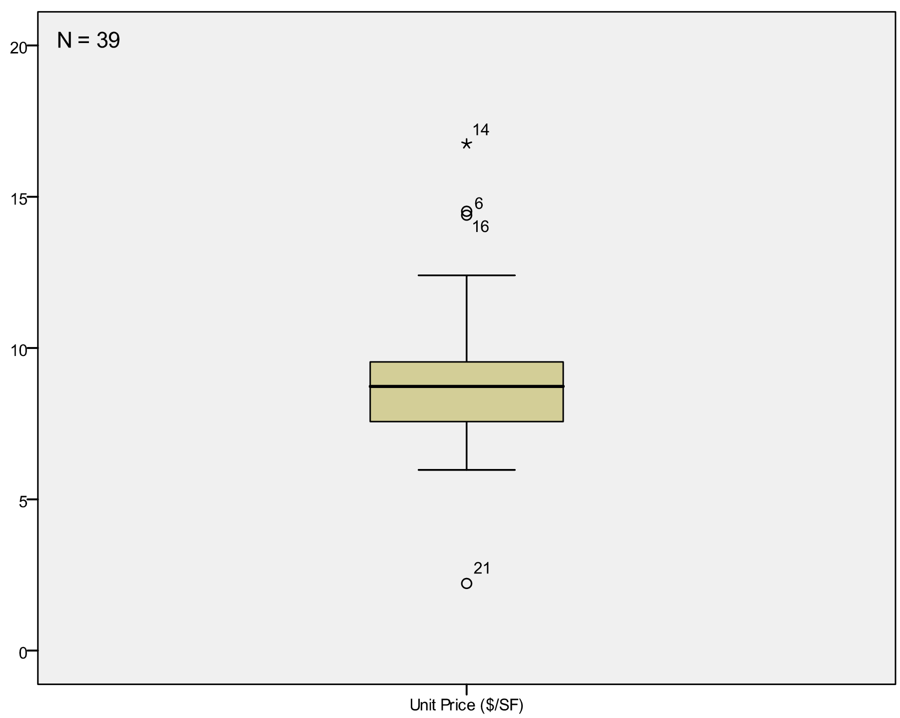


Fig. B- 28. Box plot for unit price in $/SF for concrete valley gutter

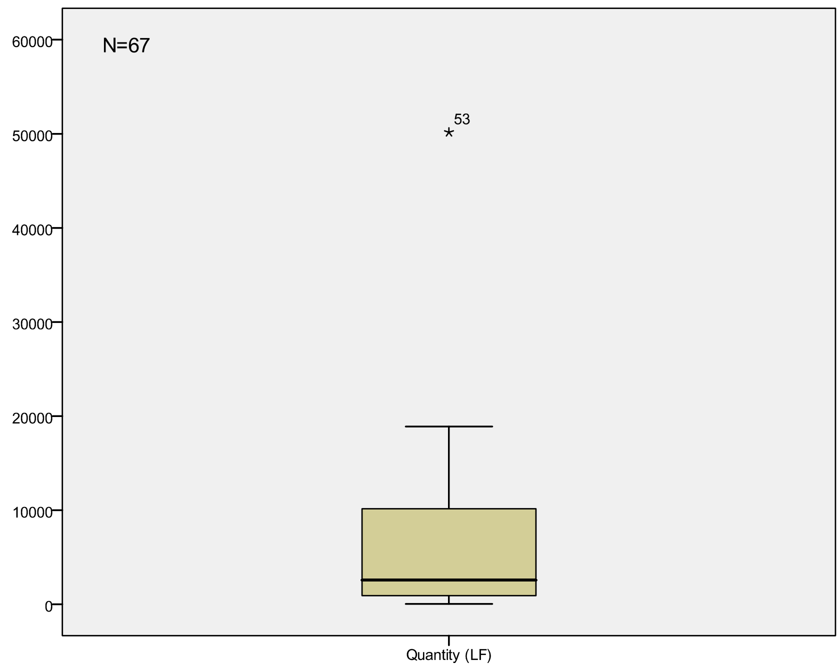


Fig. B- 29. Box plot for quantity in LF for type “L” curb and gutter before processing

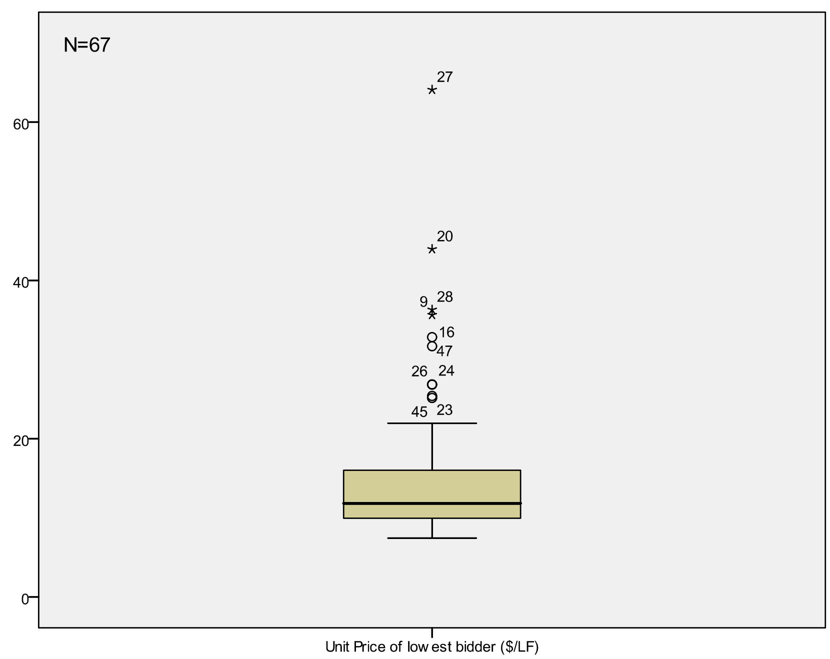


Fig. B- 30. Box plot for unit price in $/LF for type “L” curb and gutter before processing

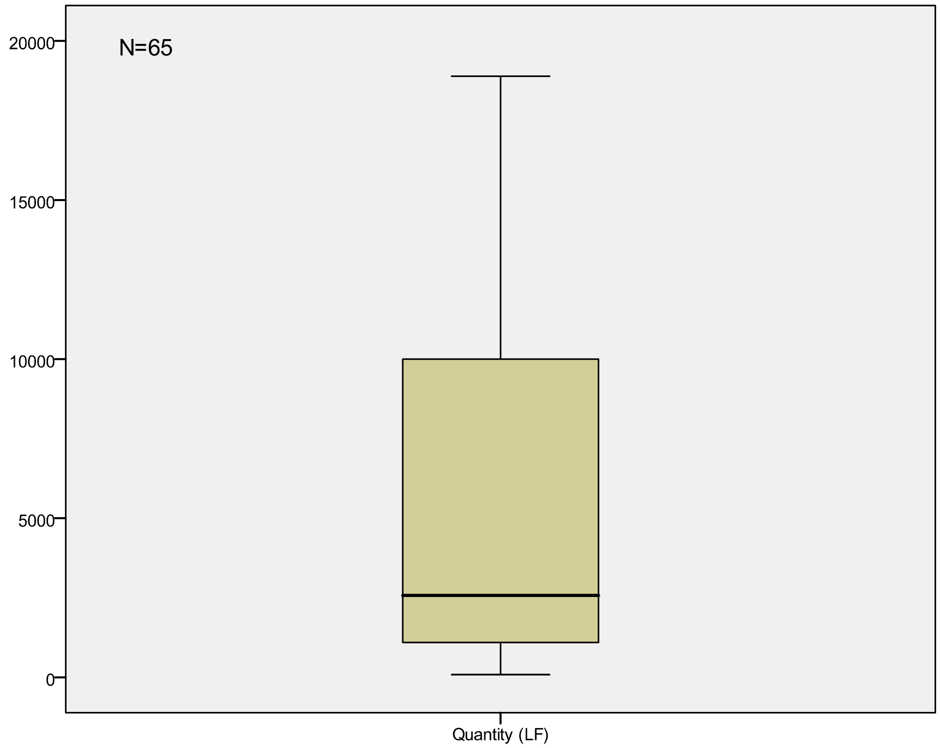


Fig. B- 31. Box plot for quantity in LF for type “L” curb and gutter after processing

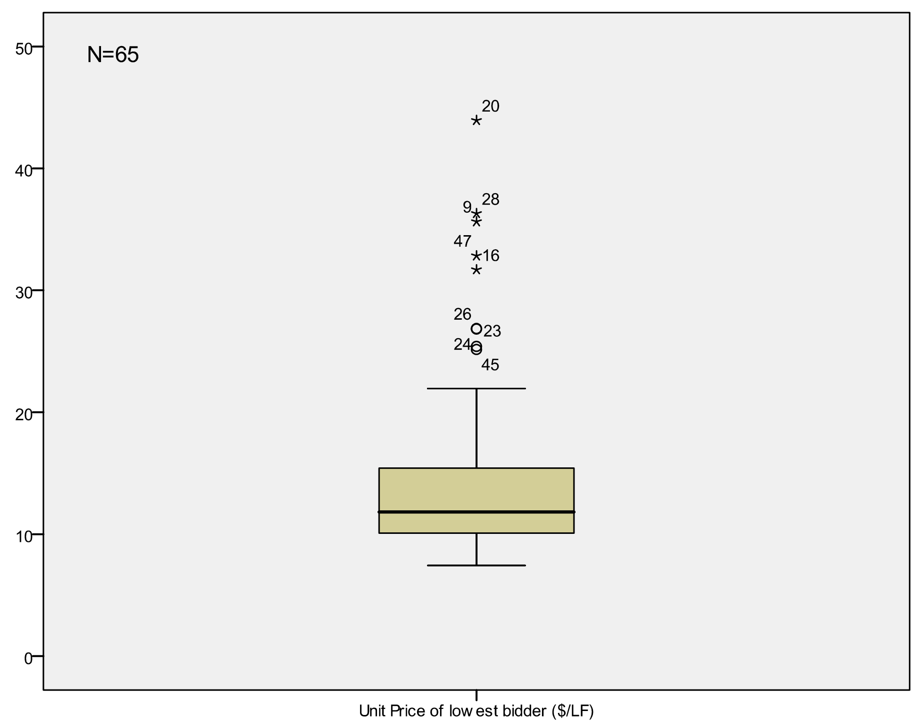


Fig. B- 32. Box plot for unit price in $/LF for type “L” curb and gutter after processing

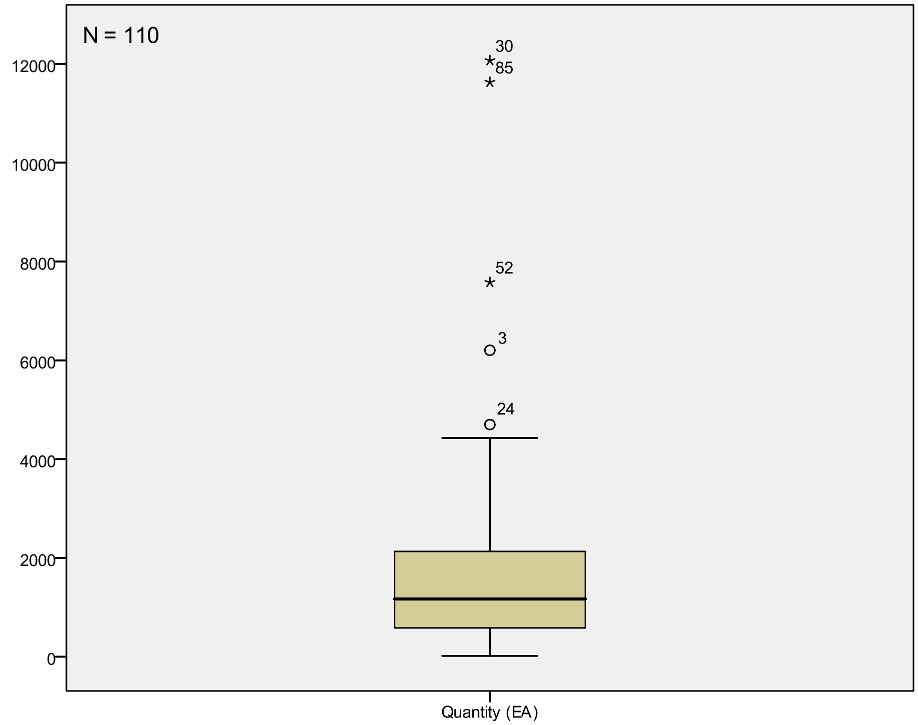


Fig. B- 33. Box plot for quantity for reflective pavement markers before processing

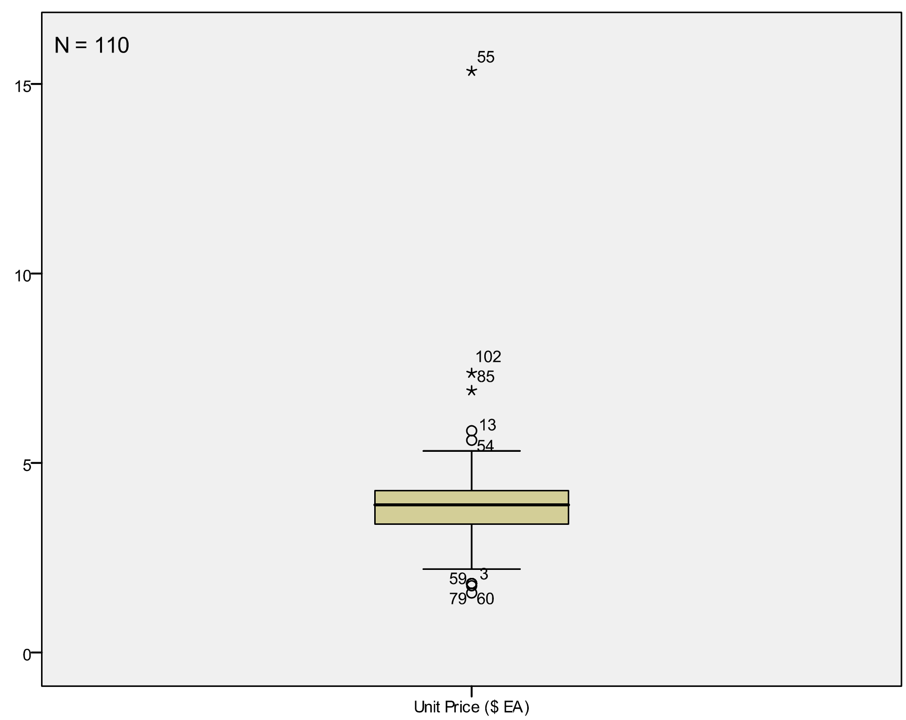


Fig. B- 34. Box plot for unit price for reflective pavement markers before processing

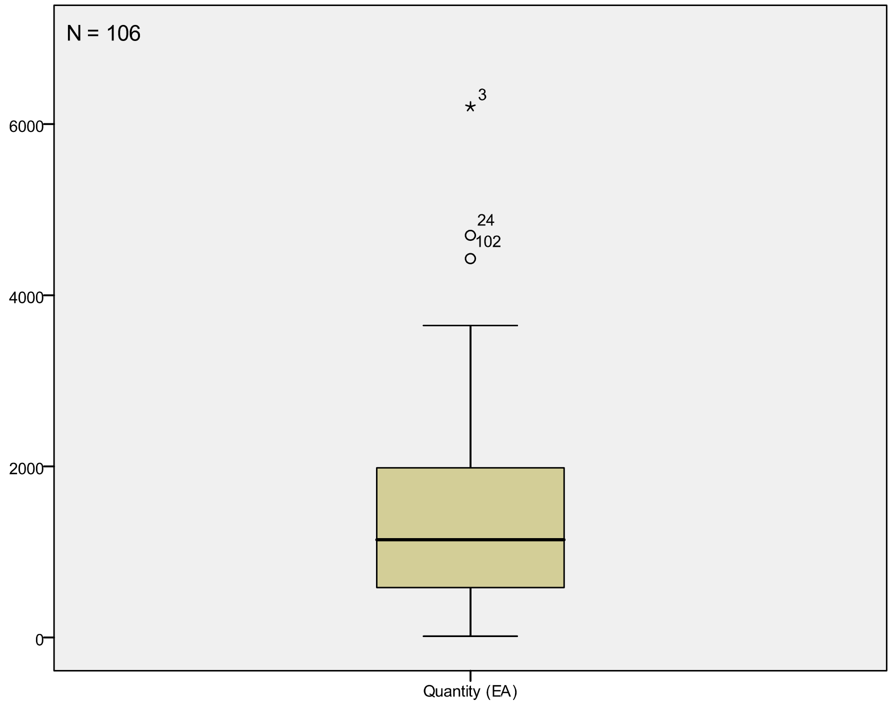


Fig. B- 35. Box plot for quantity for reflective pavement markers after processing

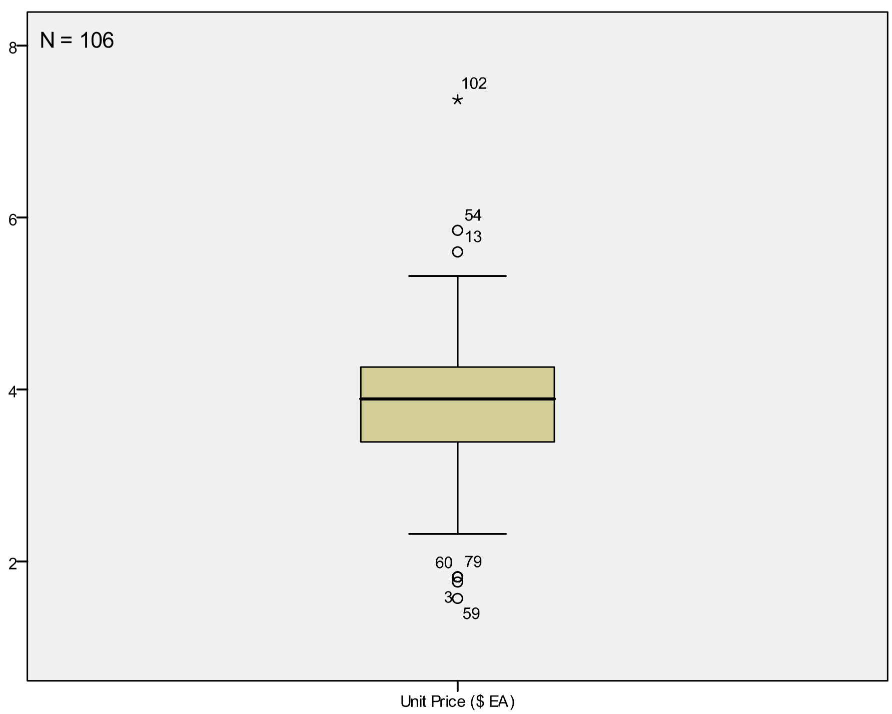


Fig. B- 36. Box plot for unit price for reflective pavement markers after processing

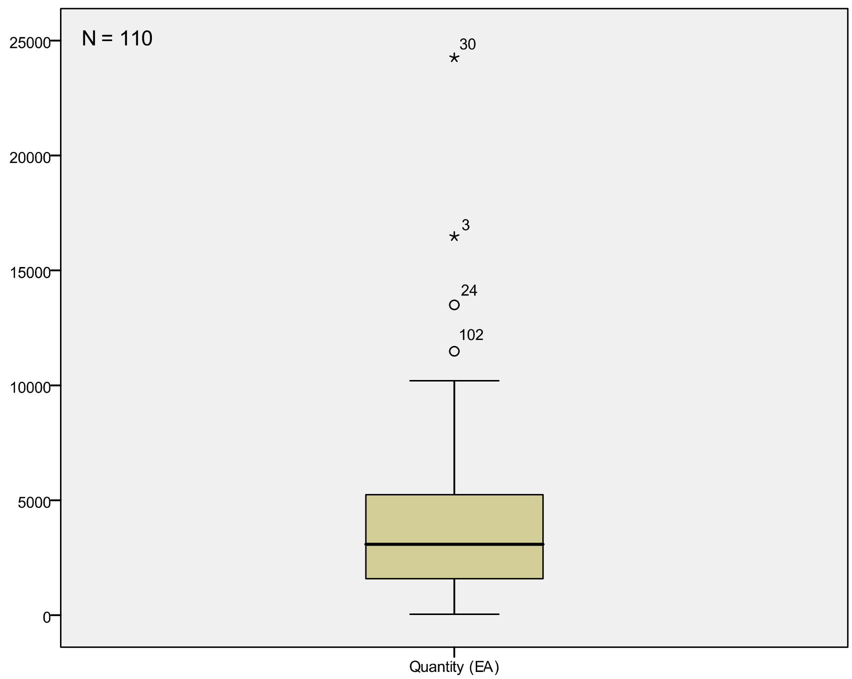


Fig. B- 37. Box plot for quantity for non reflective pavement markers before processing

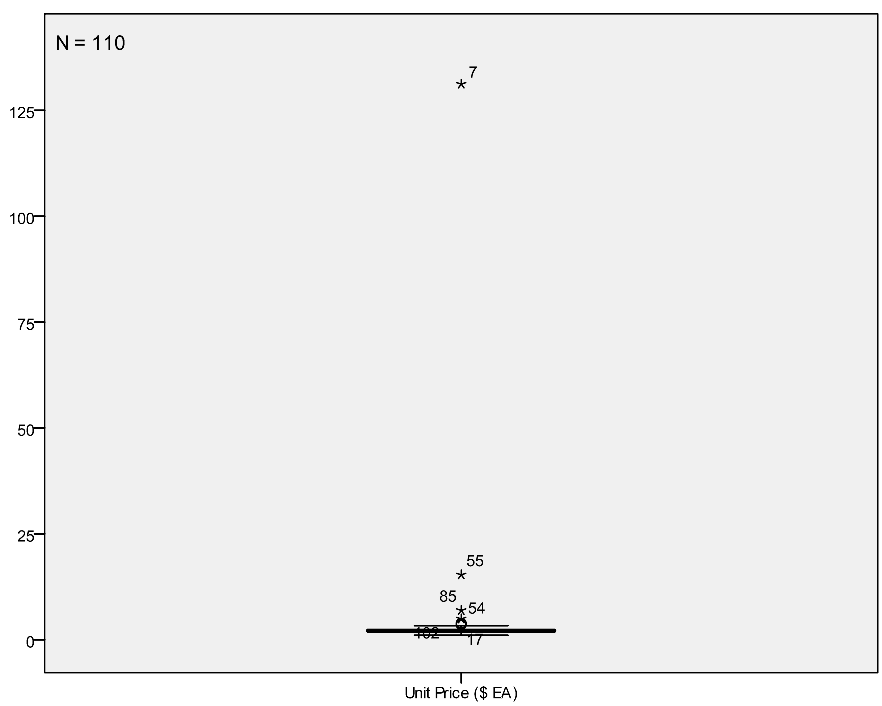


Fig. B- 38. Box plot for unit price for non reflective pavement markers surface before processing

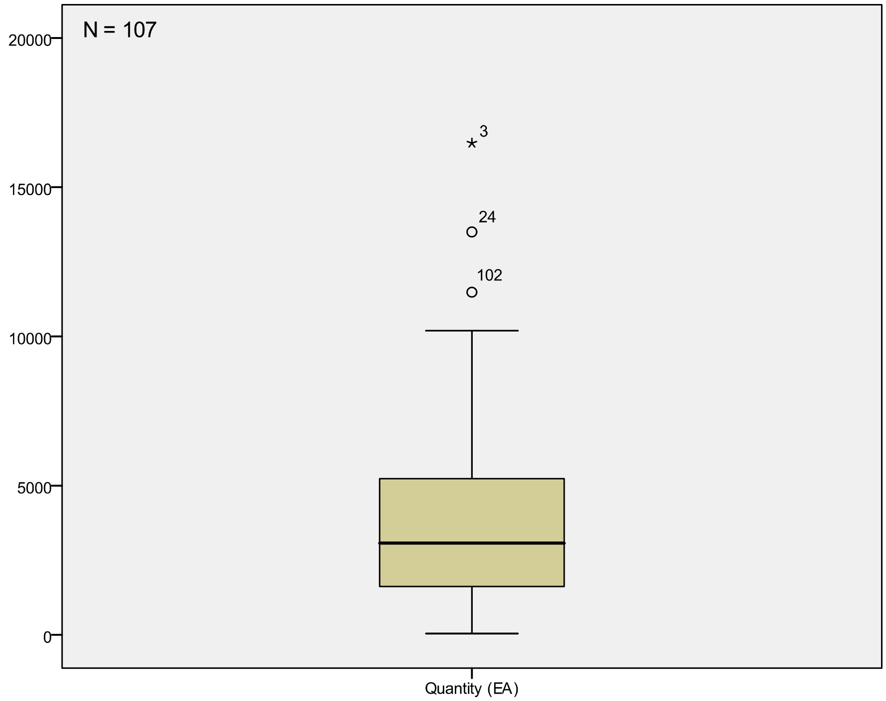


Fig. B- 39. Box plot for quantity for non reflective pavement markers after processing

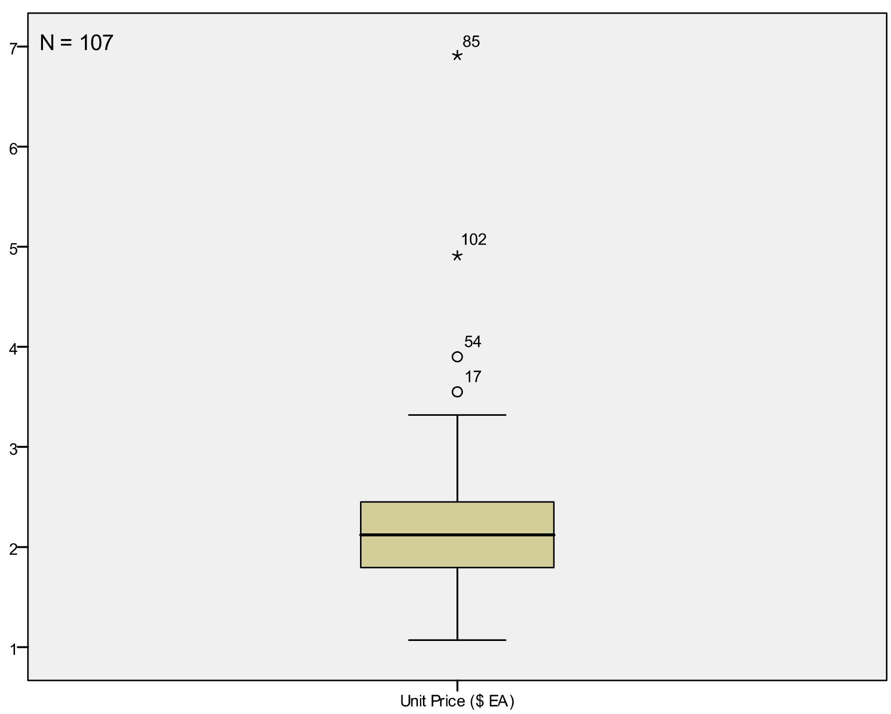


Fig. B- 40. Box plot for unit price for non reflective pavement markers after processing

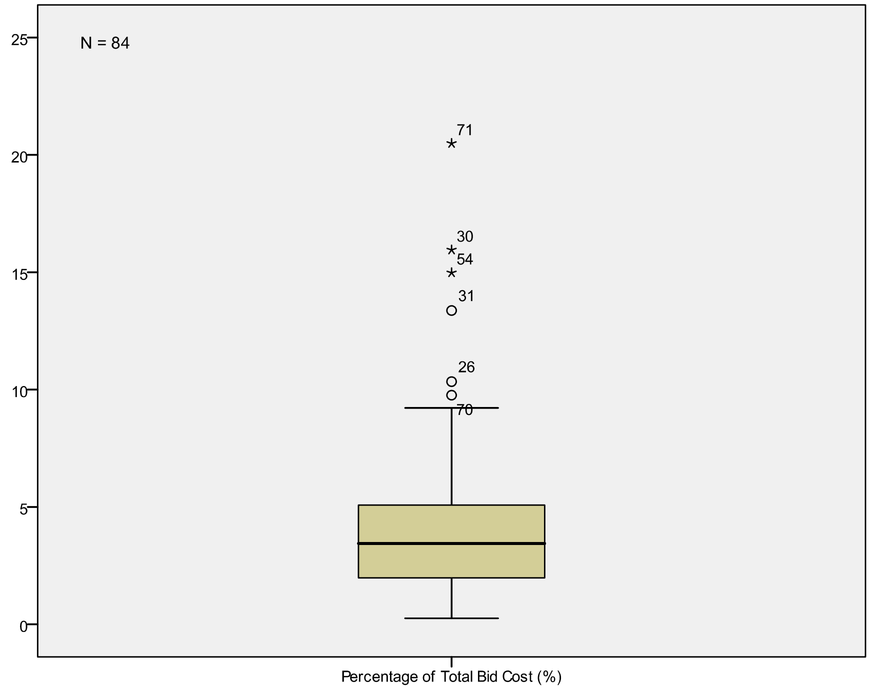


Fig. B- 41. Box plot for percentage of total bid cost for quality control before processing

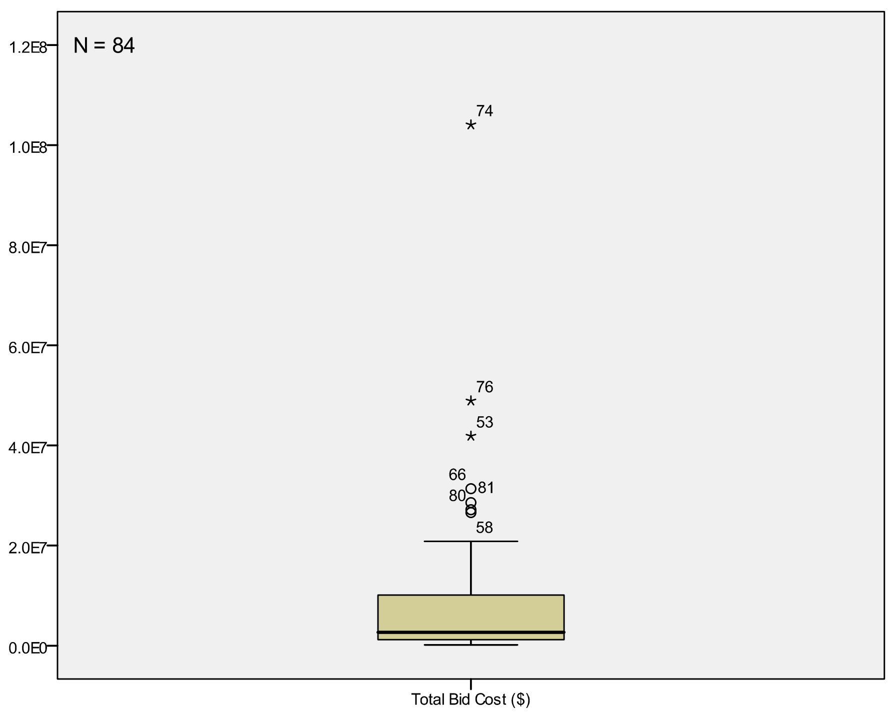


Fig. B- 42. Box plot for total bid cost for quality control before processing

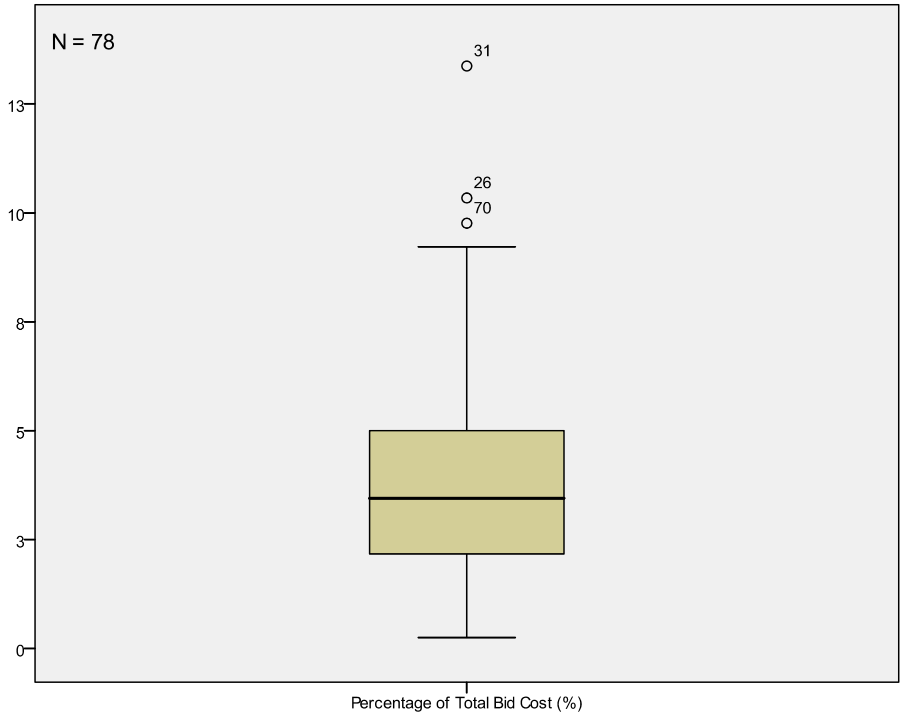


Fig. B- 43. Box plot for percentage of total bid cost for quality control after processing

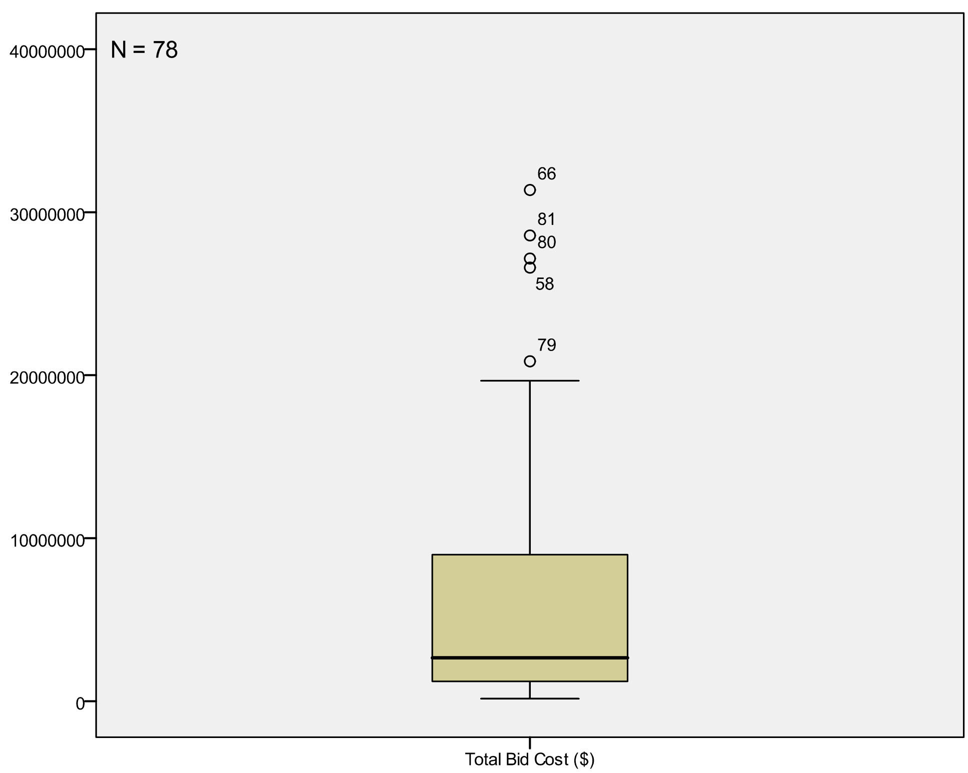


Fig. B- 44. Box plot for total bid cost for quality control after processing

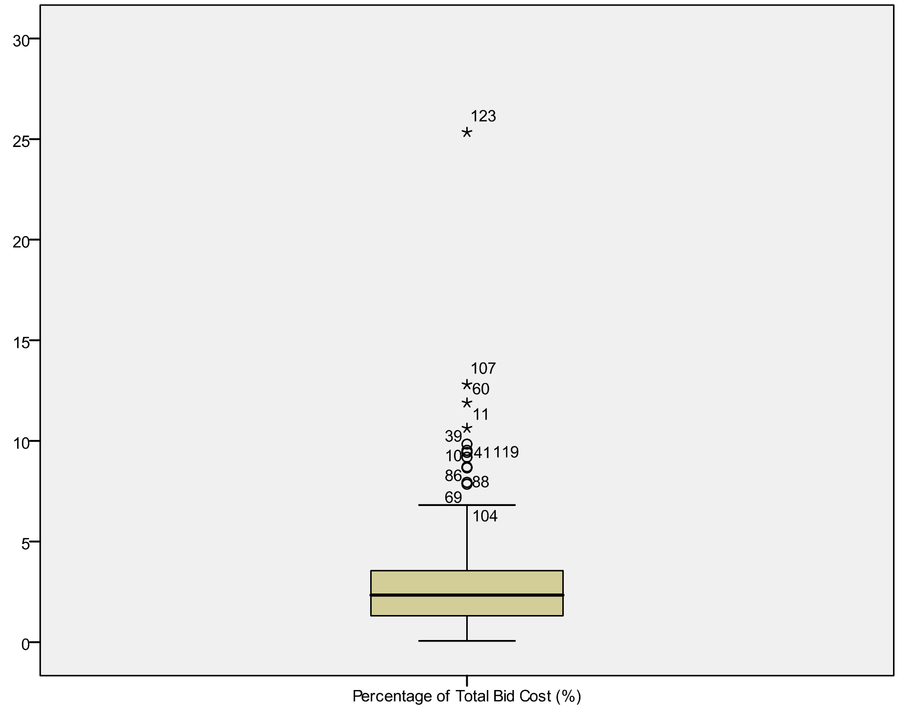


Fig. B- 45. Box plot for percentage of total bid cost for traffic control before processing

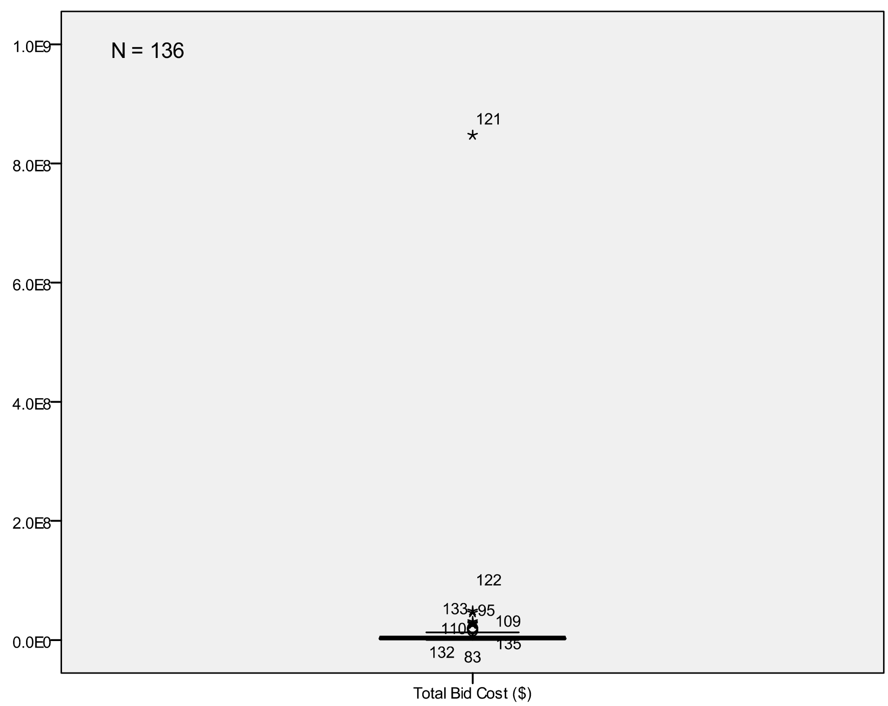


Fig. B- 46. Box plot for total bid cost for traffic control before processing

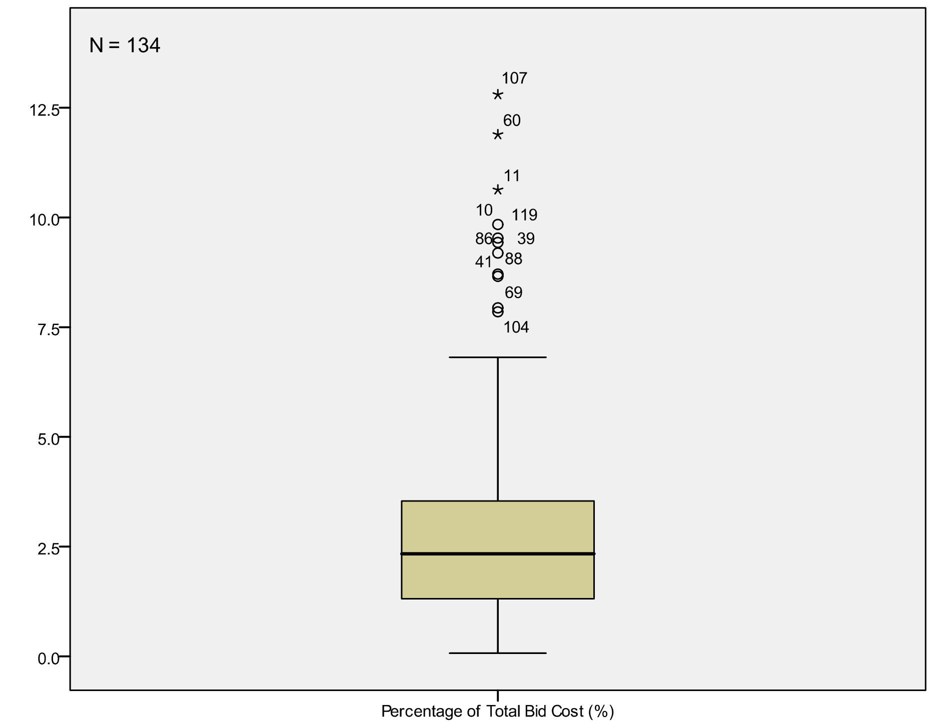


Fig. B- 47. Box plot for percentage of total bid cost for traffic control after processing

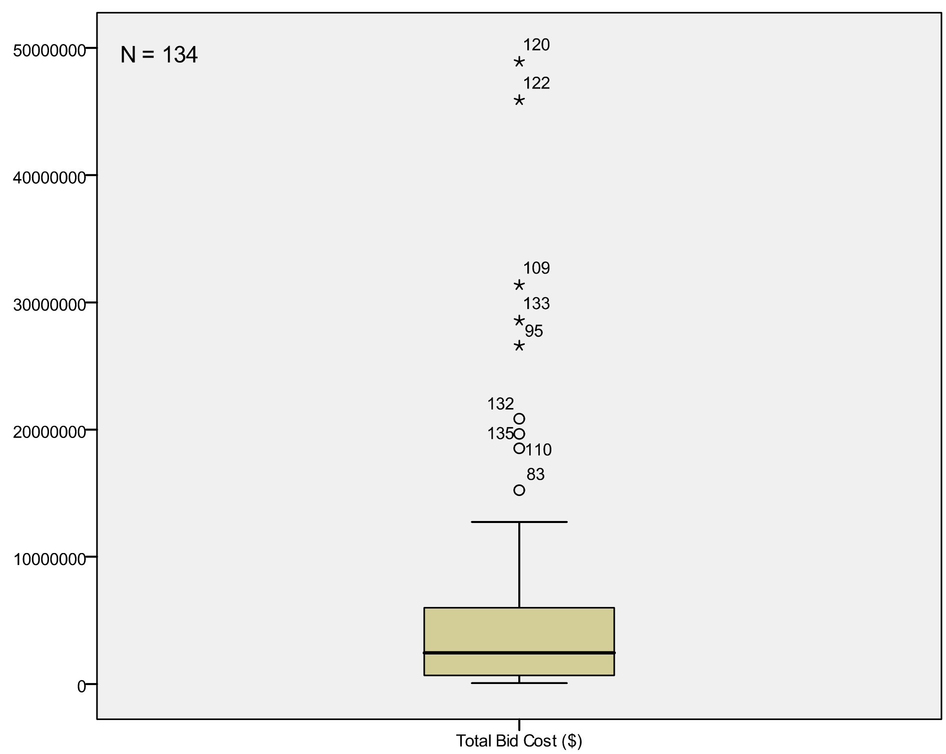


Fig. B- 48. Box plot for total bid cost for traffic control after processing

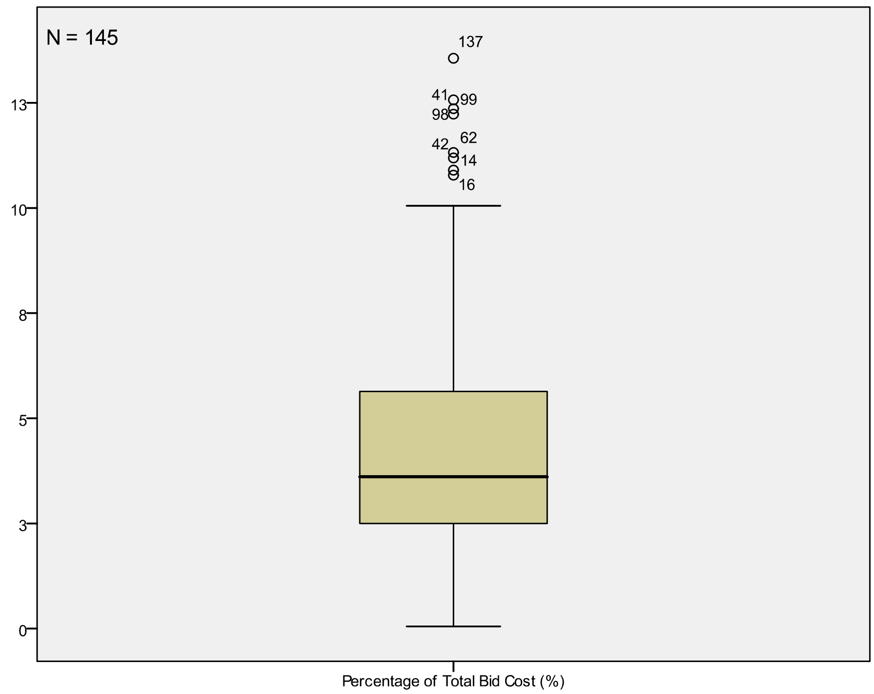


Fig. B- 49. Box plot for percentage of total bid cost for construction conflicts and additional works before processing

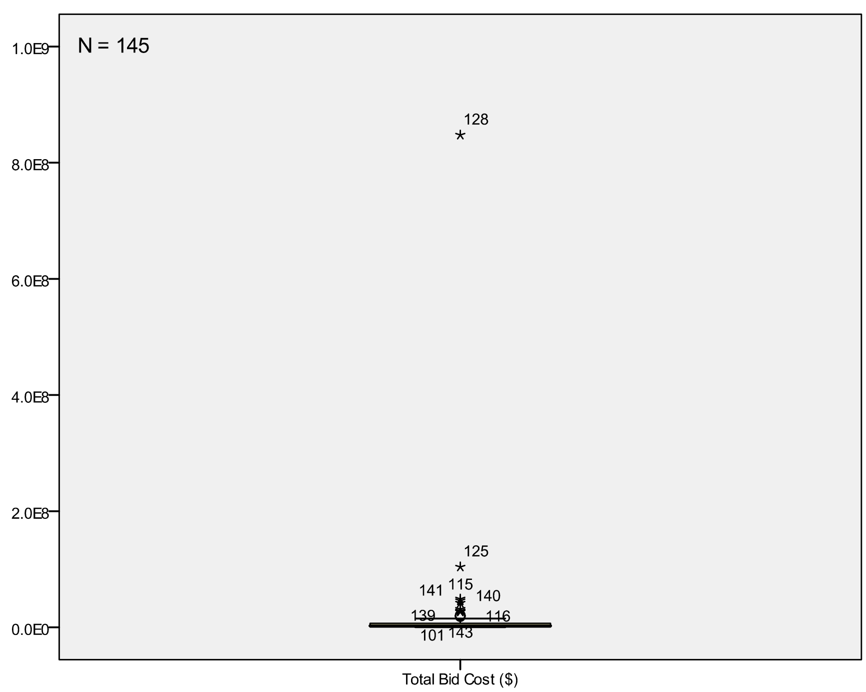


Fig. B- 50. Box plot for total bid cost for construction conflicts and additional works before processing

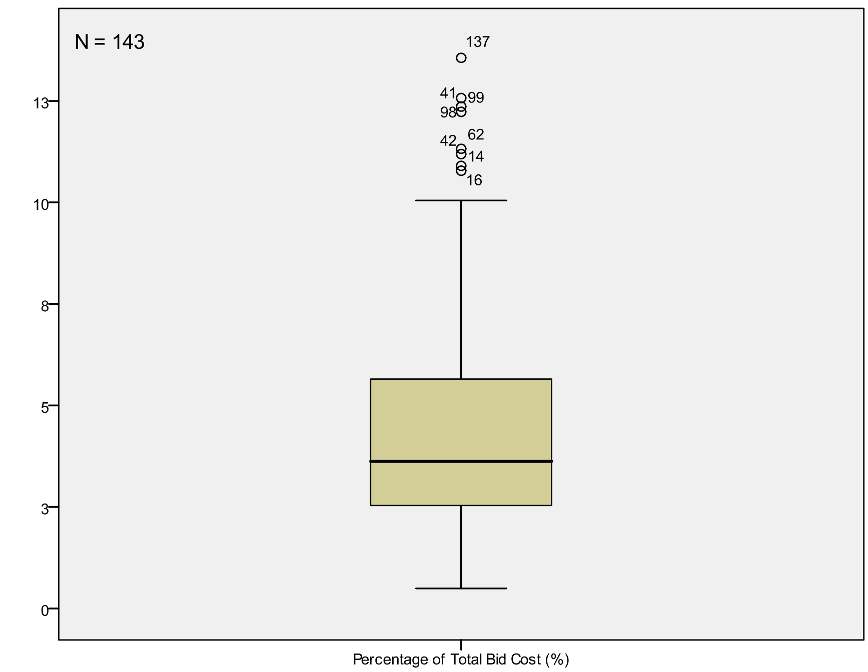


Fig. B- 51. Box plot for percentage of total bid cost for construction conflicts and additional works after processing

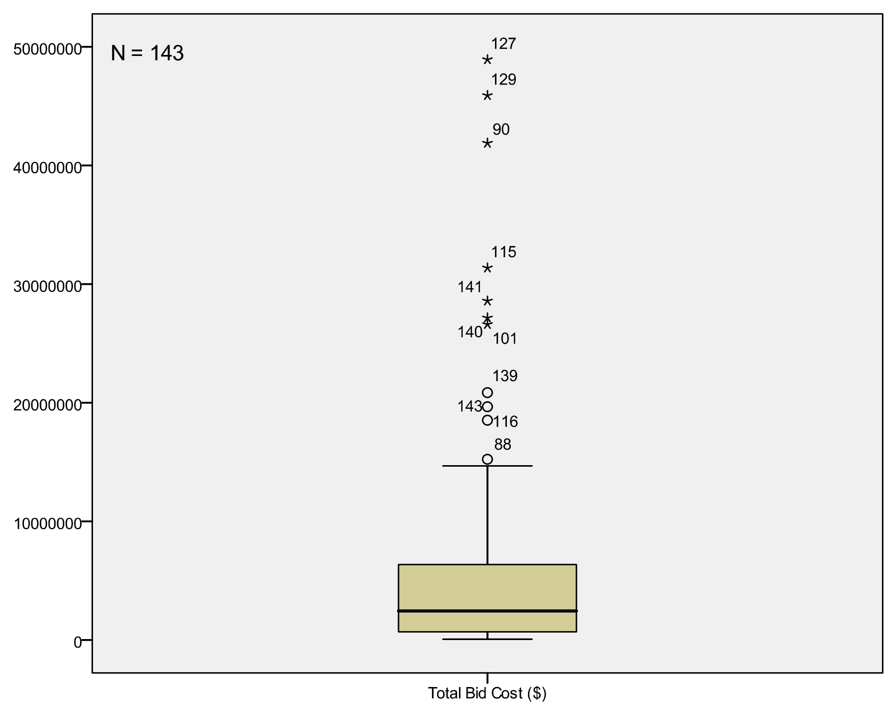


Fig. B- 52. Box plot for total bid cost for construction conflicts and additional works after processing

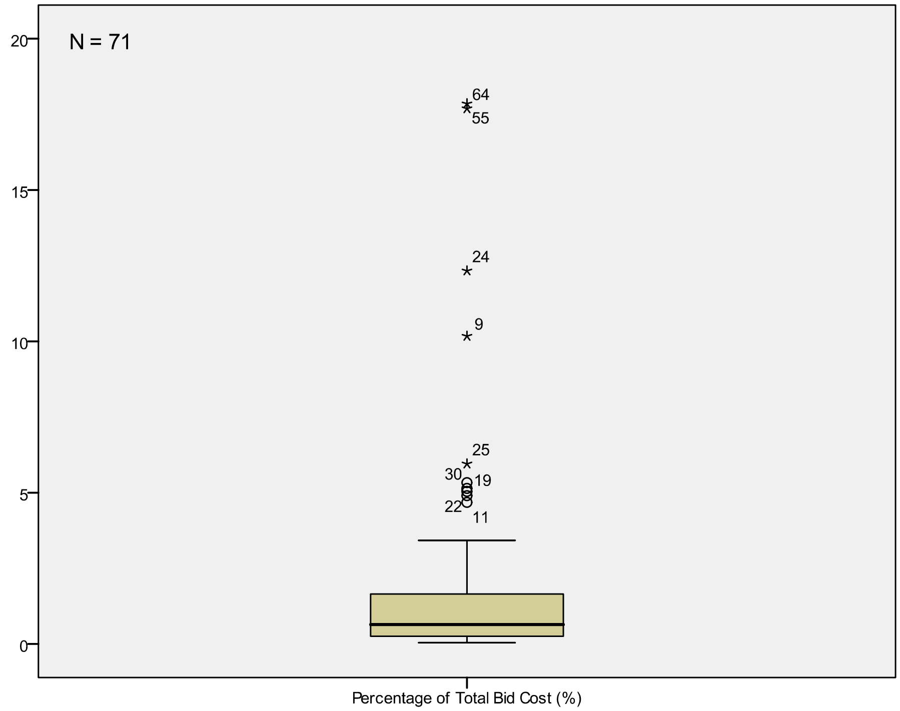


Fig. B- 53. Box plot for percentage of total bid cost for clearing and grubbing before processing

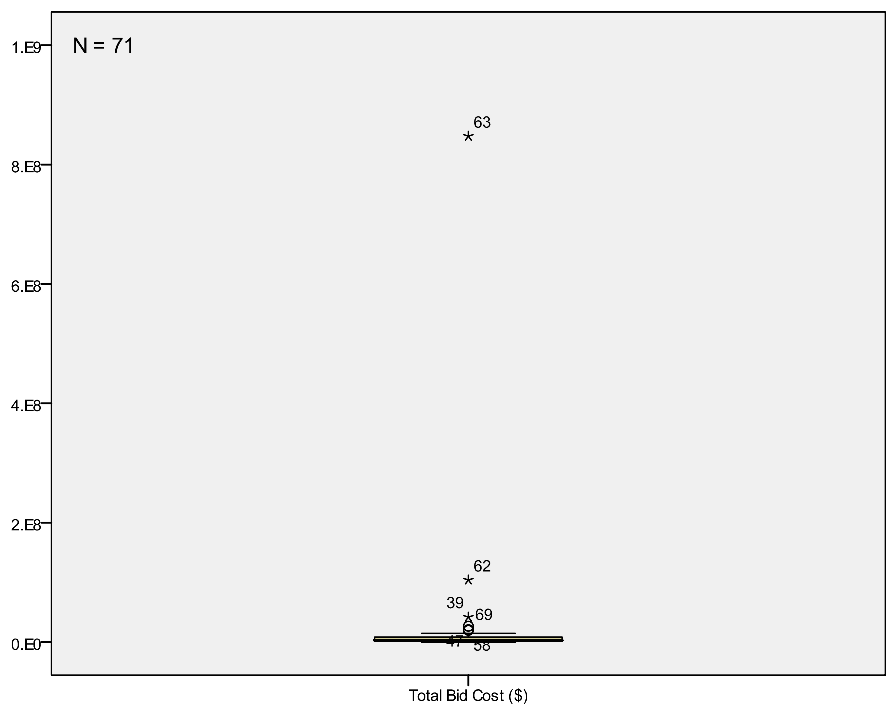


Fig. B- 54. Box plot for total bid cost for clearing and grubbing before processing

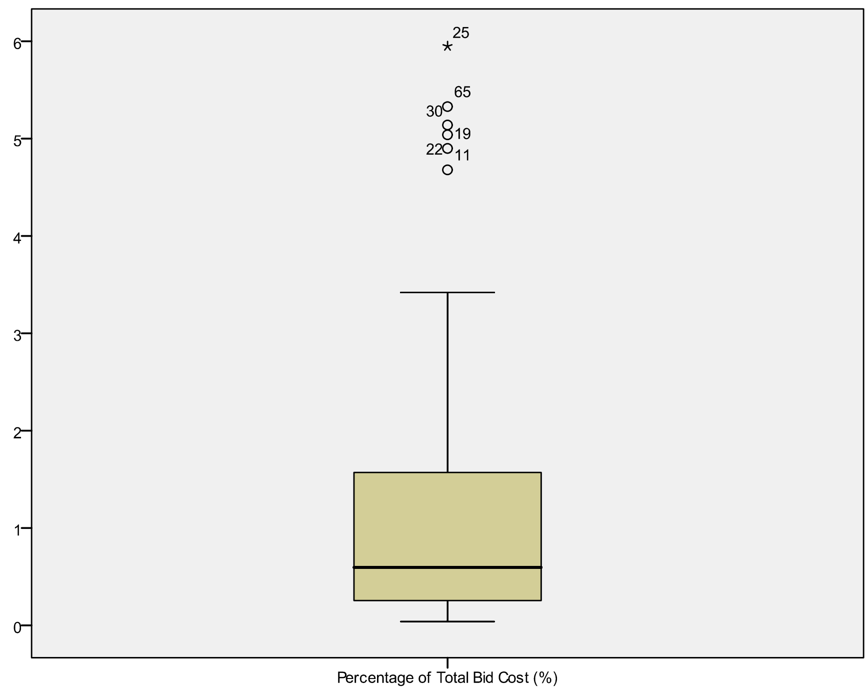


Fig. B- 55. Box plot for percentage of total bid cost for clearing and grubbing after processing

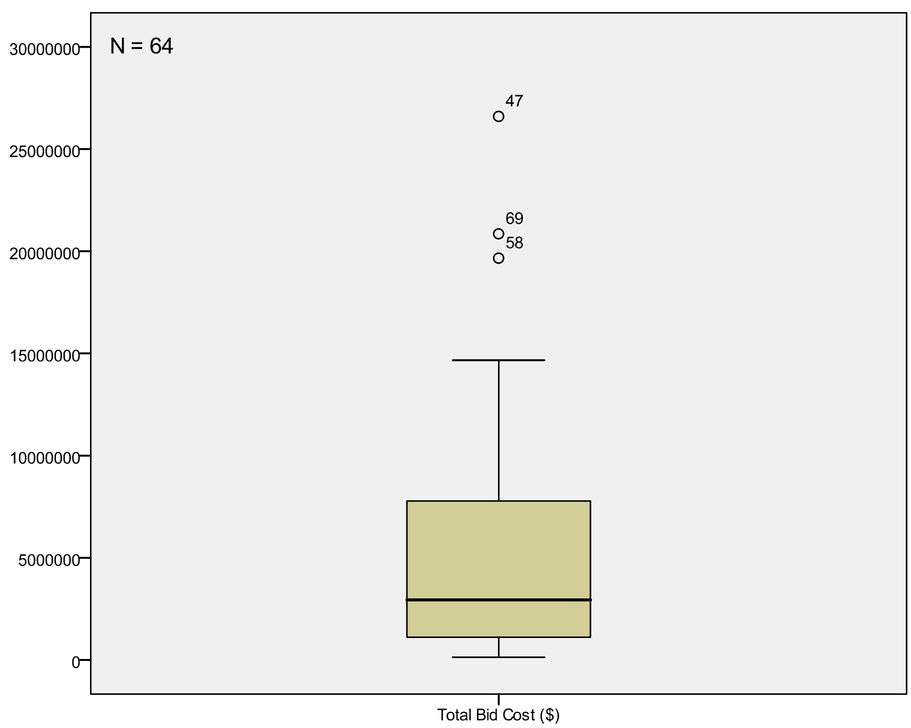


Fig. B- 56. Box plot for total bid cost for clearing and grubbing after processing

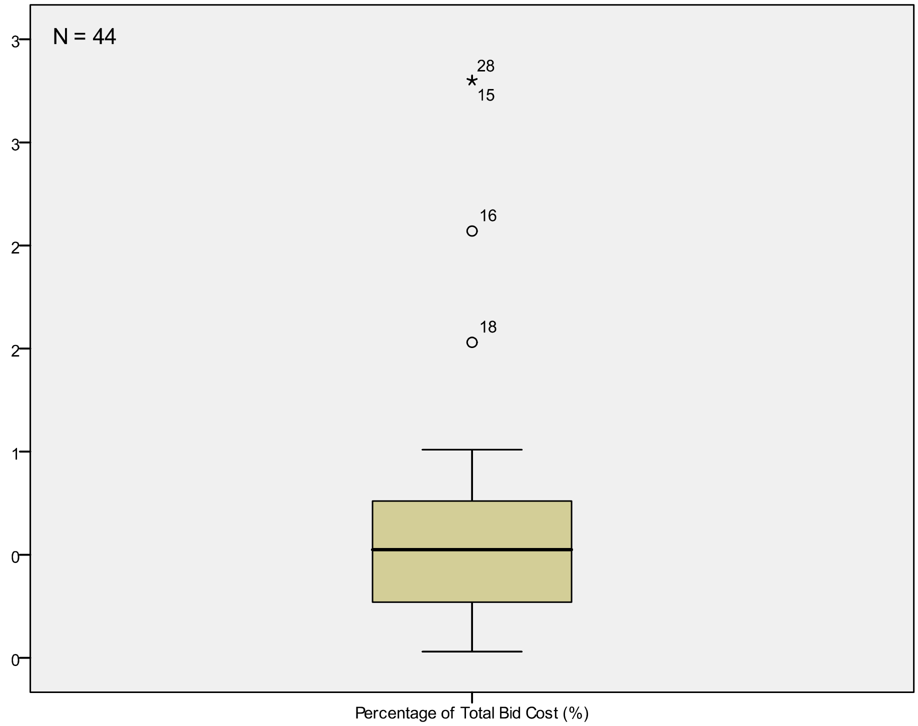


Fig. B- 57. Box plot for percentage of total bid cost for dust control

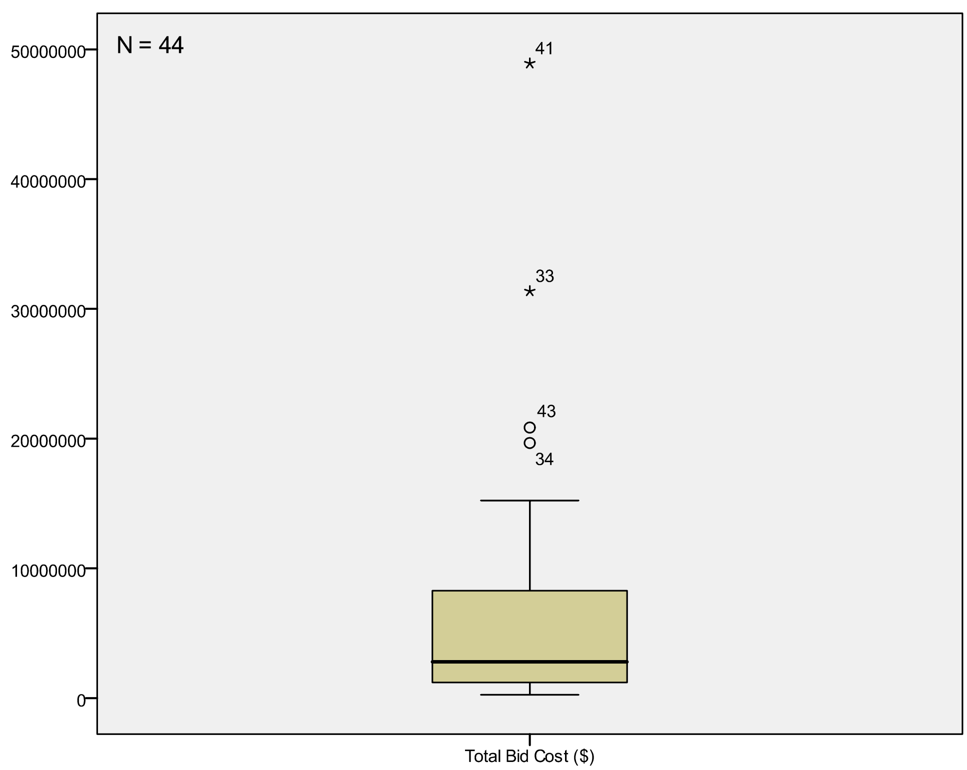


Fig. B- 58. Box plot for total bid cost for dust control

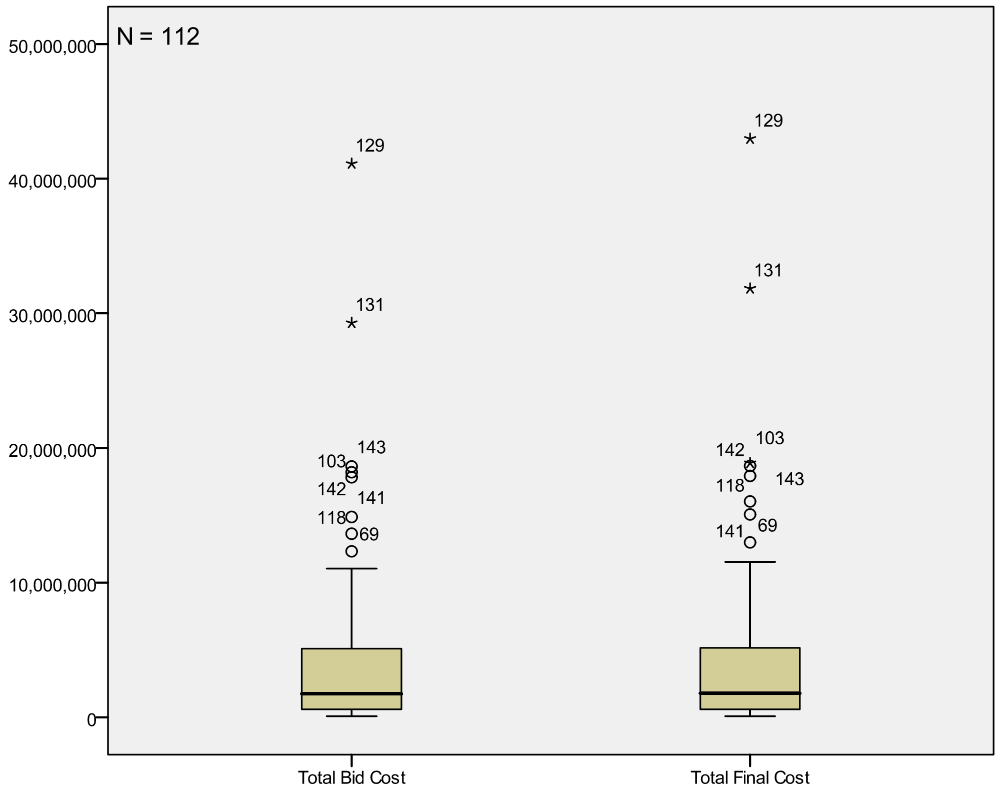


Fig. B- 59. Box plot for total bid cost and total completion cost

APPENDIX C

RESIDUAL PLOT WITH INDEPENDENT VARIABLE

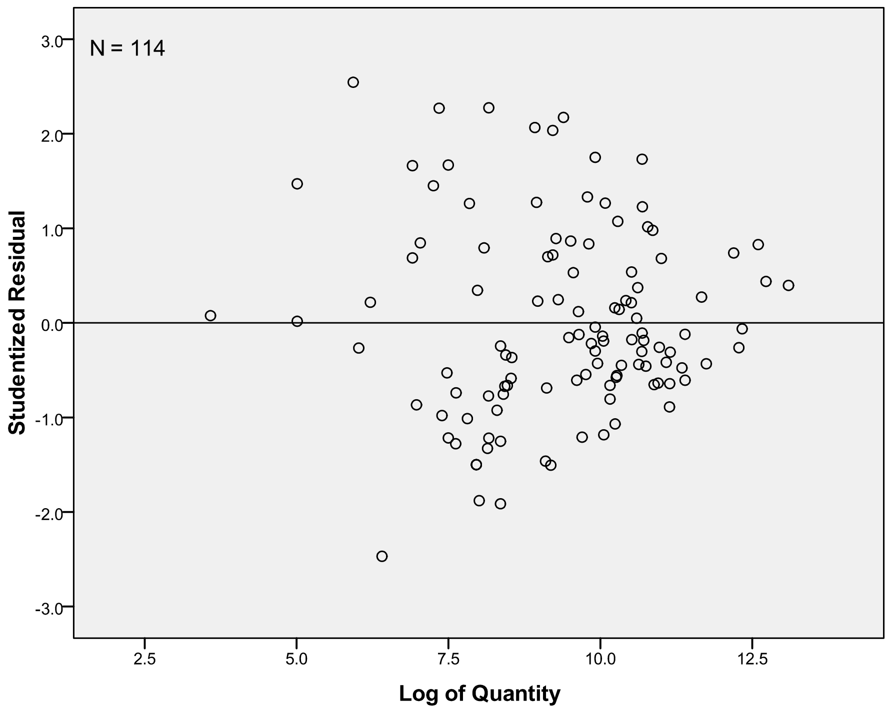


Fig. C- 1. Residual plot with logarithm of quantity for roadway excavation

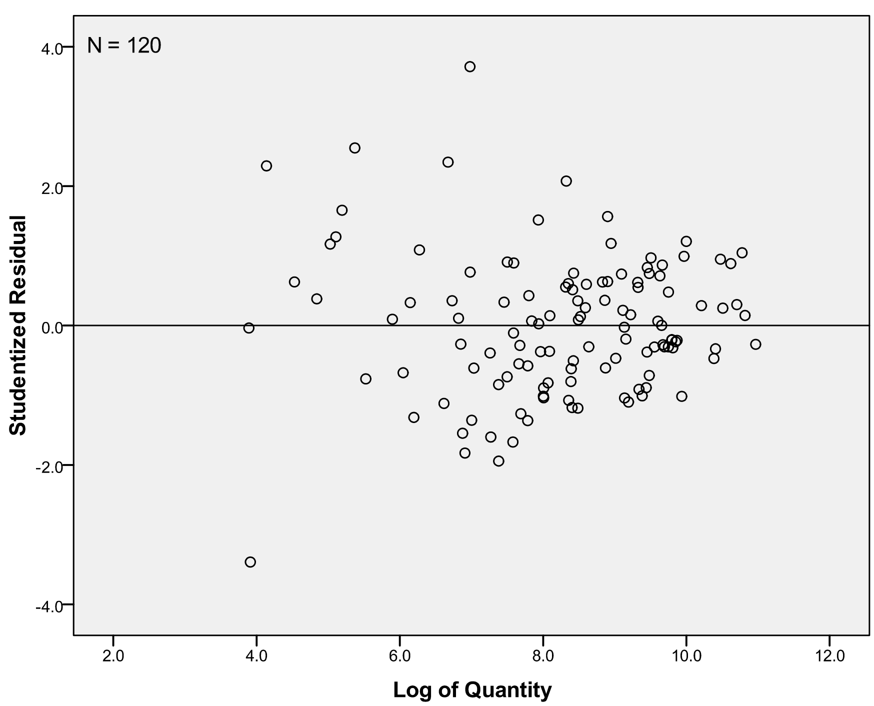


Fig. C- 2. Residual plot with log of quantity for type II aggregate base

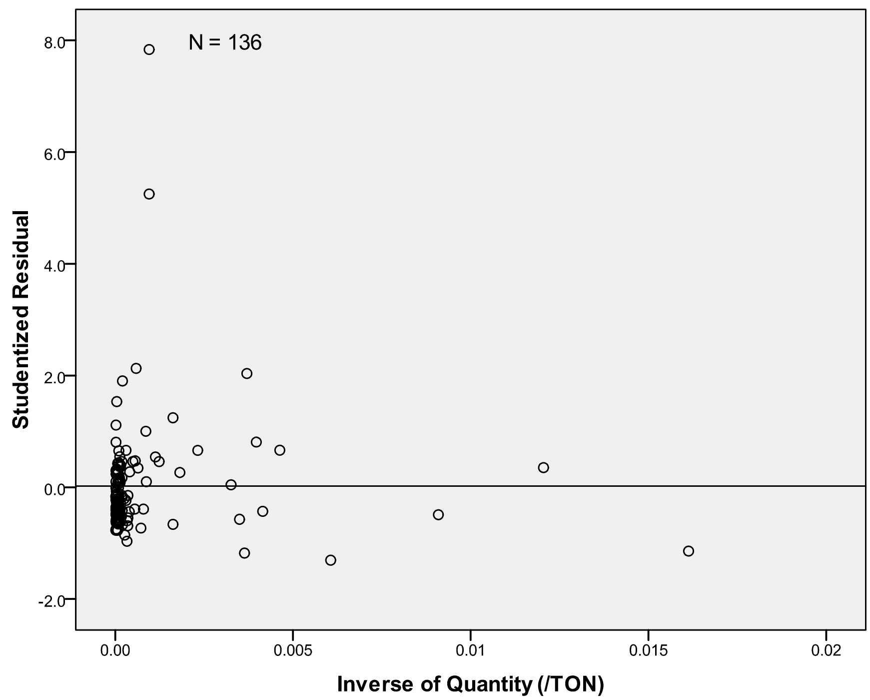


Fig. C- 3. Residual plot with inverse of quantity for plantmix bituminous surface

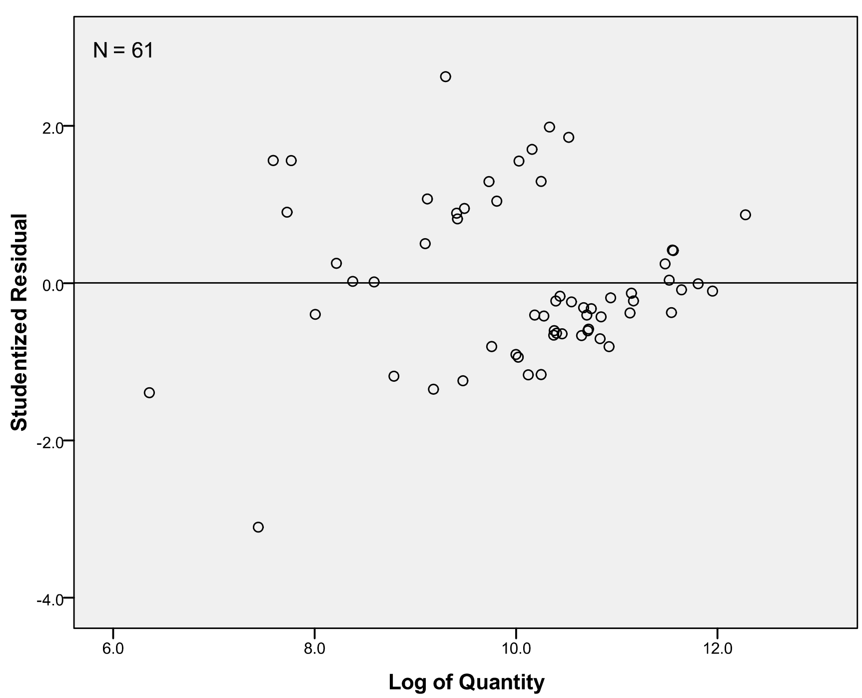


Fig. C- 4. Residual plot with logarithm of quantity for plantmix bituminous open-graded surface (3/4" depth)

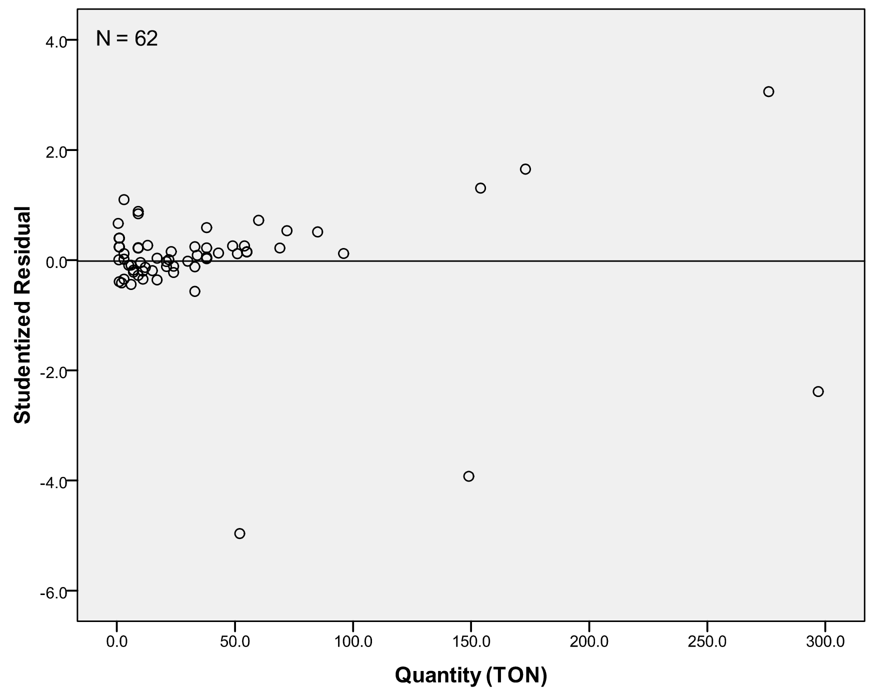


Fig. C- 5. Residual plot with quantity in TON for prime coat

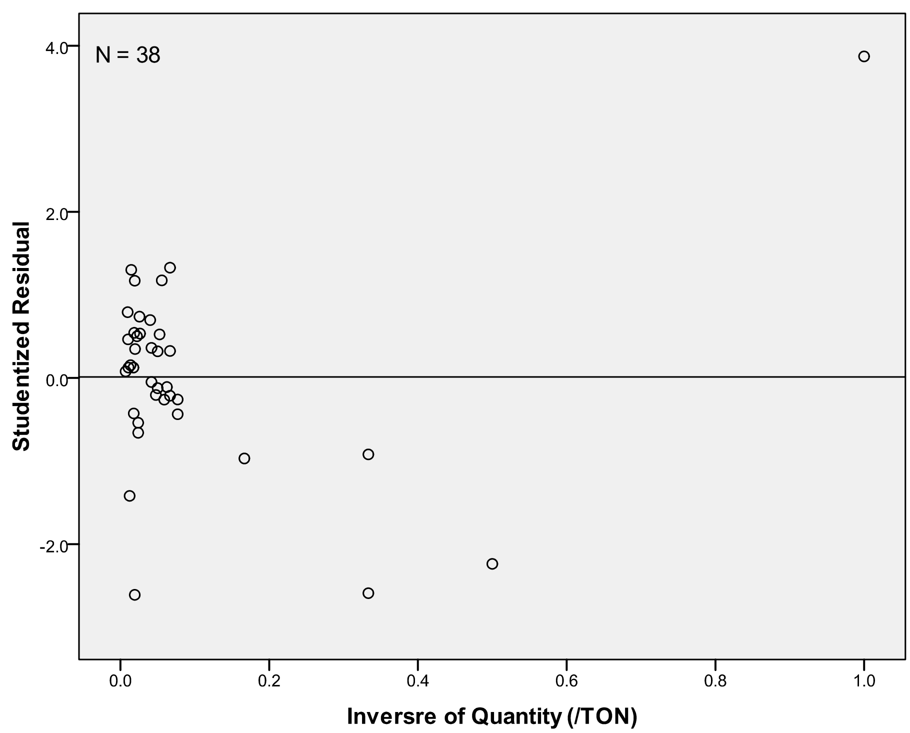


Fig. C- 6. Residual plot with logarithm of quantity for tack coat

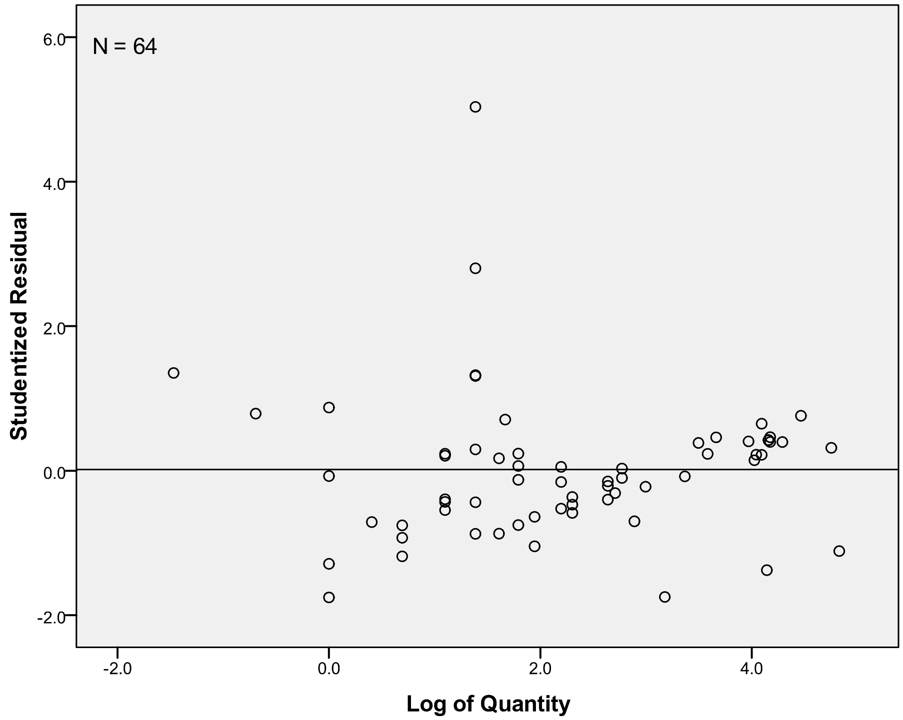


Fig. C- 7. Residual plot with logarithm of quantity for seal coat

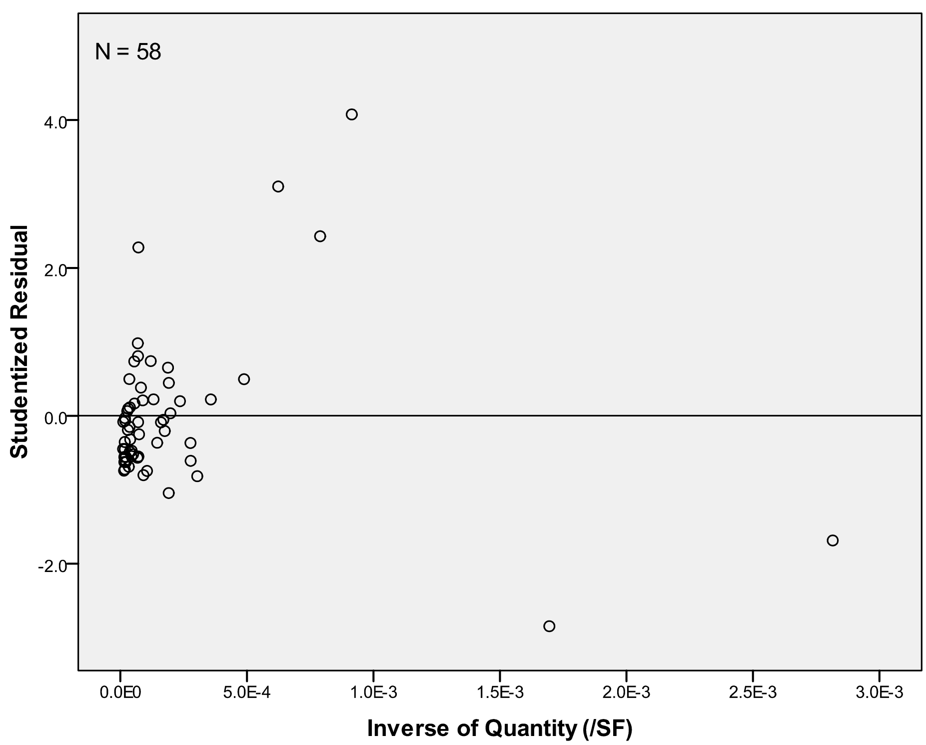


Fig. C- 8. Residual plot with inverse of quantity for concrete sidewalk

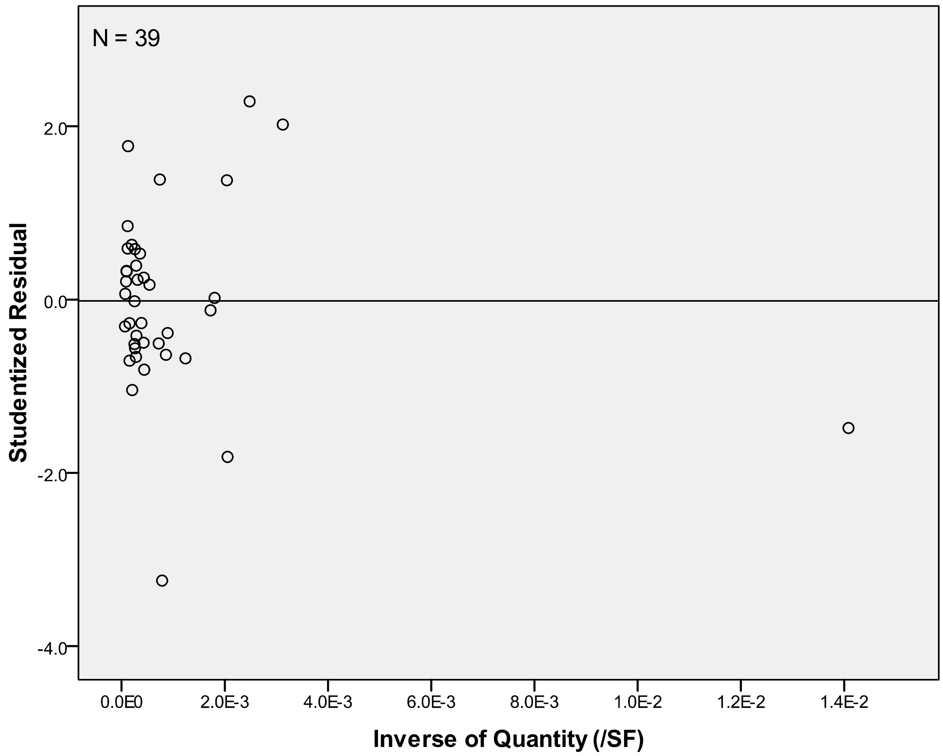


Fig. C- 9. Residual plot with inverse of quantity for concrete valley gutter

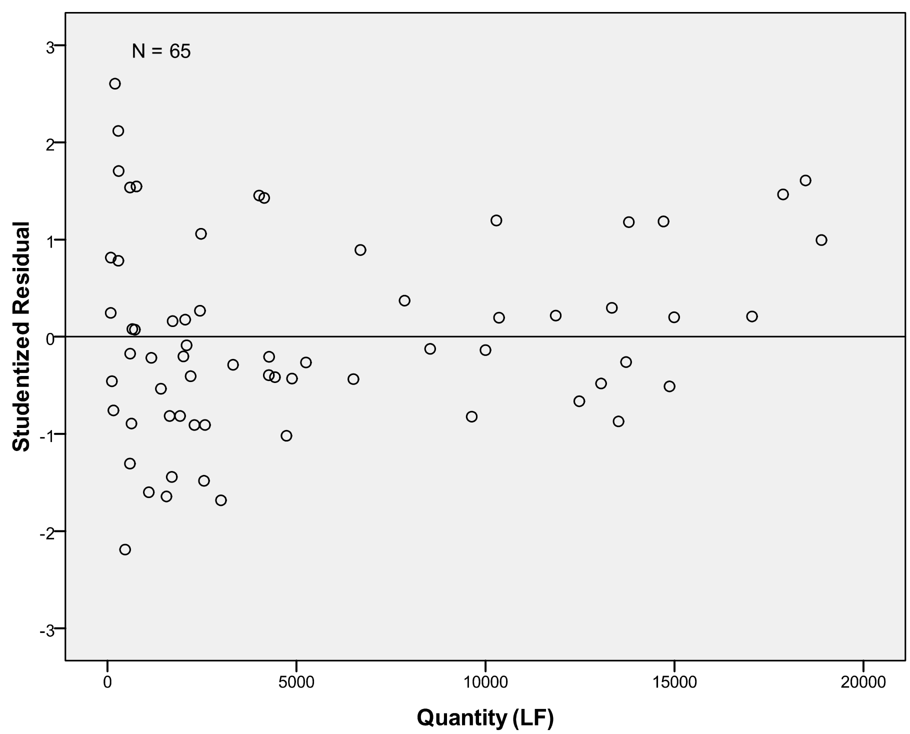


Fig. C- 10. Residual plot with quantity for type "L" curb and gutter

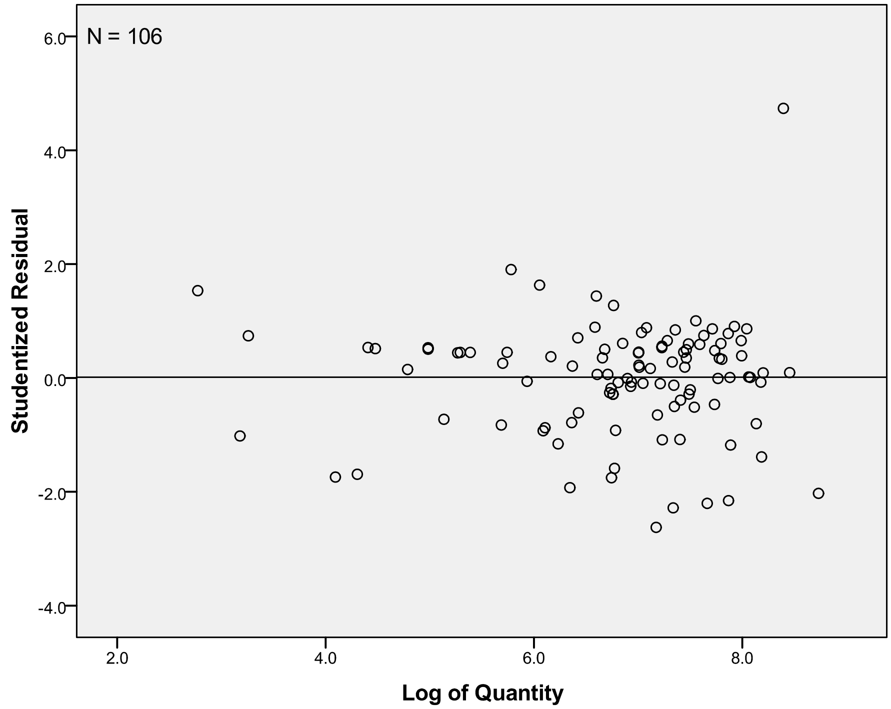


Fig. C- 11. Residual plot with inverse of quantity for reflective pavement markers

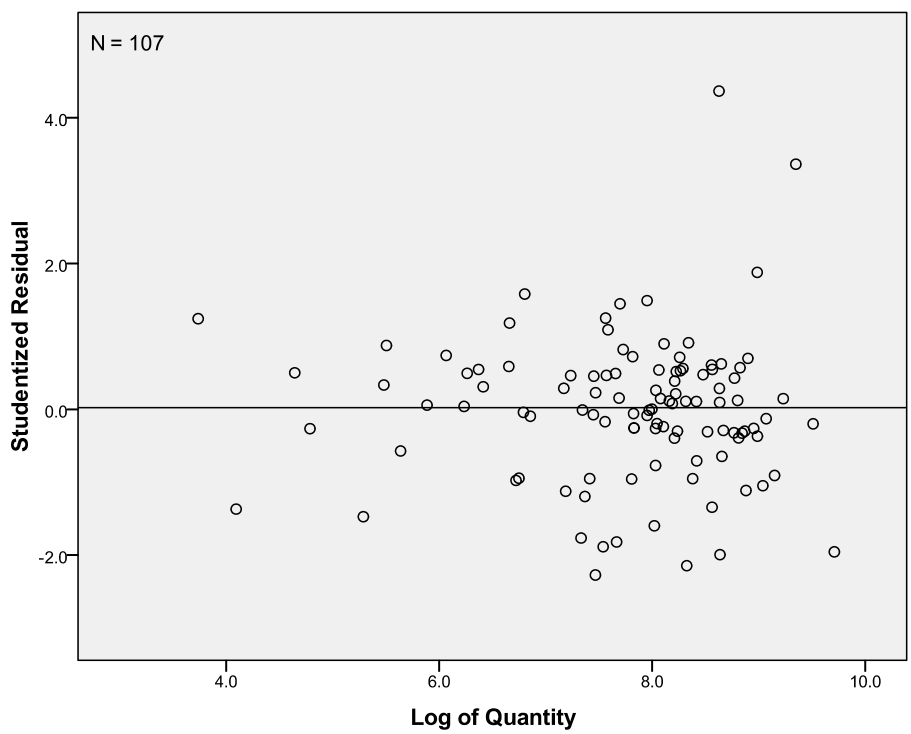


Fig. C- 12. Residual plot with logarithm of quantity for non reflective pavement markers

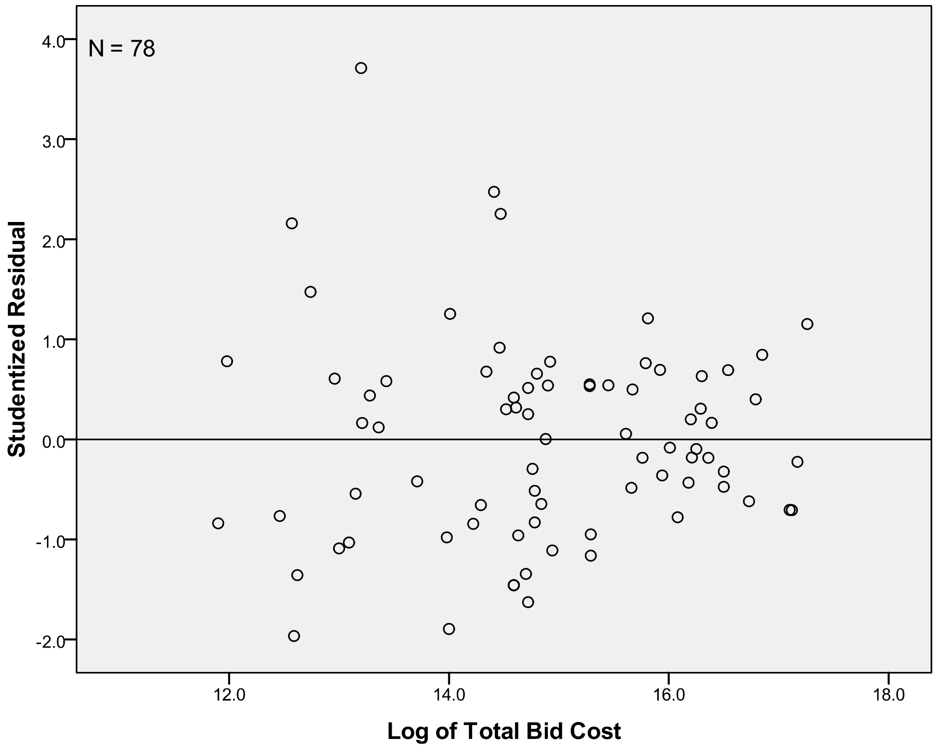


Fig. C- 13. Residual plot with logarithm of total bid cost for quality control

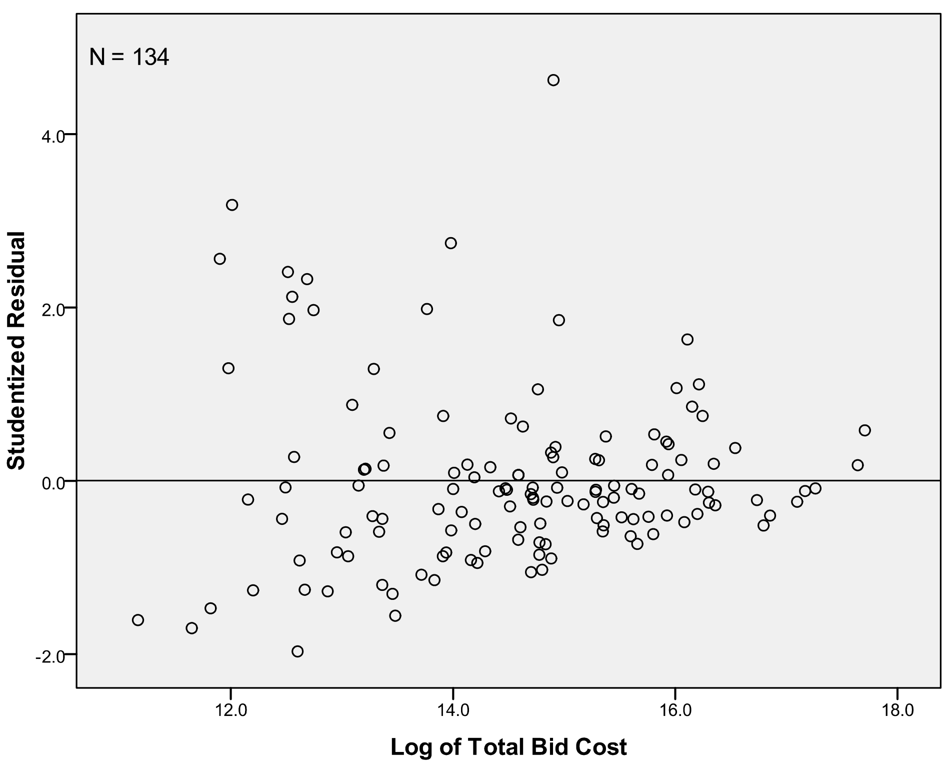


Fig. C- 14. Residual plot with logarithm of total bid cost for traffic control

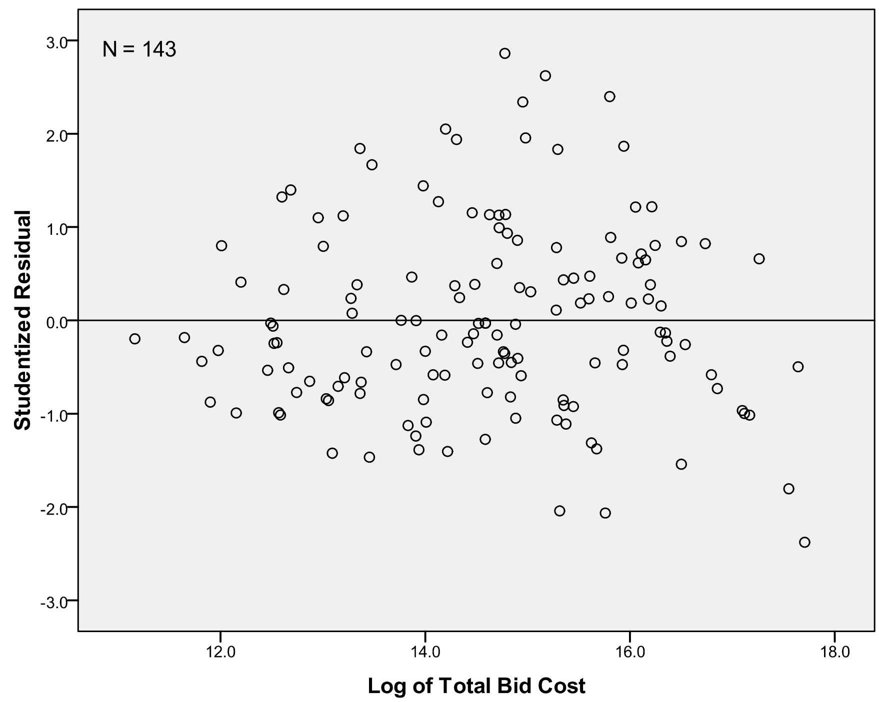


Fig. C- 15. Residual plot with logarithm of total bid cost for construction conflicts and additional works

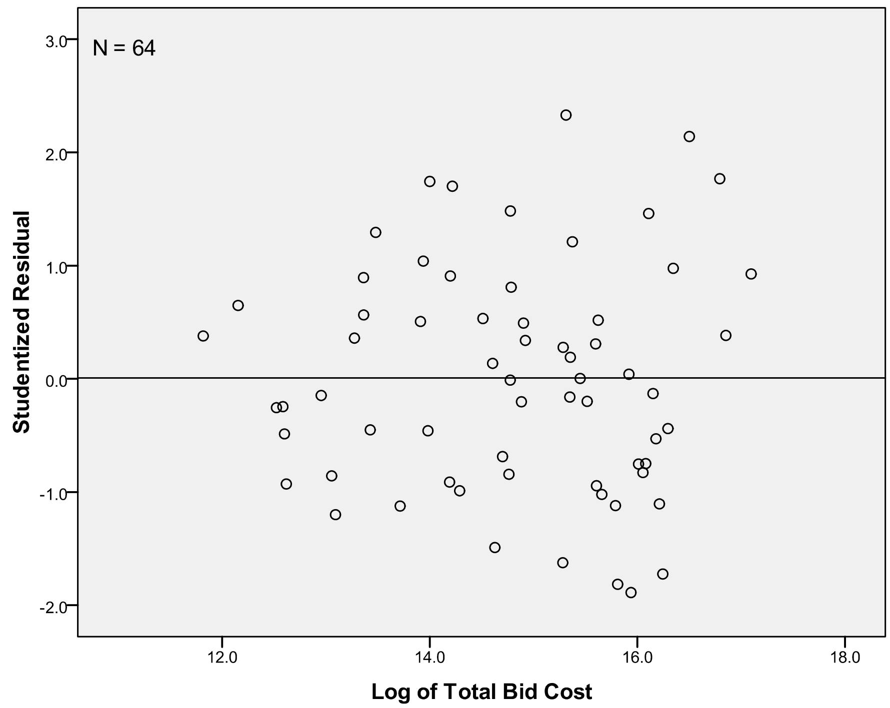


Fig. C- 16. Residual plot with logarithm of total bid cost for clearing and grubbing

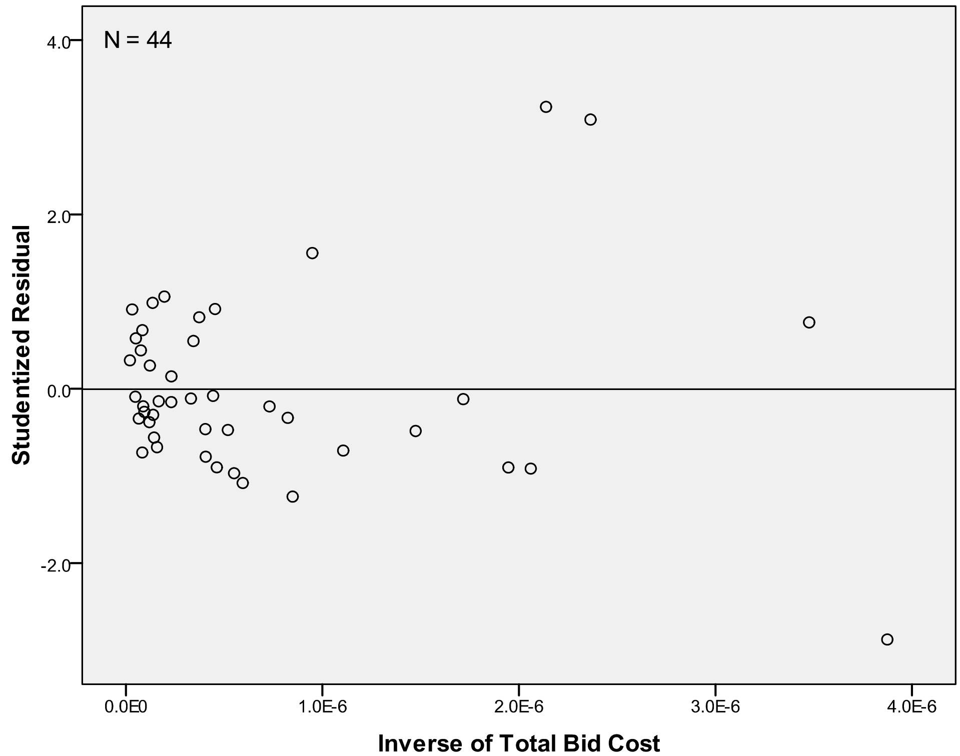


Fig. C- 17. Residual plot with inverse of total bid cost for dust control

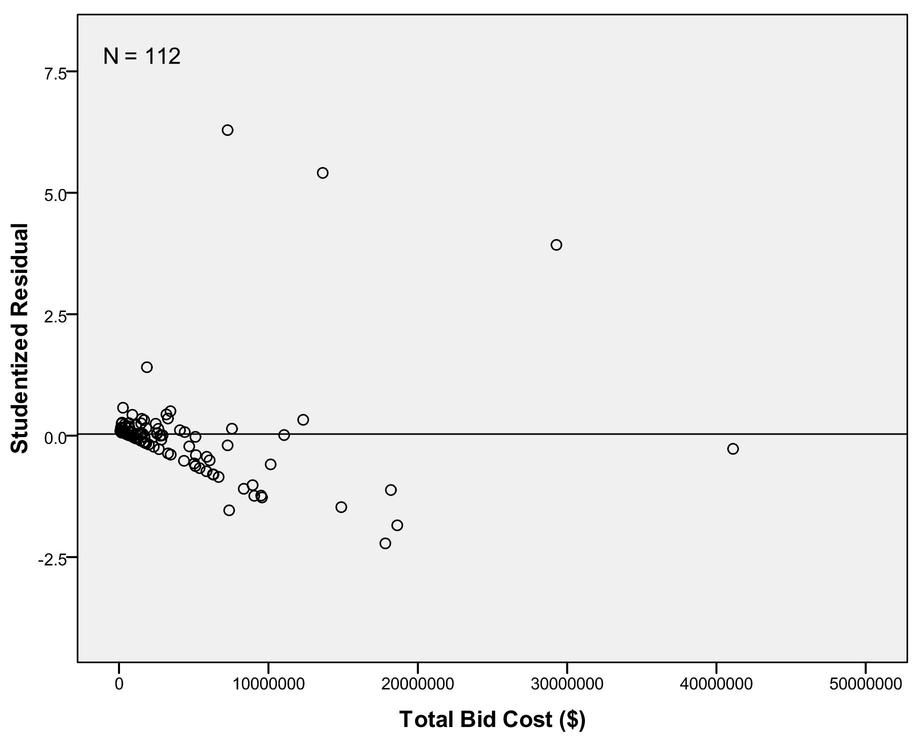


Fig. C- 18. Residual plot with total bid cost ($)

APPENDIX D

RESIDUAL PLOT WITH PREDICTED VALUE

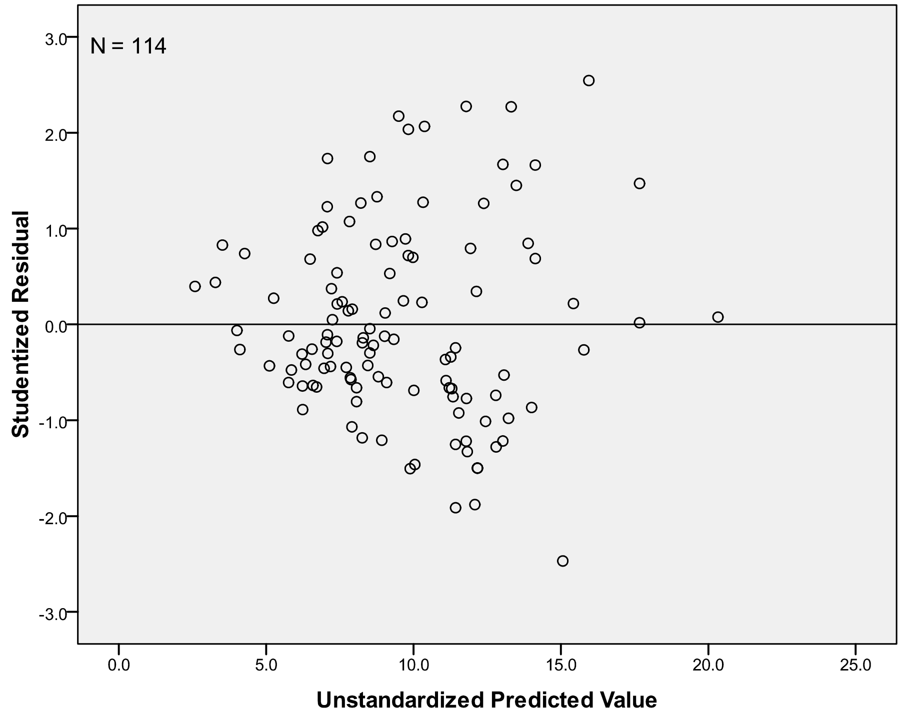


Fig. D- 1. Residual plot with predicted value for roadway excavation

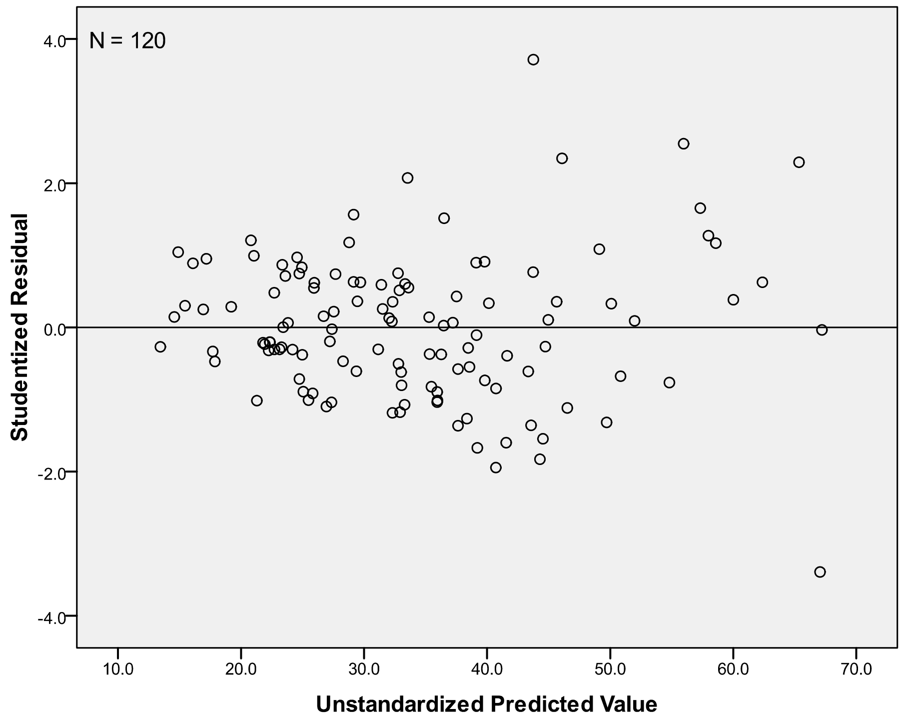


Fig. D- 2. Residual plot with predicted value for type II aggregate base

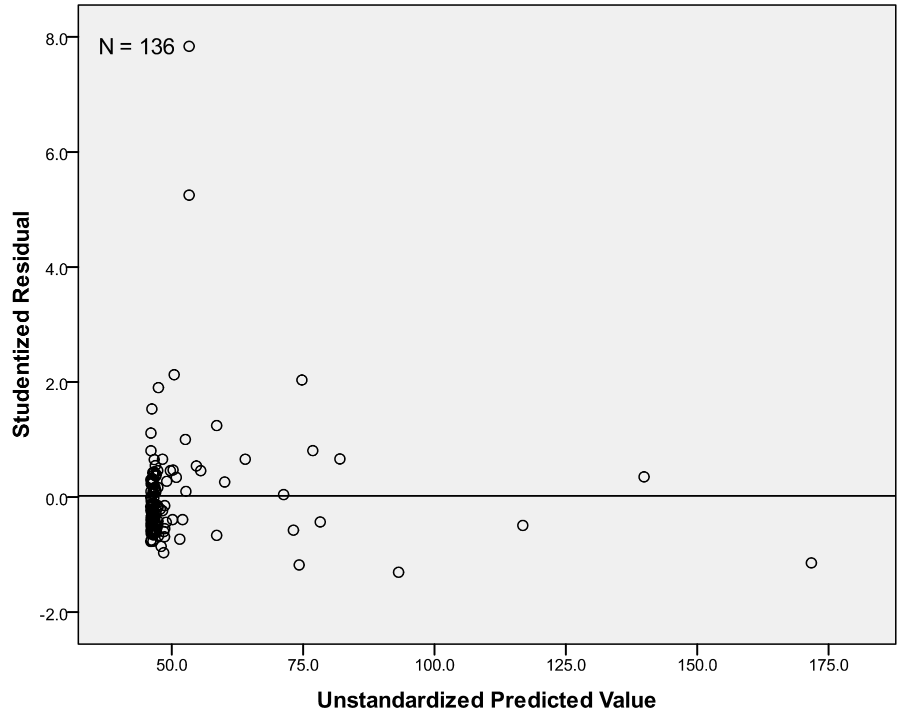


Fig. D- 3. Residual plot with predicted value for plantmix bituminous surface

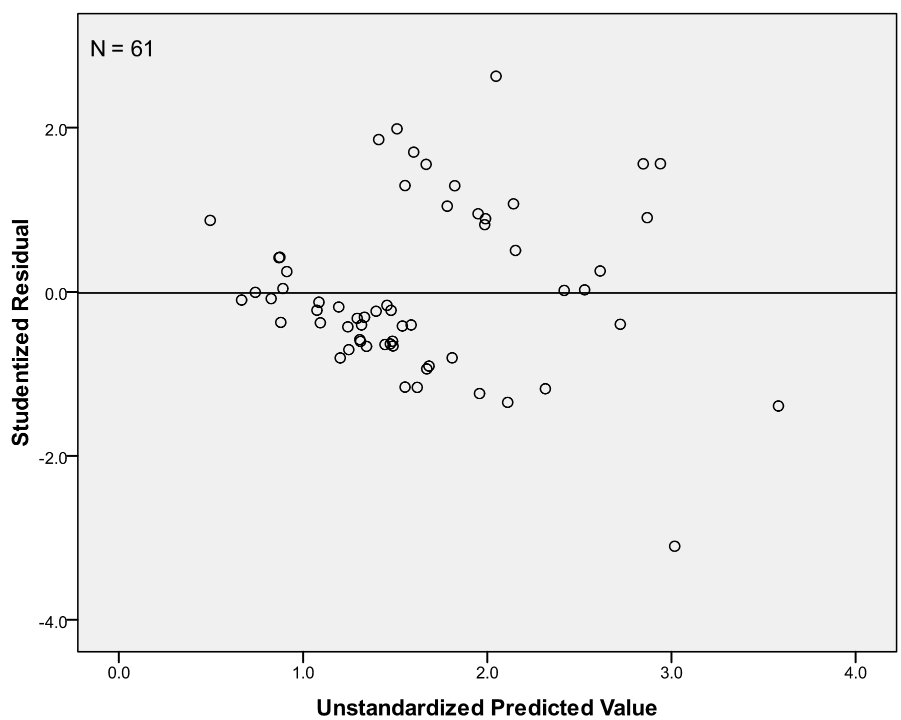


Fig. D- 4. Residual plot with predicted value for plantmix bituminous open-graded surface (3/4" depth)

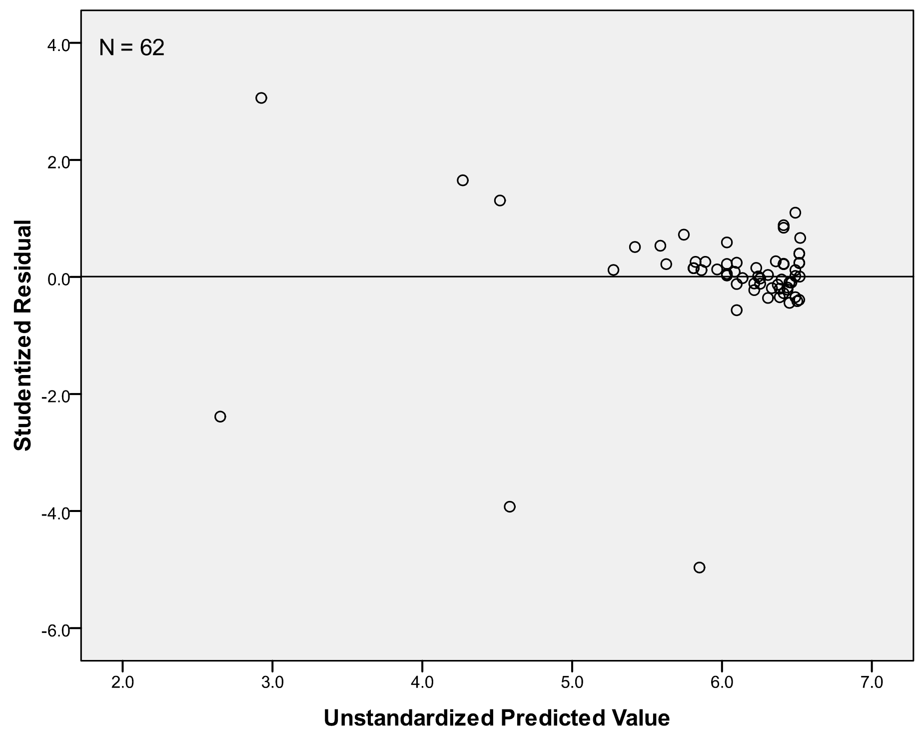


Fig. D- 5. Residual plot with predicted value for prime coat

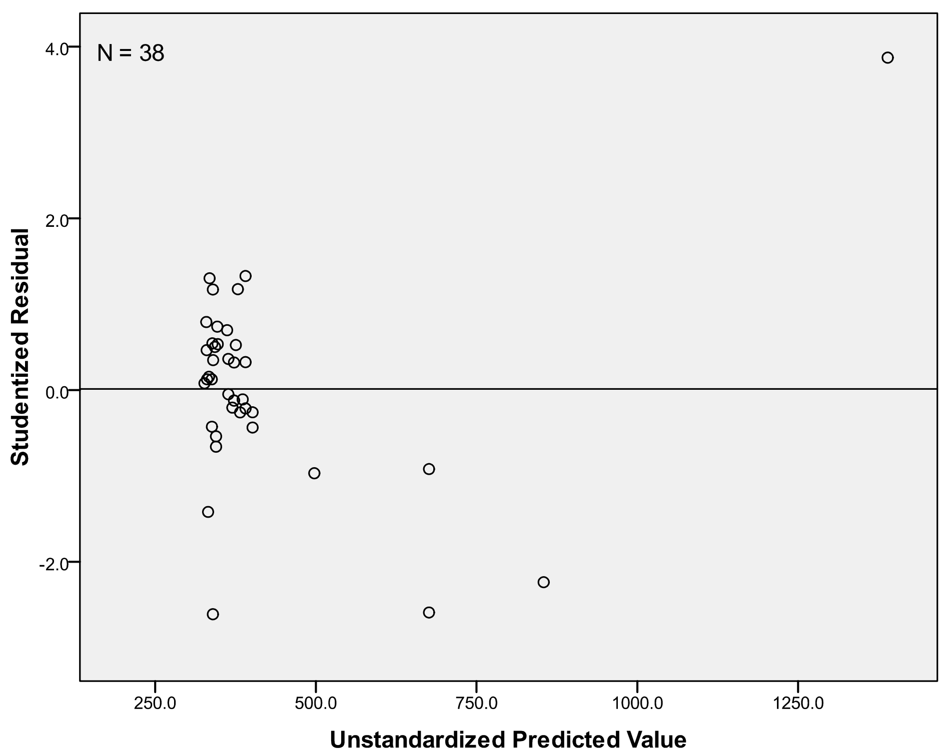


Fig. D- 6. Residual plot with predicted value for tack coat

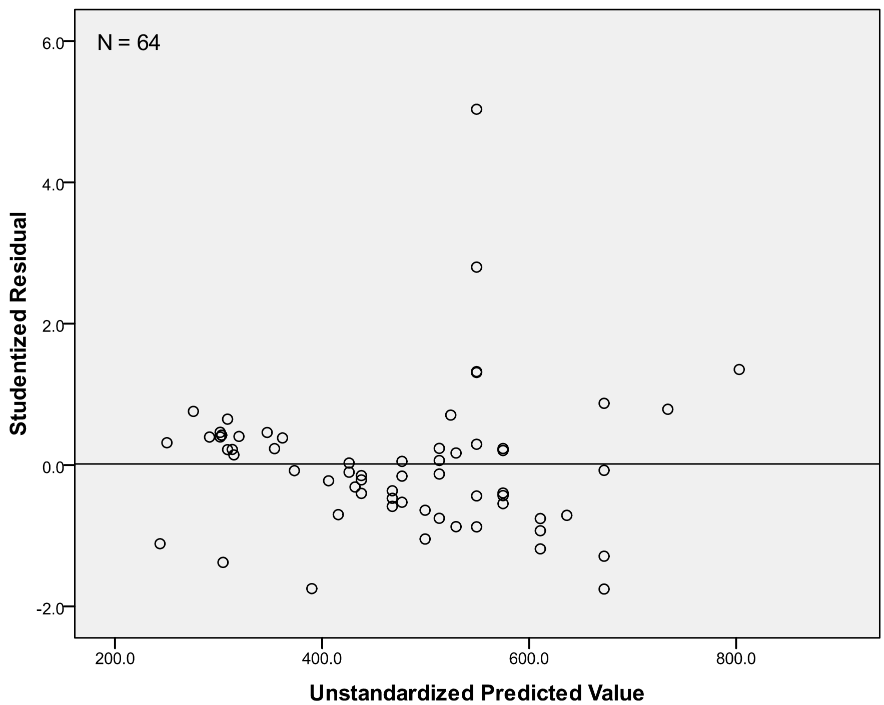


Fig. D- 7. Residual plot with predicted value for seal coat

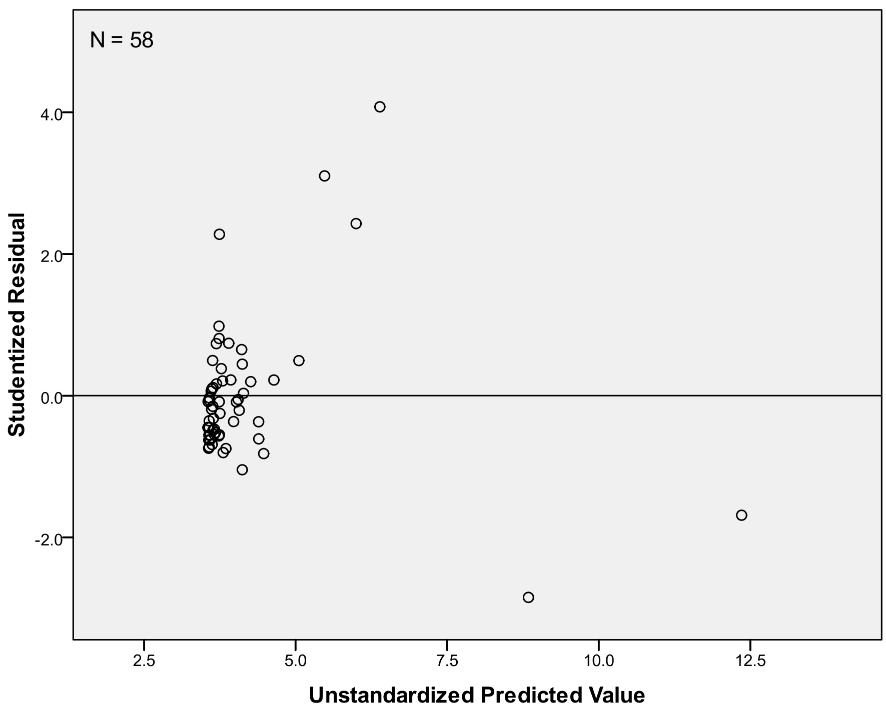


Fig. D- 8. Residual plot with predicted value for concrete sidewalk

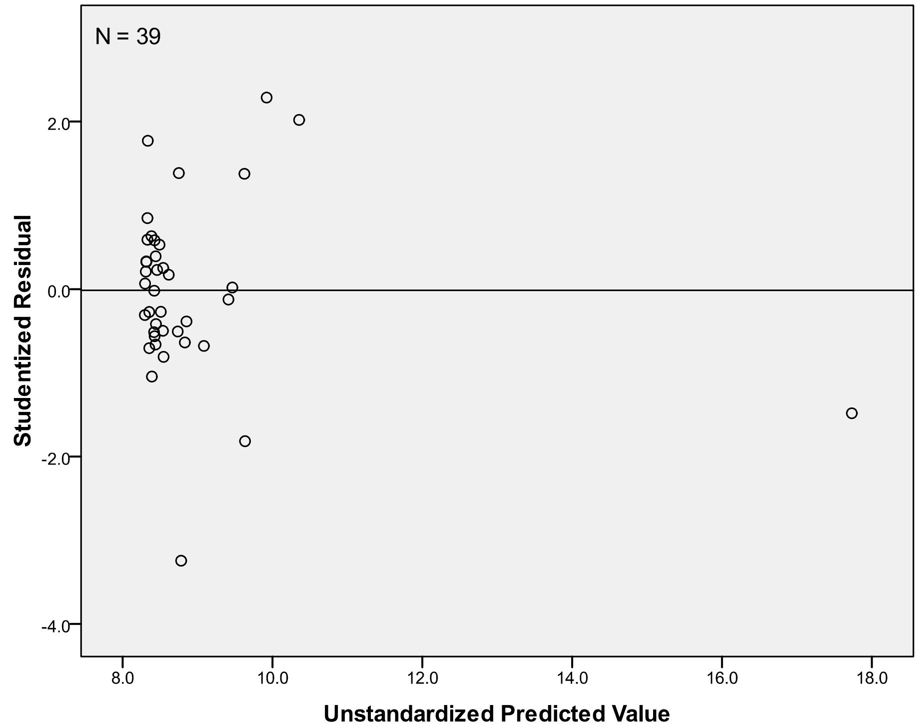


Fig. D- 9. Residual plot with predicted value for concrete valley gutter

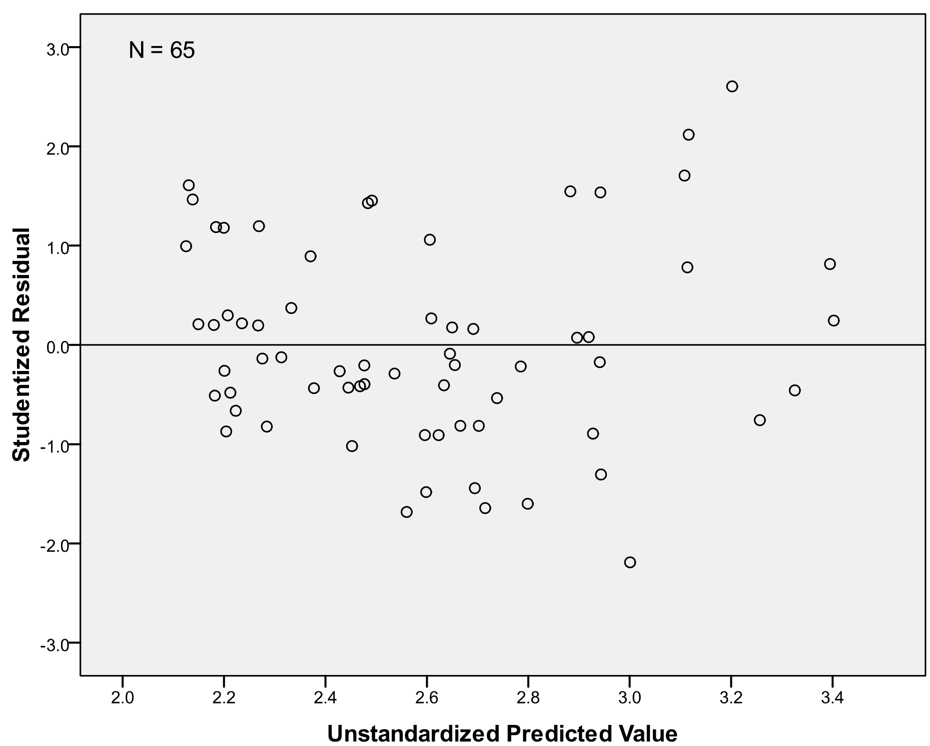


Fig. D- 10. Residual plot with predicted value for type “L” curb and gutter

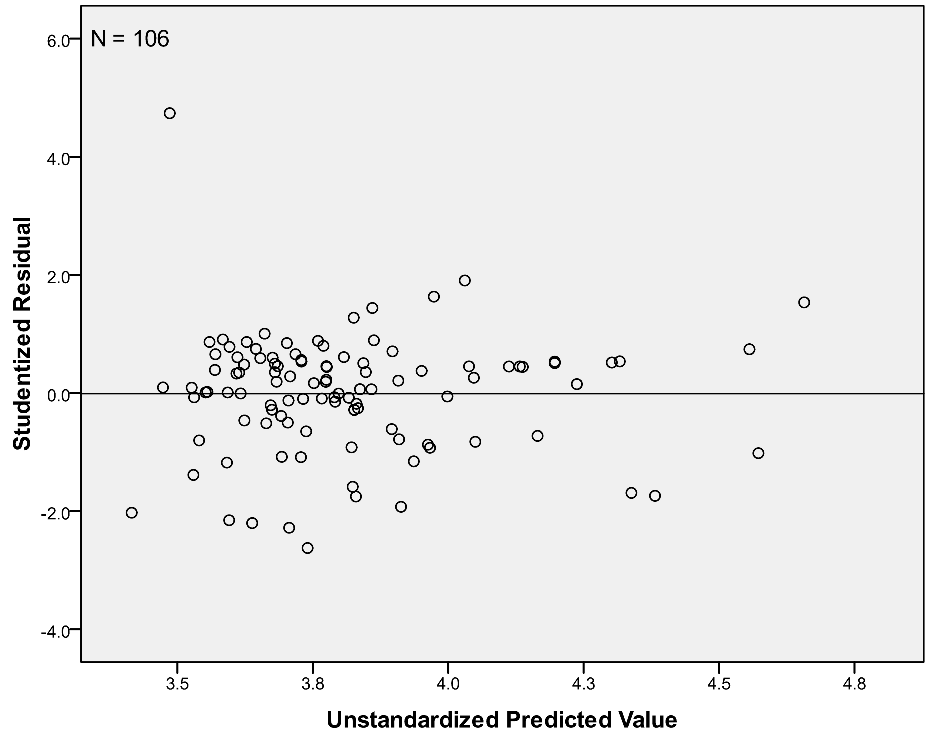


Fig. D- 11. Residual plot with predicted value for reflective pavement markers

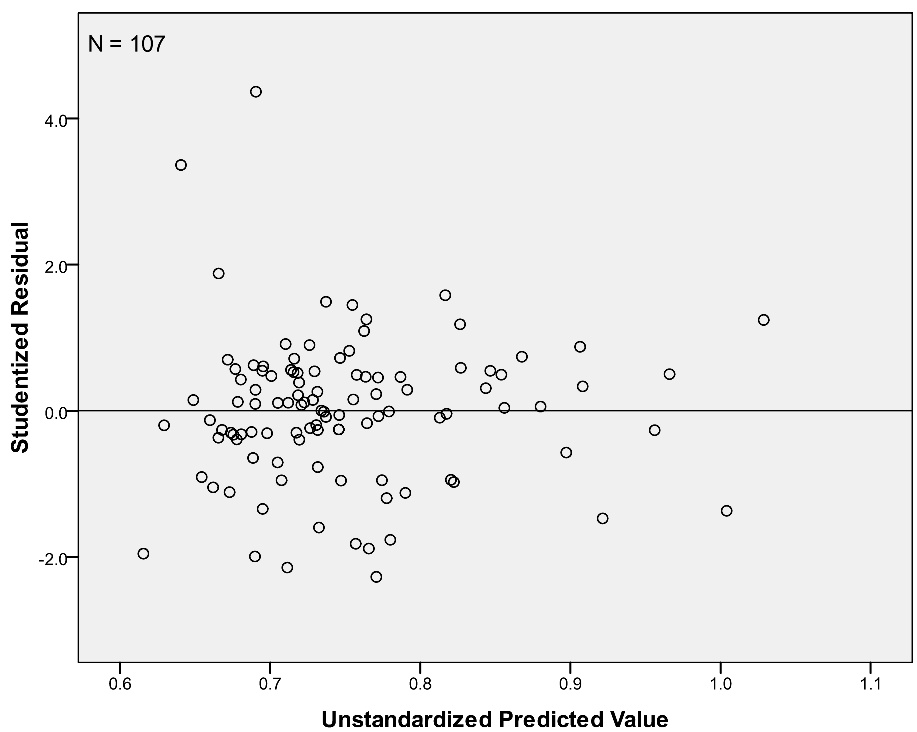


Fig. D- 12. Residual plot with predicted value for non reflective pavement markers

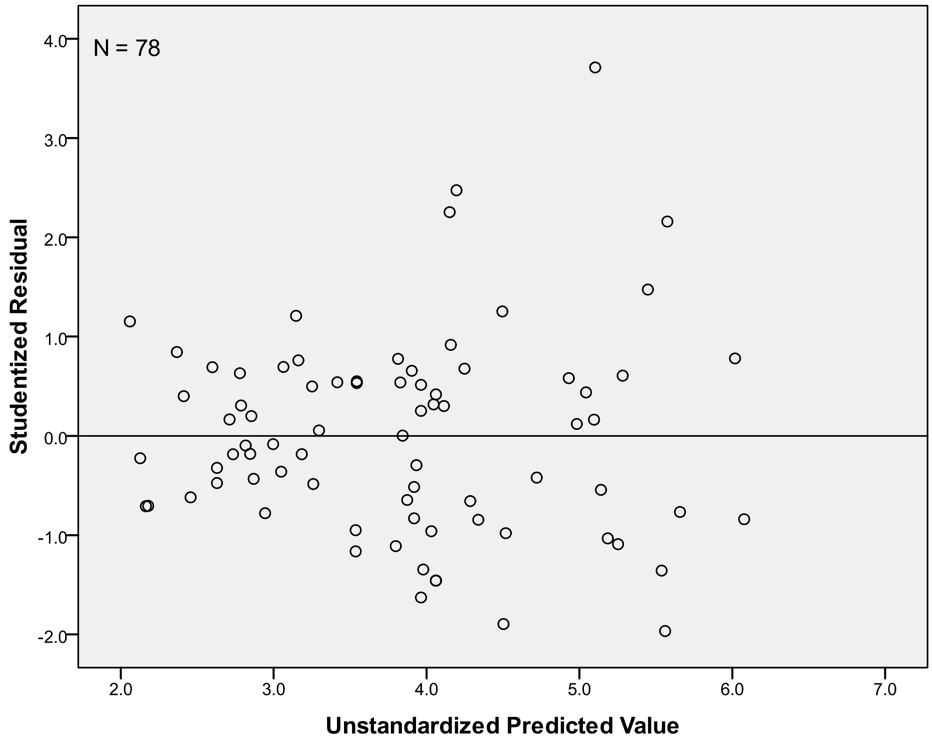


Fig. D- 13. Residual plot with predicted value for quality control

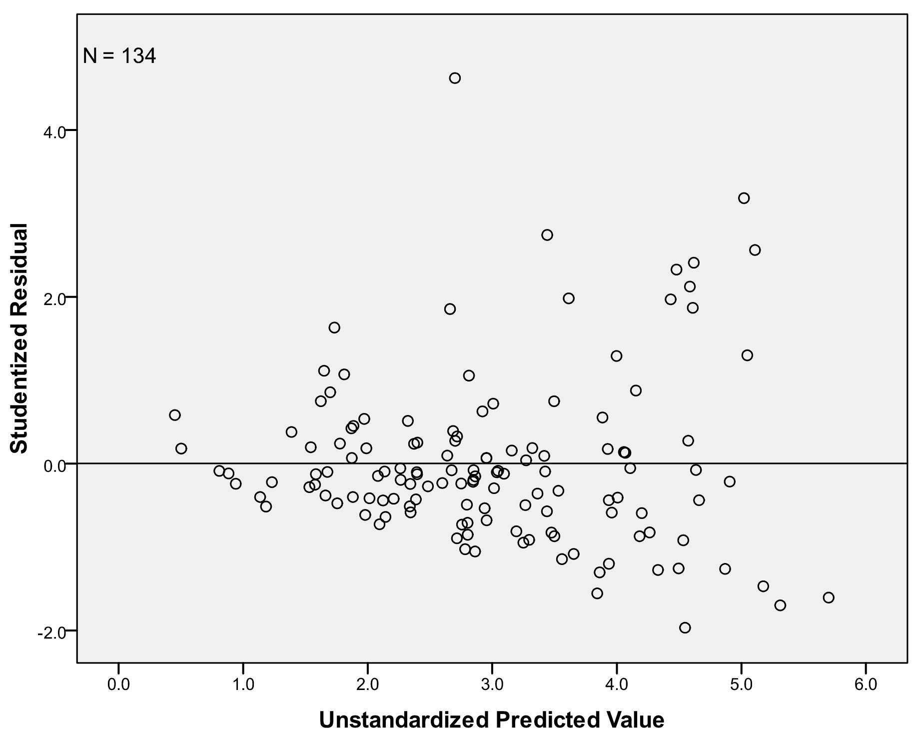


Fig. D- 14. Residual plot with predicted value for traffic control

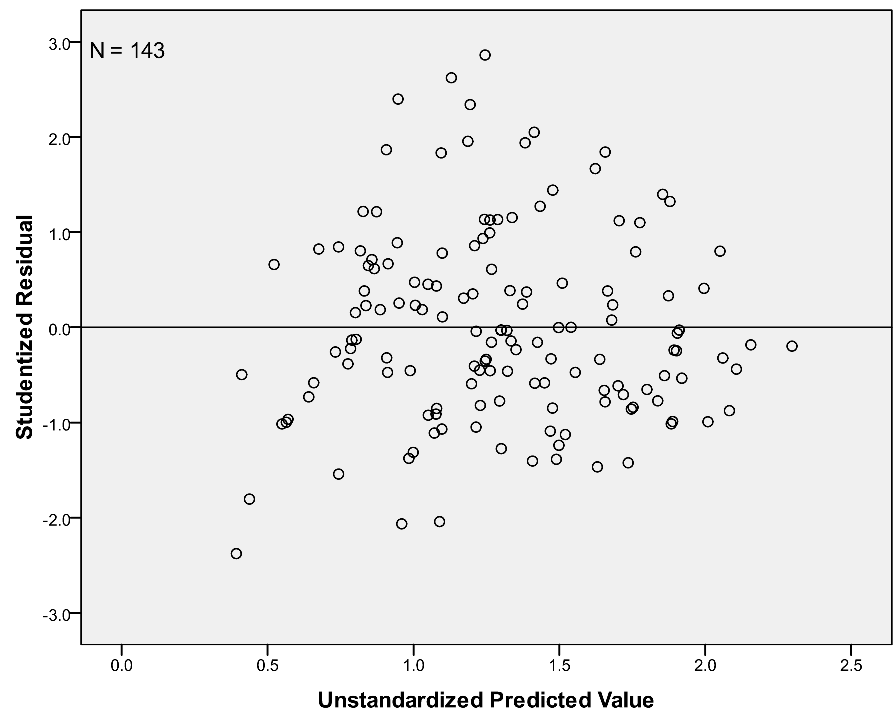


Fig. D- 15. Residual plot with predicted value for construction conflicts and additional works

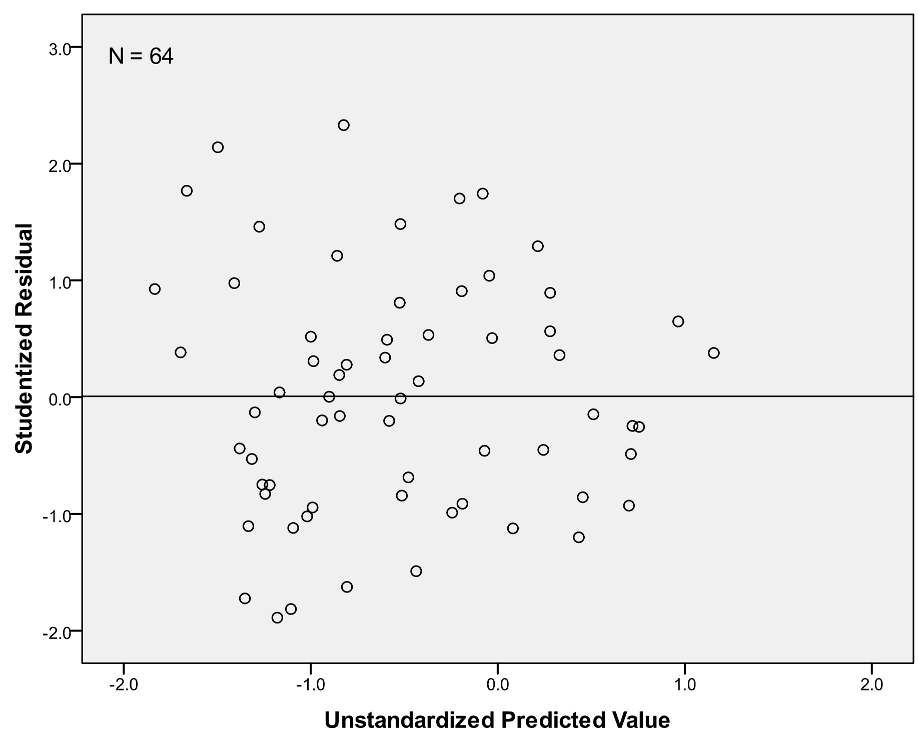


Fig. D- 16. Residual plot with predicted value for clearing and grubbing

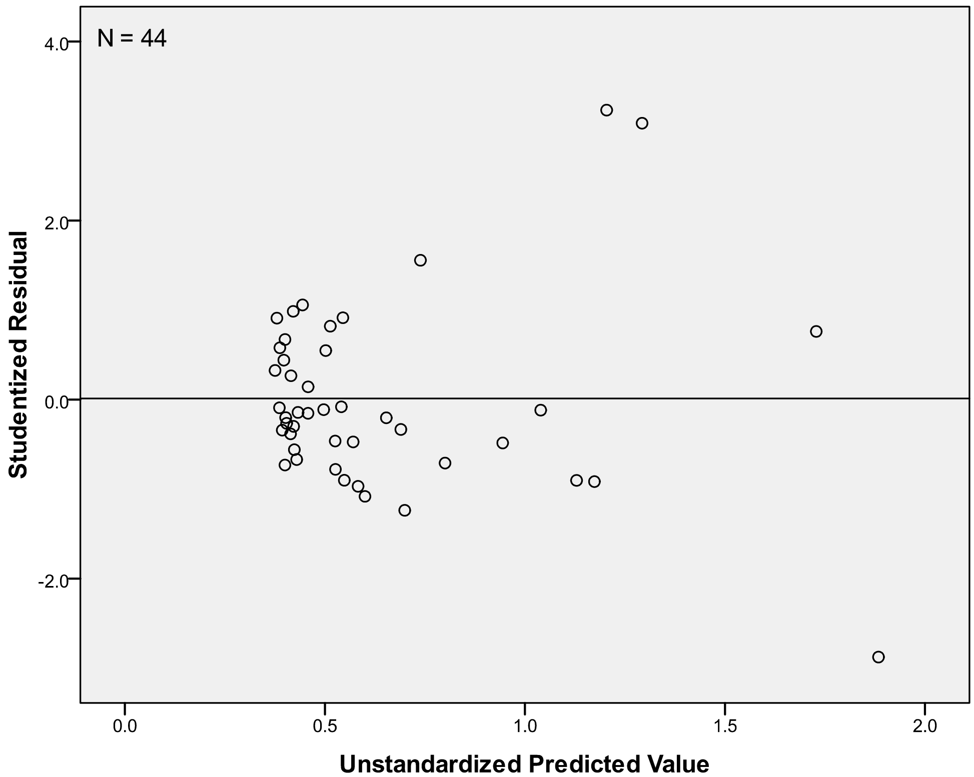


Fig. D- 17. Residual plot with predicted value for dust control

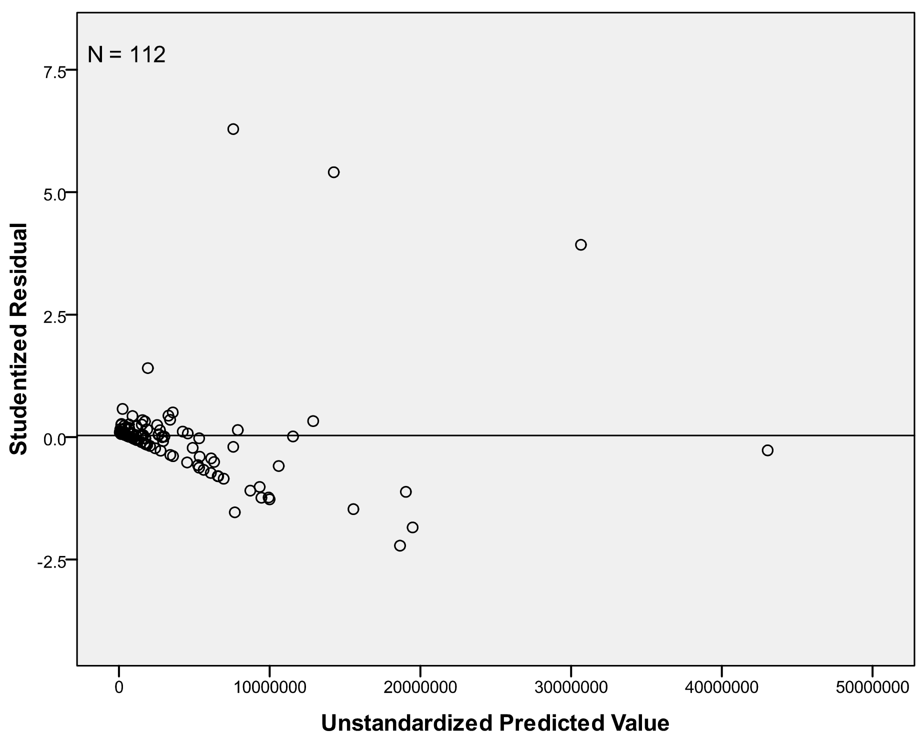


Fig. D- 18. Residual plot with predicted value for total completion cost

APPENDIX E

HISTOGRAM OF RESIDUALS

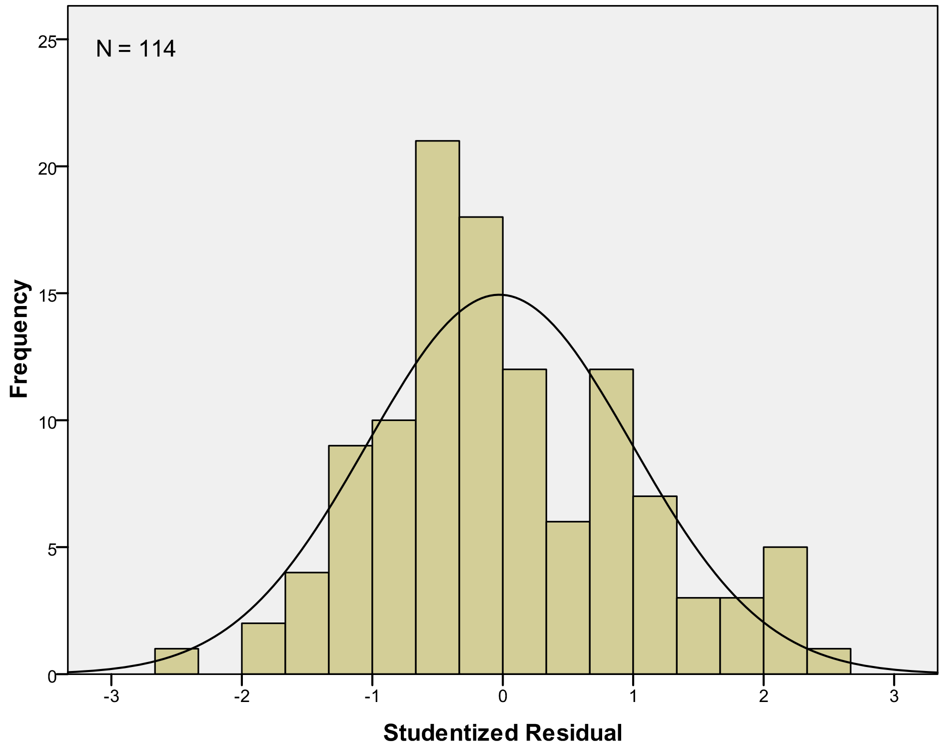


Fig. E- 1. Histogram of the residuals for roadway excavation

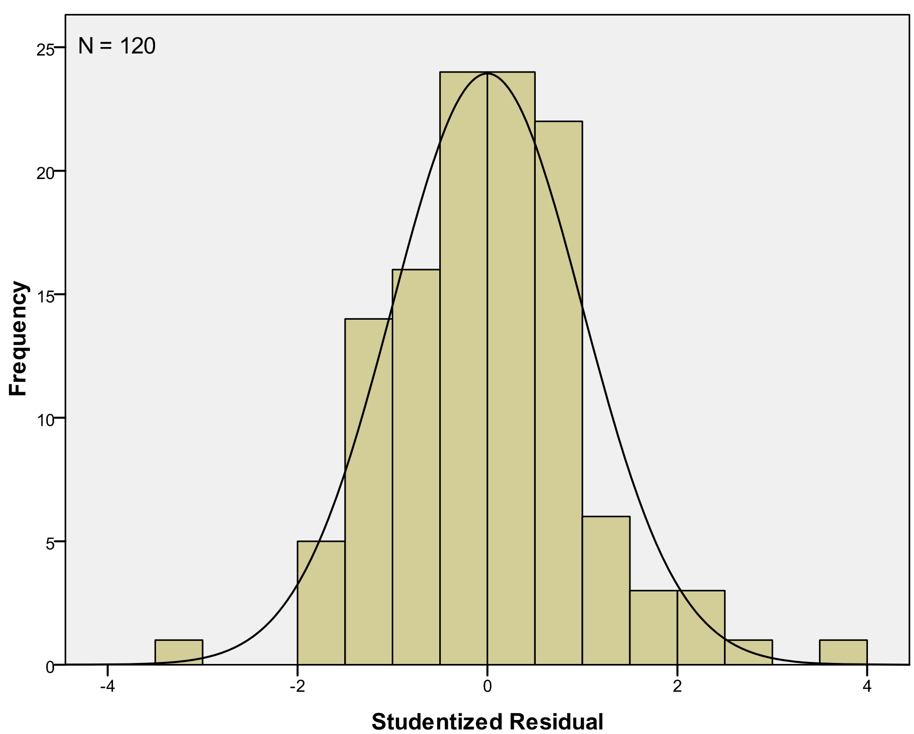


Fig. E- 2. Histogram of the residuals for type II aggregate base

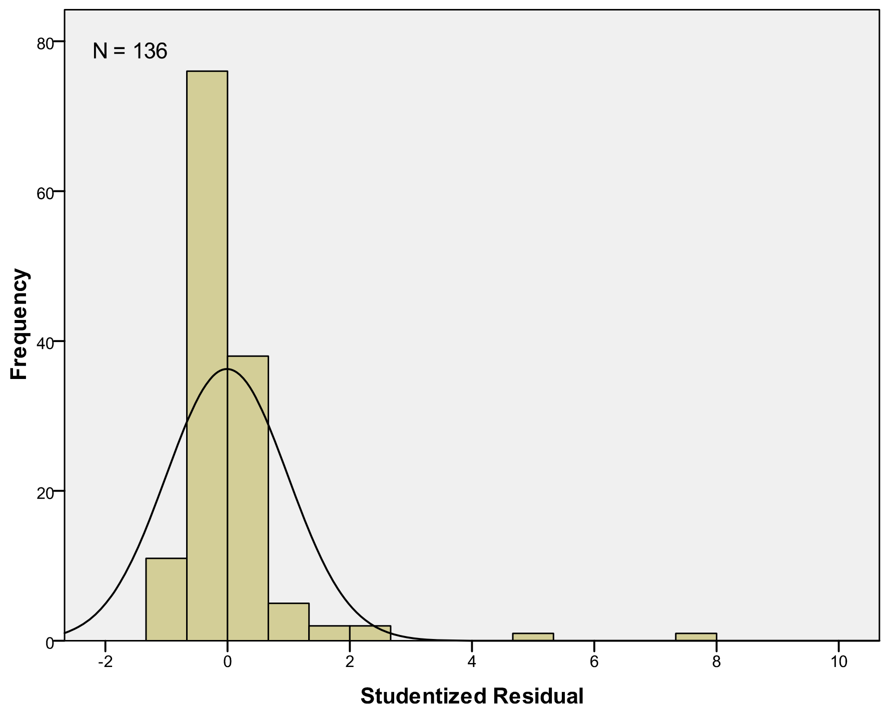


Fig. E- 3. Histogram of the residuals for plantmix bituminous surface

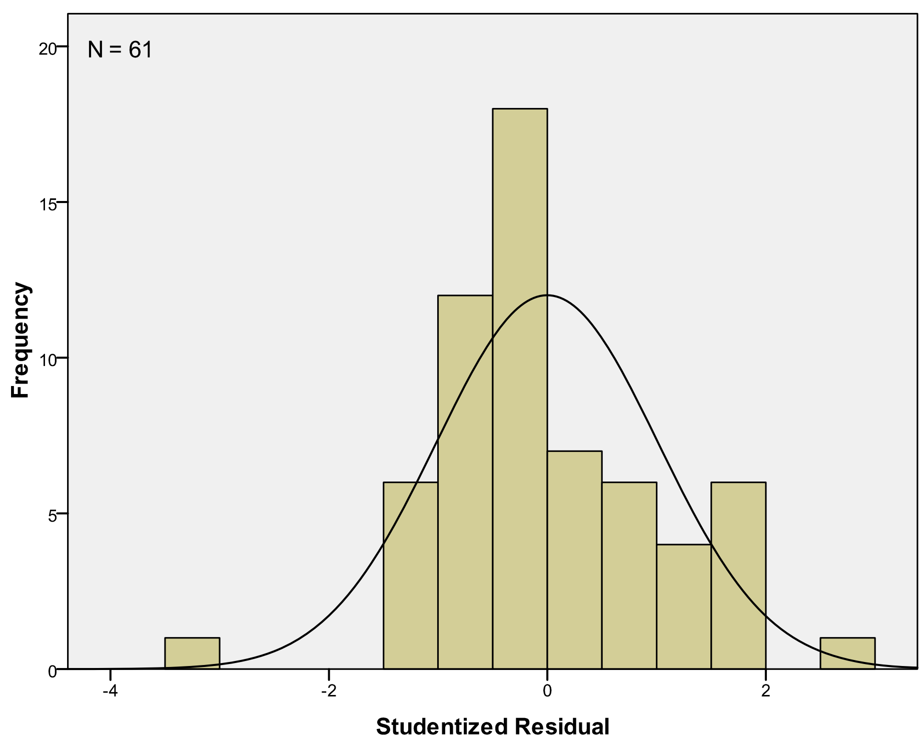


Fig. E- 4. Histogram of the residuals for plantmix bituminous open-graded surface (3/4" depth)

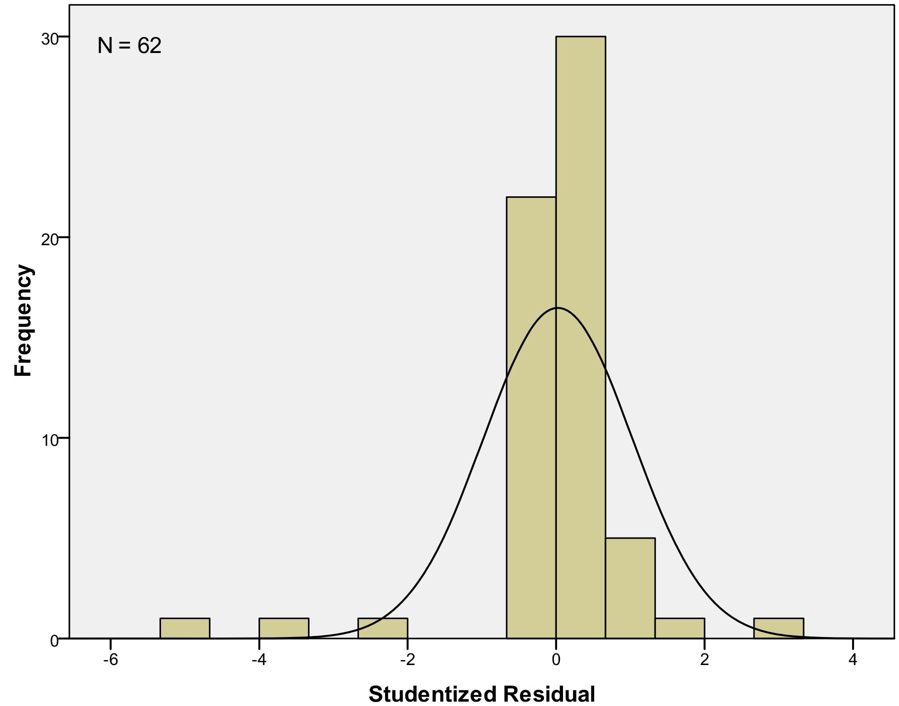


Fig. E- 5. Histogram of the residuals for prime coat

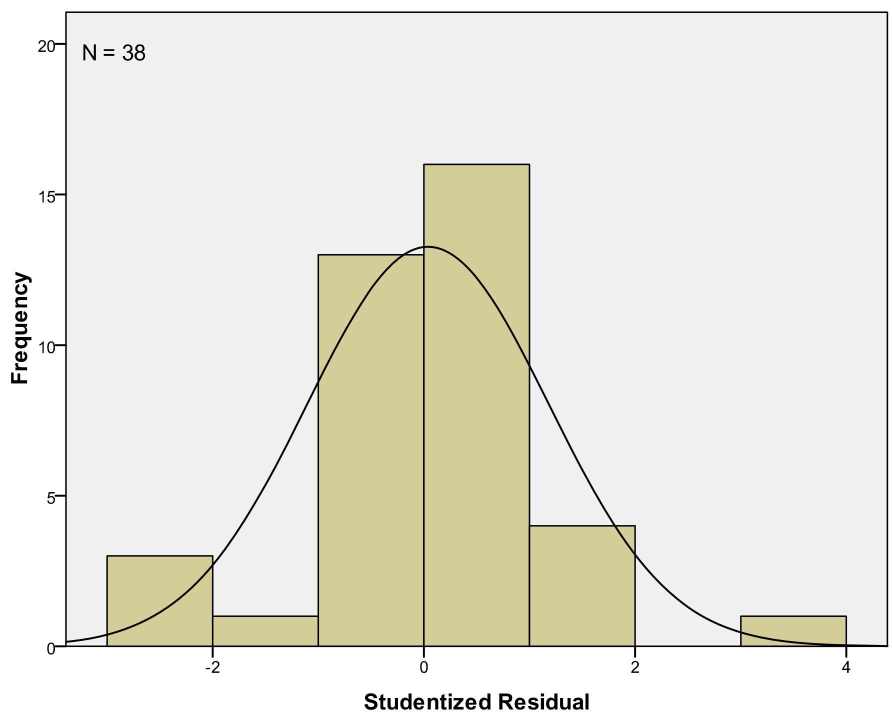


Fig. E- 6. Histogram of the residuals for tack coat

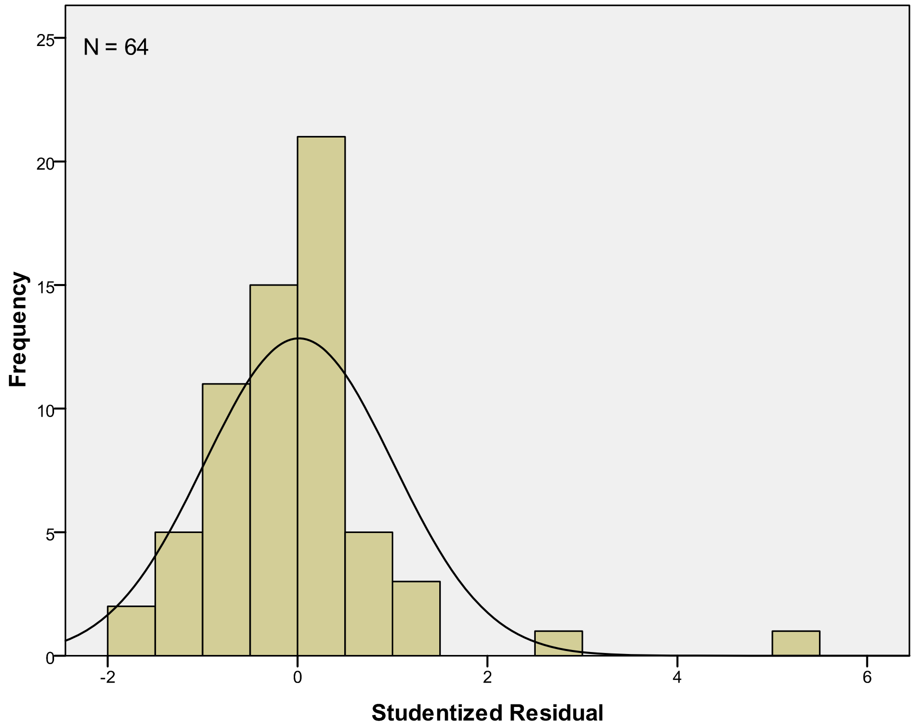


Fig. E- 7. Histogram of the residuals for seal coat

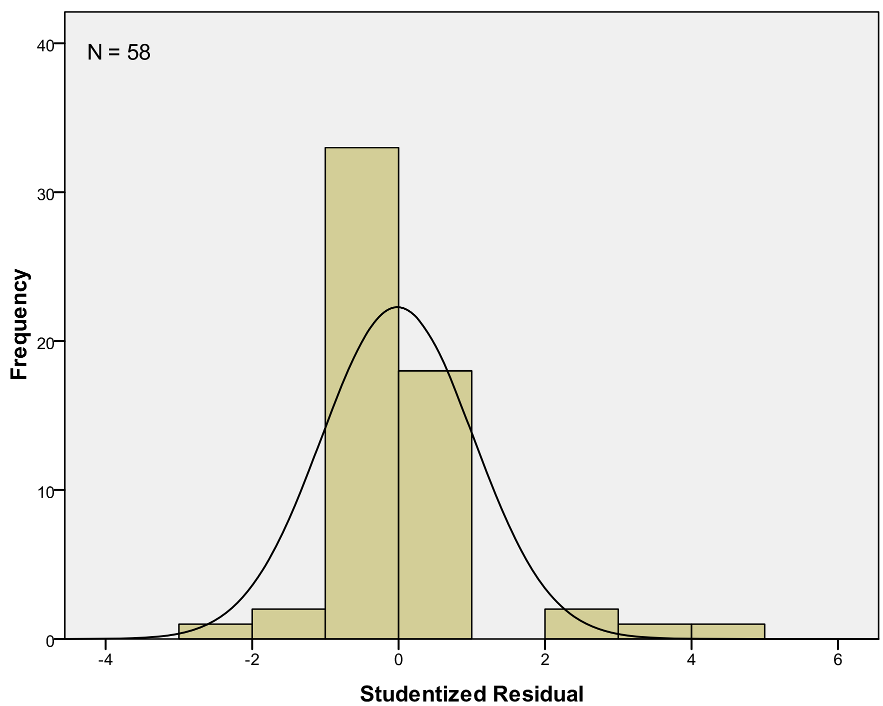


Fig. E- 8. Histogram of the residuals for concrete sidewalk

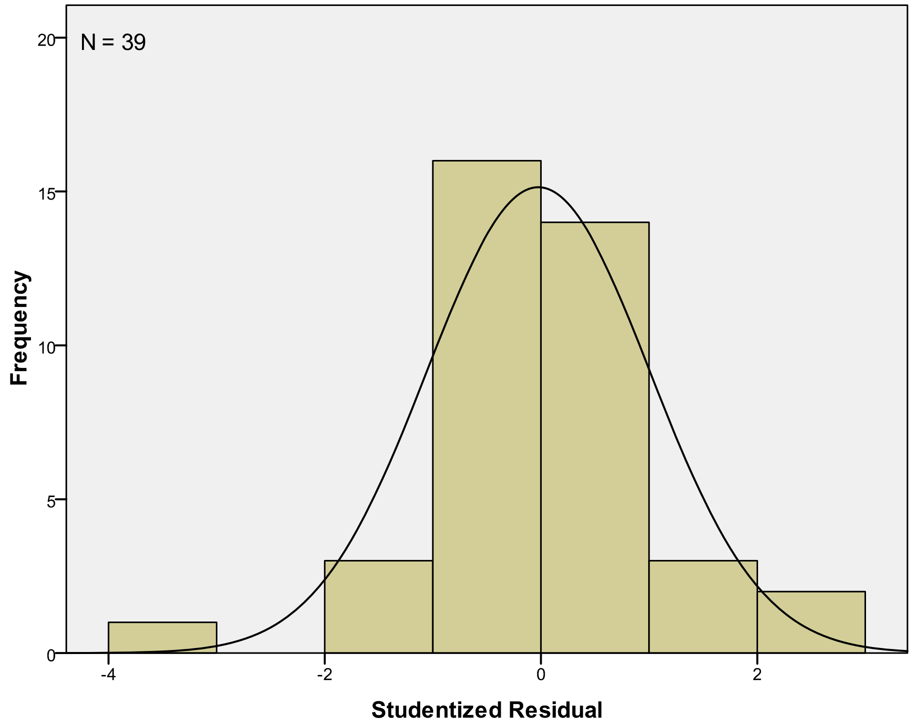


Fig. E- 9. Histogram of the residuals for concrete valley gutter

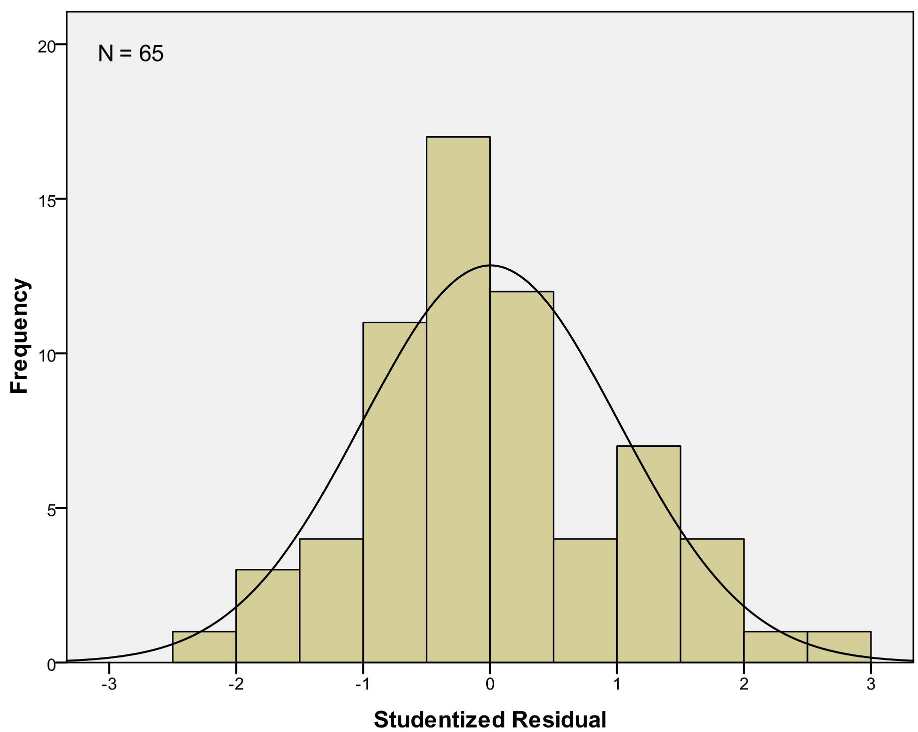


Fig. E- 10. Histogram of the residuals for type “L” curb and gutter

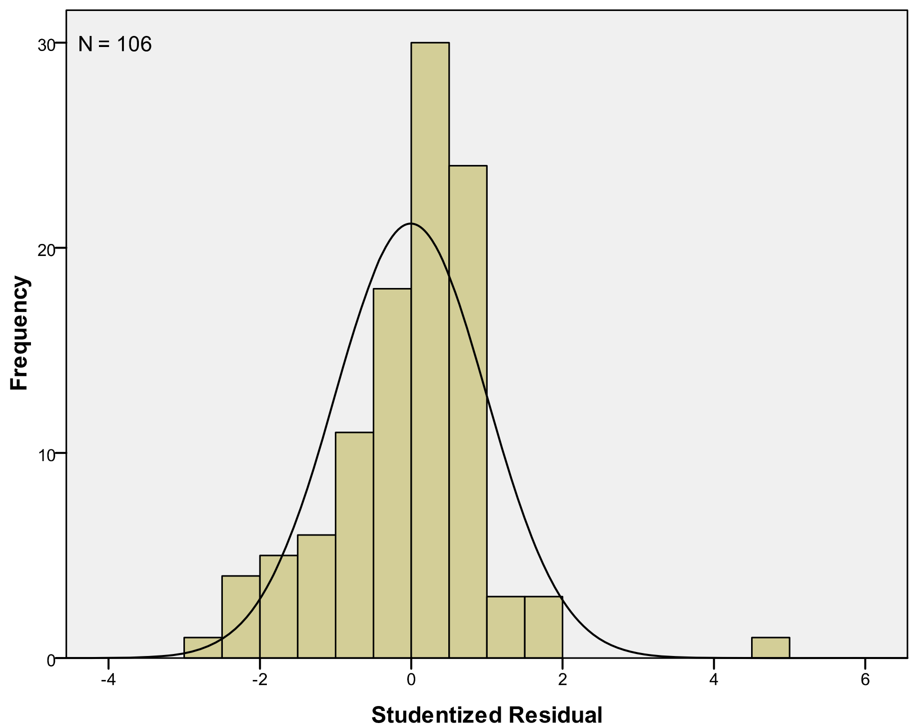


Fig. E- 11. Histogram of the residuals for reflective pavement markers

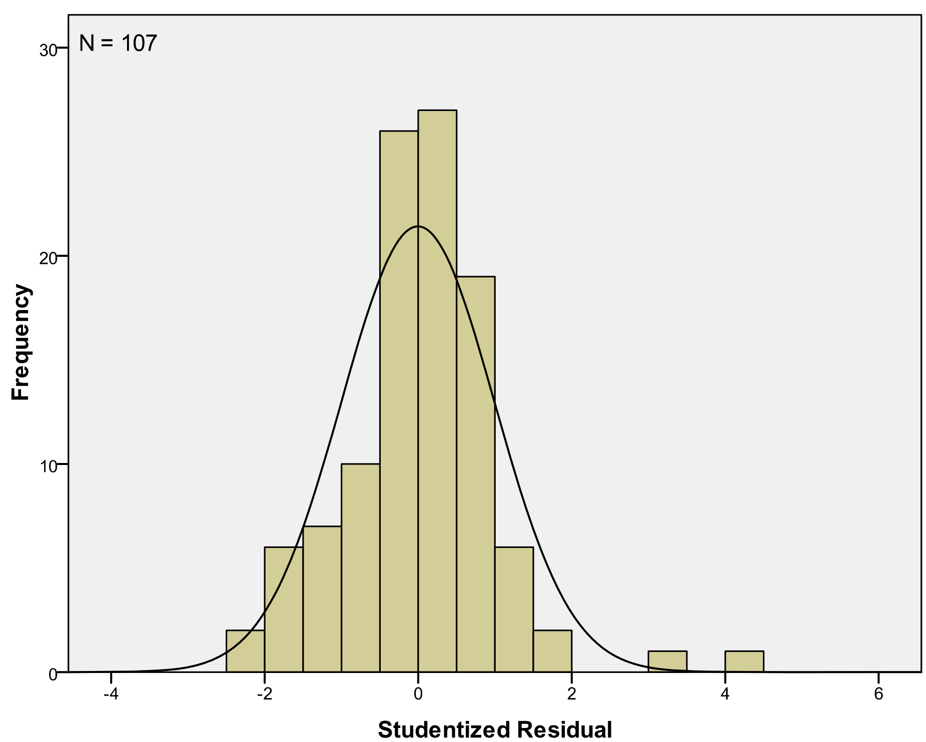


Fig. E- 12. Histogram of the residuals for non reflective pavement markers

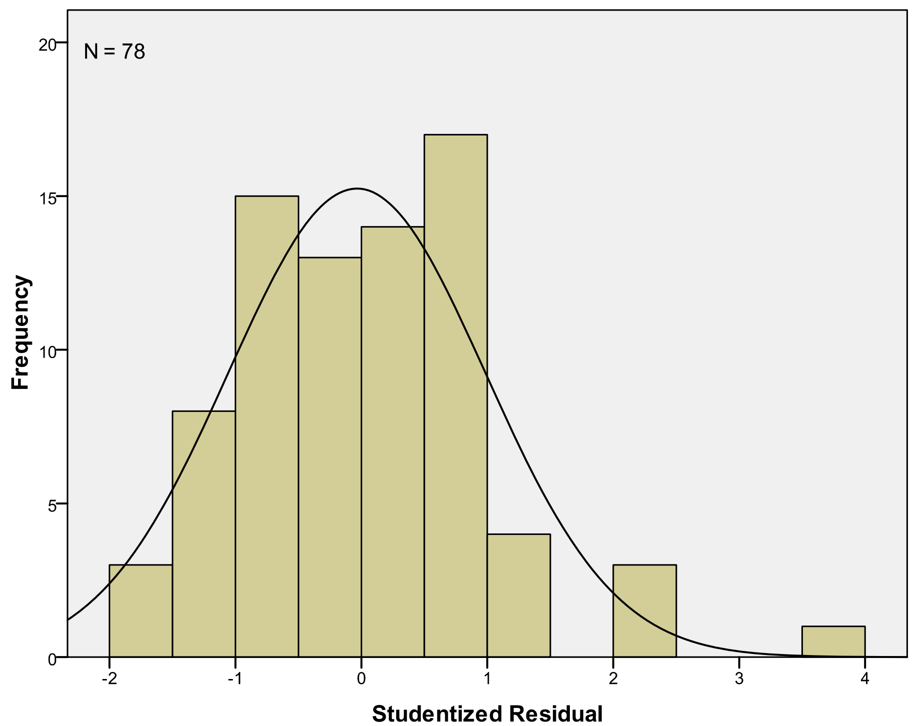


Fig. E- 13. Histogram of the residuals for quality control

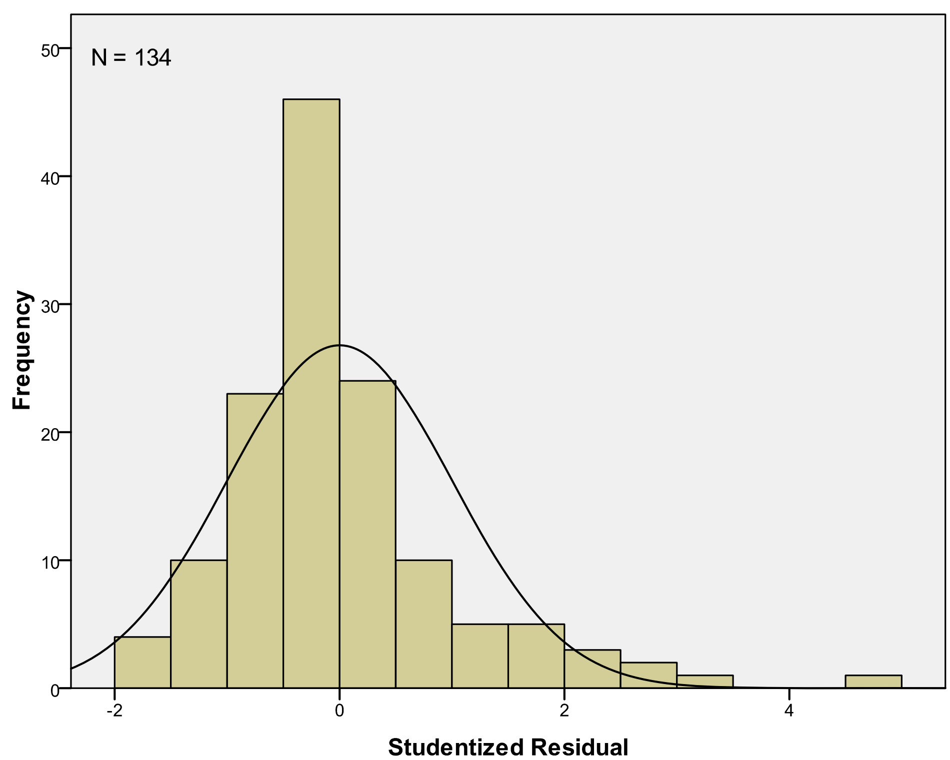


Fig. E- 14. Histogram of the residuals for traffic control

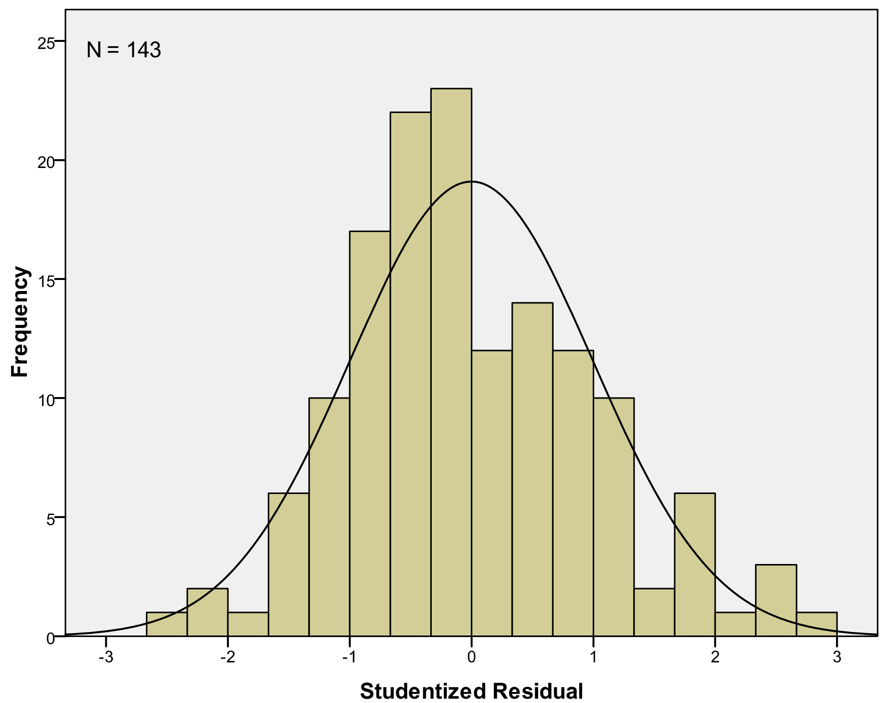


Fig. E- 15. Histogram of the residuals for construction conflicts and additional works

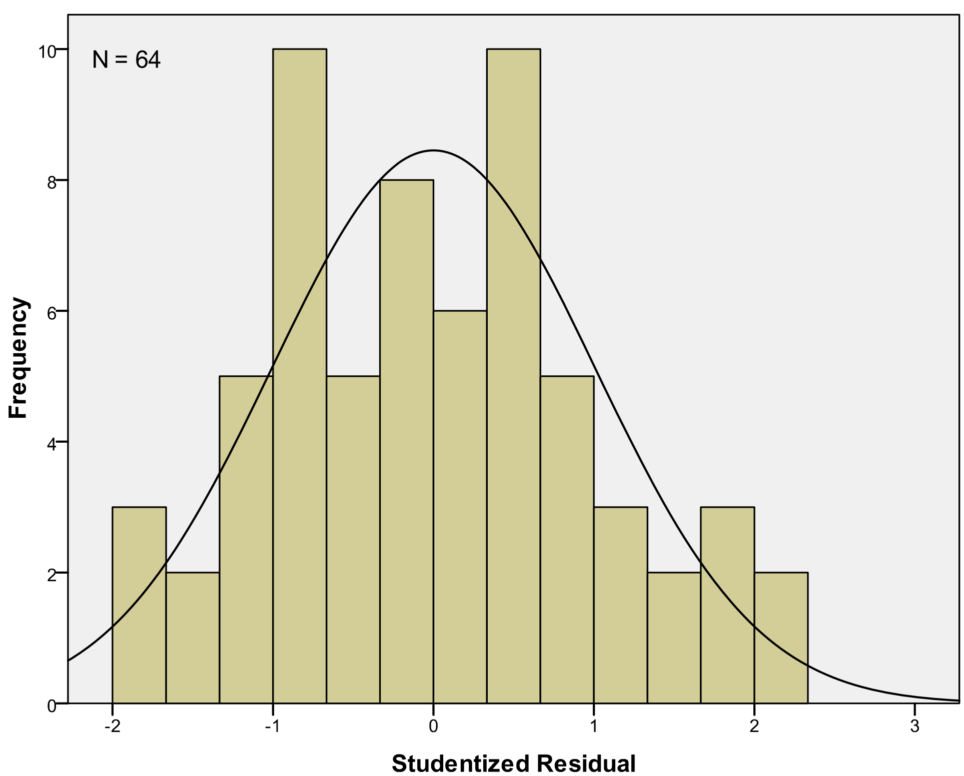


Fig. E- 16. Histogram of the residuals for clearing and grubbing

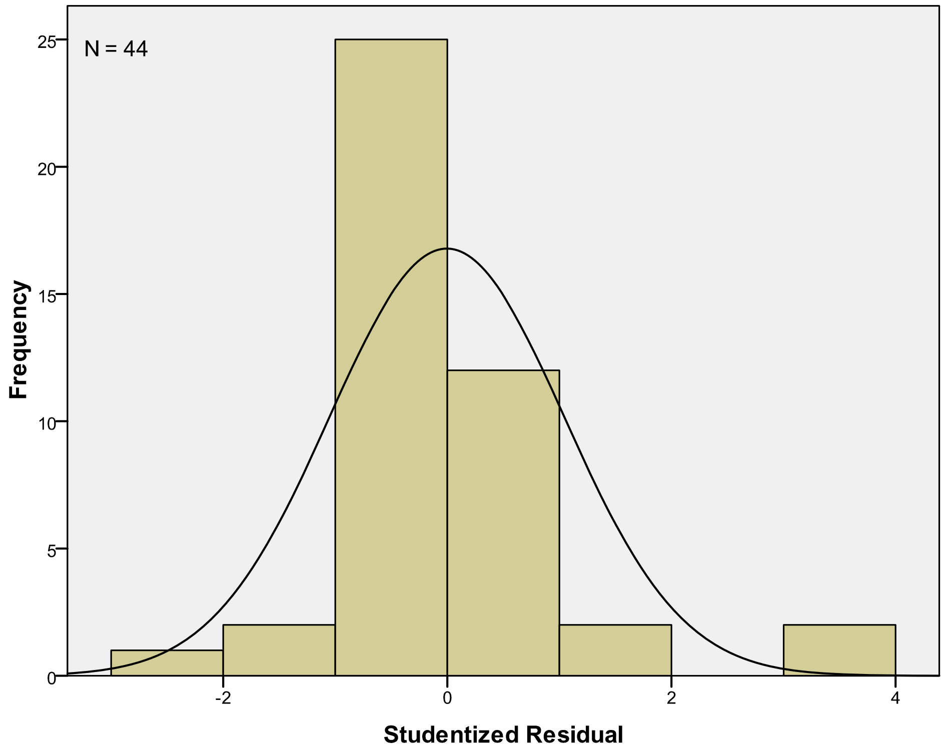


Fig. E- 17. Histogram of the residuals for dust control

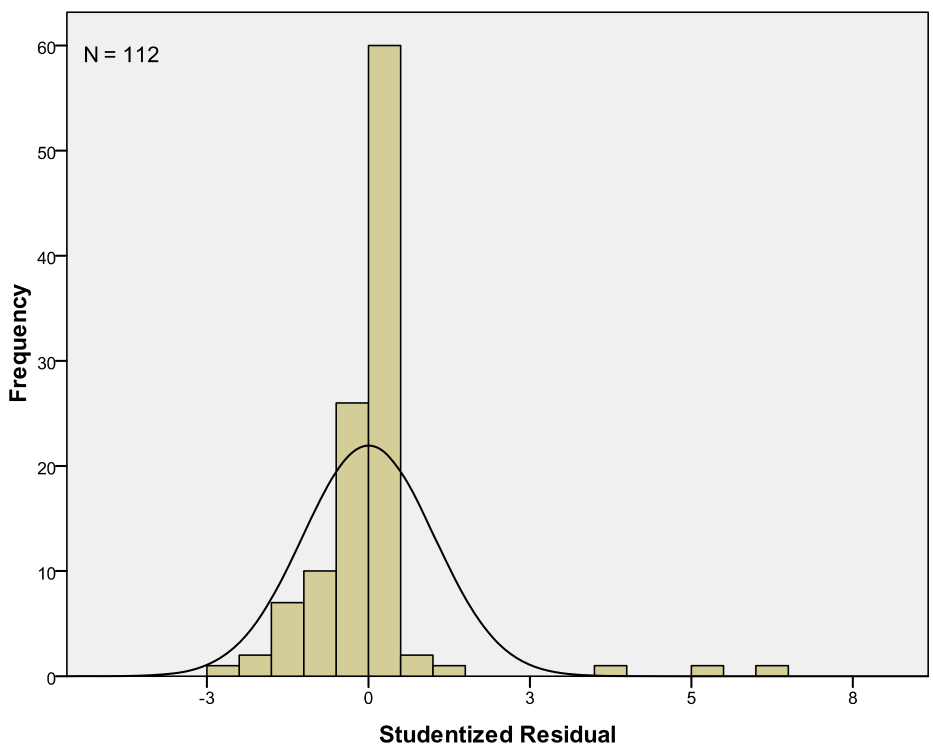


Fig. E- 18. Histogram of the residuals for total completion cost

APPENDIX F

RESIDUAL PLOT FOR YEARLY TIME SERIES MODEL

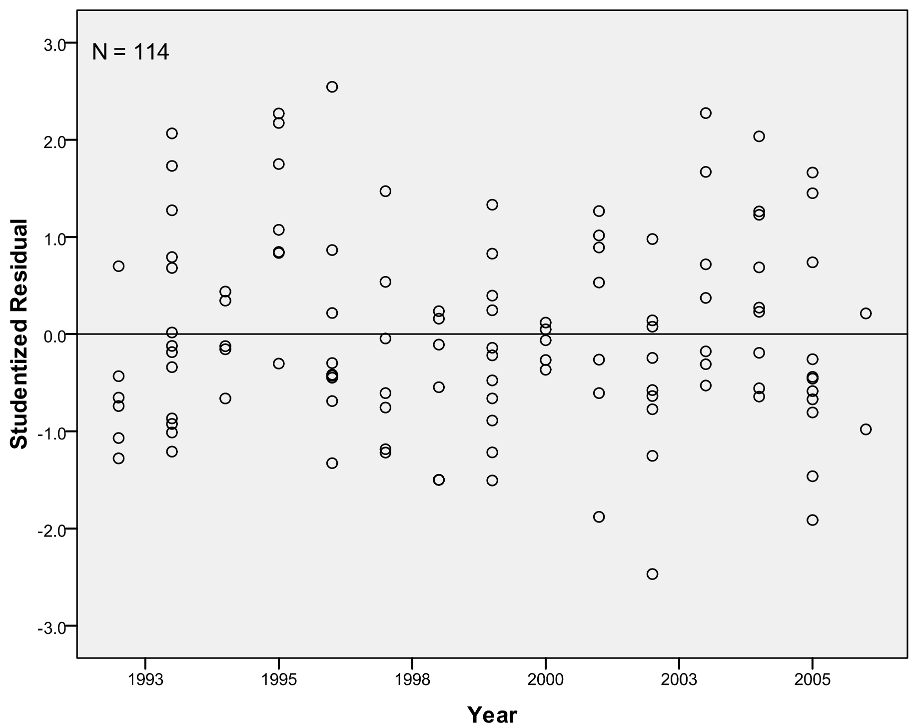


Fig. F- 1. Residual plot for yearly time series model for roadway excavation

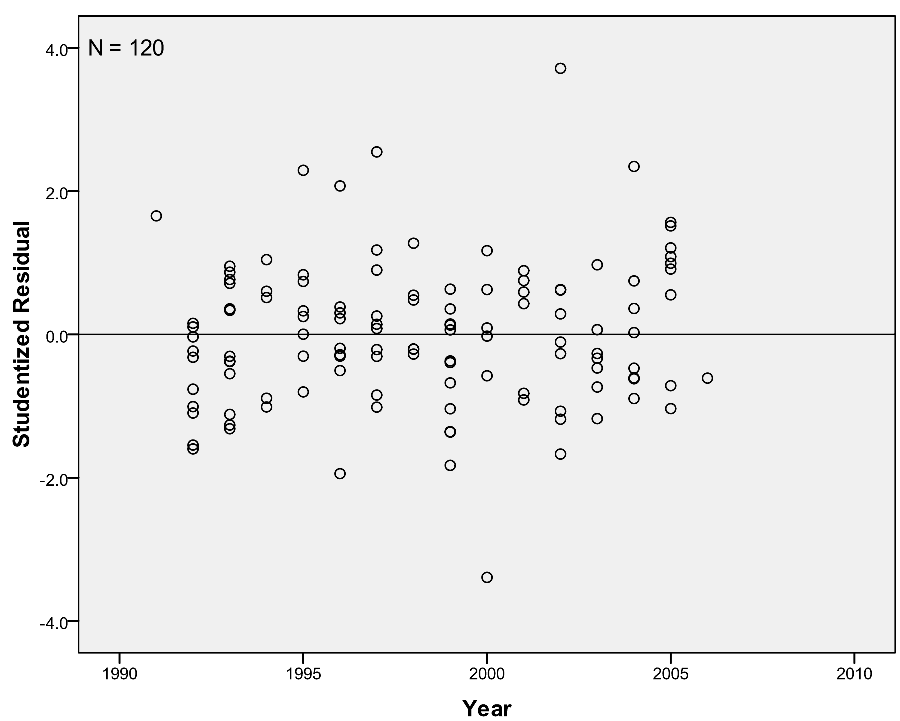


Fig. F- 2. Residual plot for yearly time series model for type II aggregate base

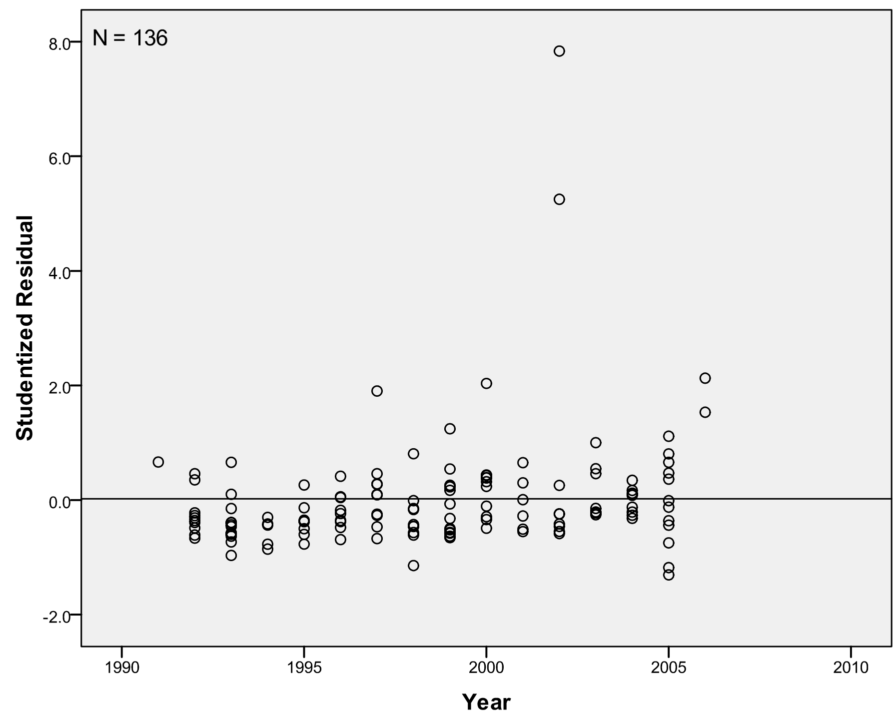


Fig. F- 3. Residual plot for yearly time series model for plantmix bituminous surface

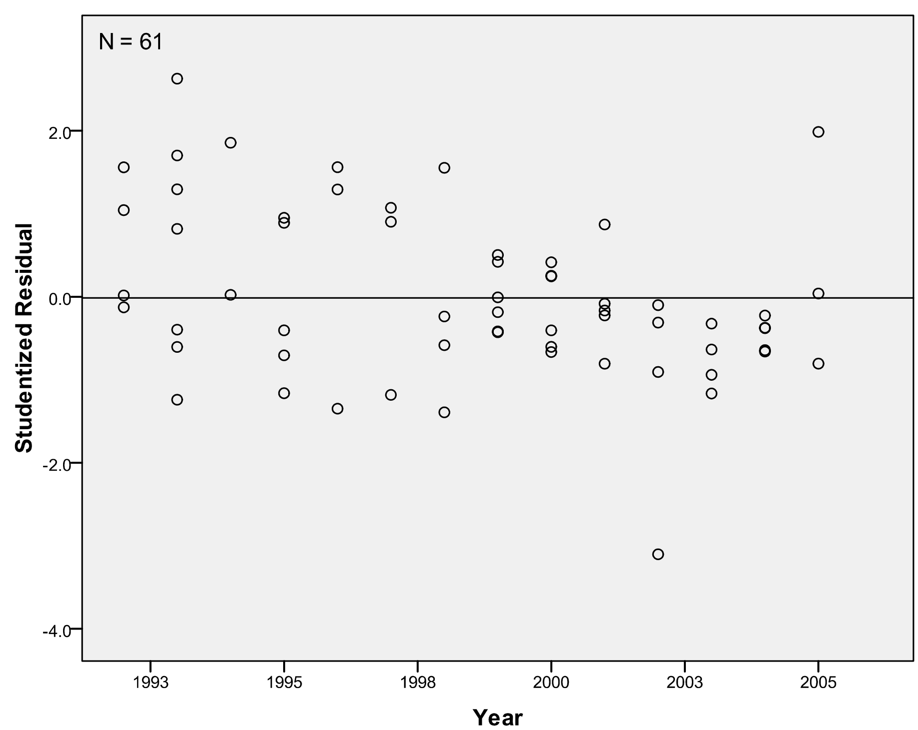


Fig. F- 4. Residual plot for yearly time series model for plantmix bituminous open-graded surface (3/4” depth)

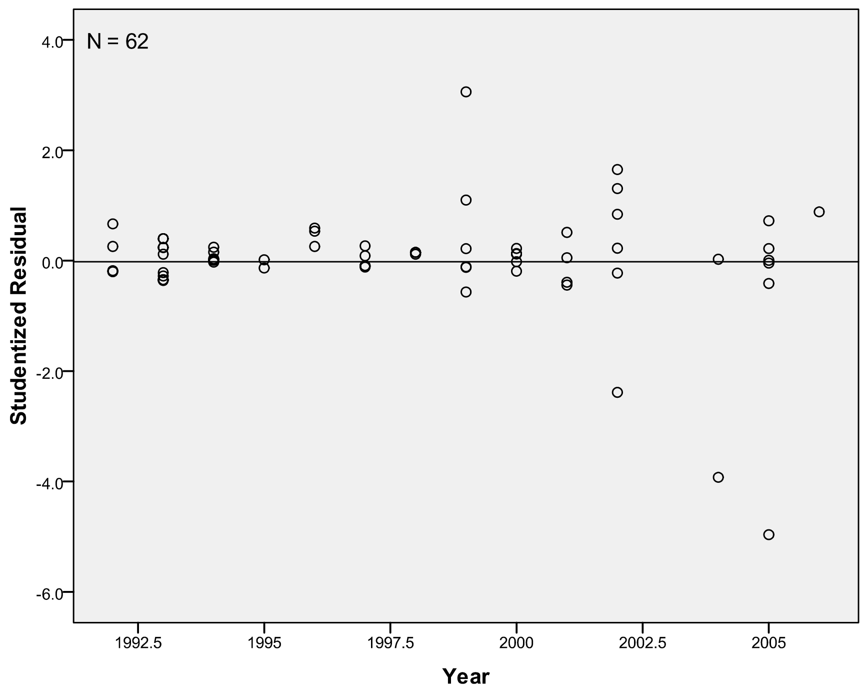


Fig. F- 5. Residual plot for yearly time series model for prime coat

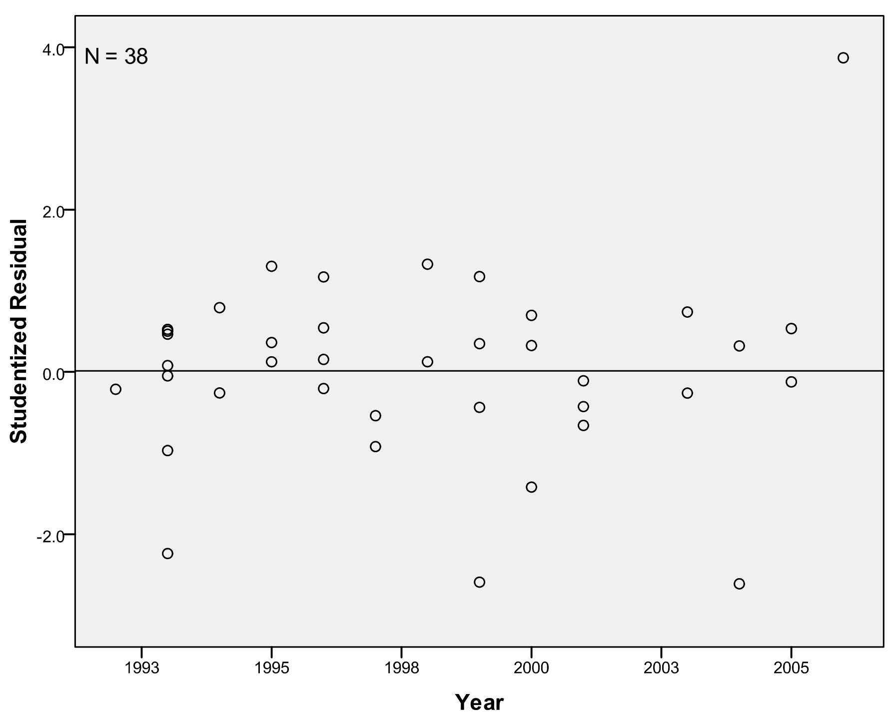


Fig. F- 6. Residual plot for yearly time series model for tack coat

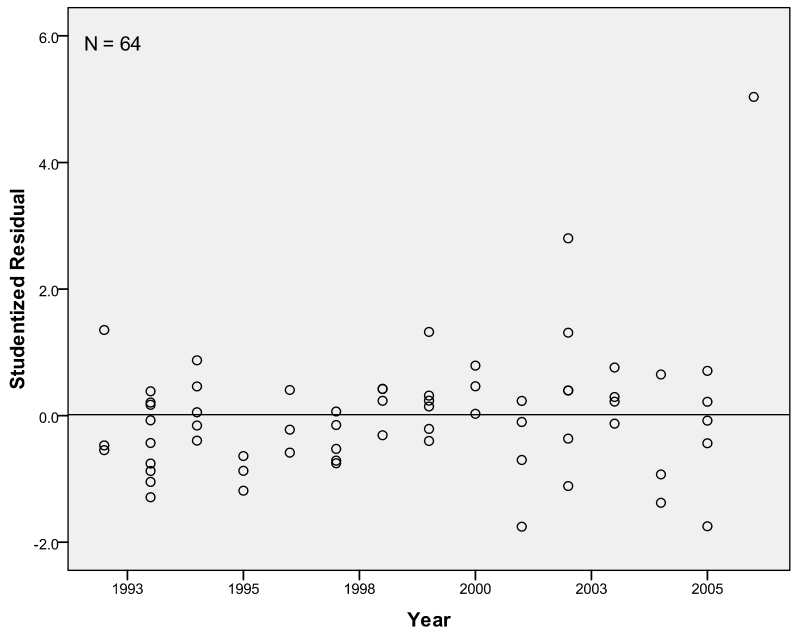


Fig. F- 7. Residual plot for yearly time series model for seal coat

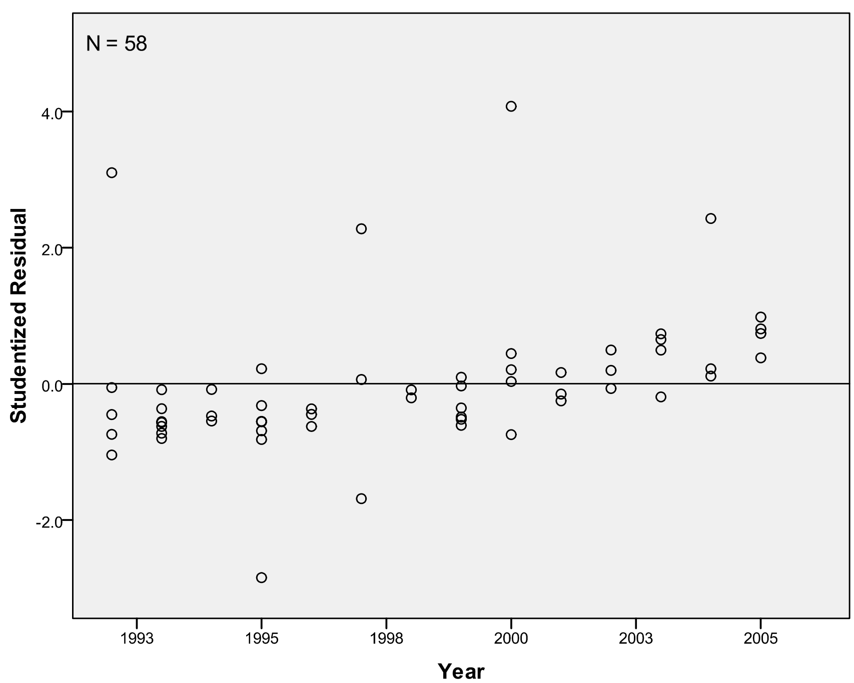


Fig. F- 8. Residual plot for yearly time series model for concrete sidewalk

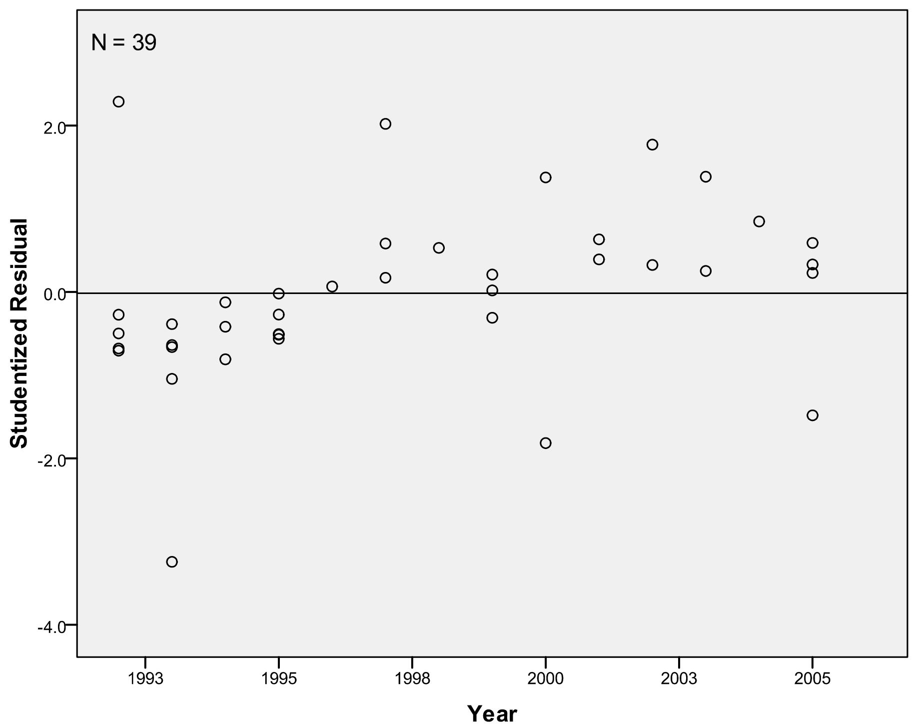


Fig. F- 9. Residual plot for yearly time series model for concrete valley gutter

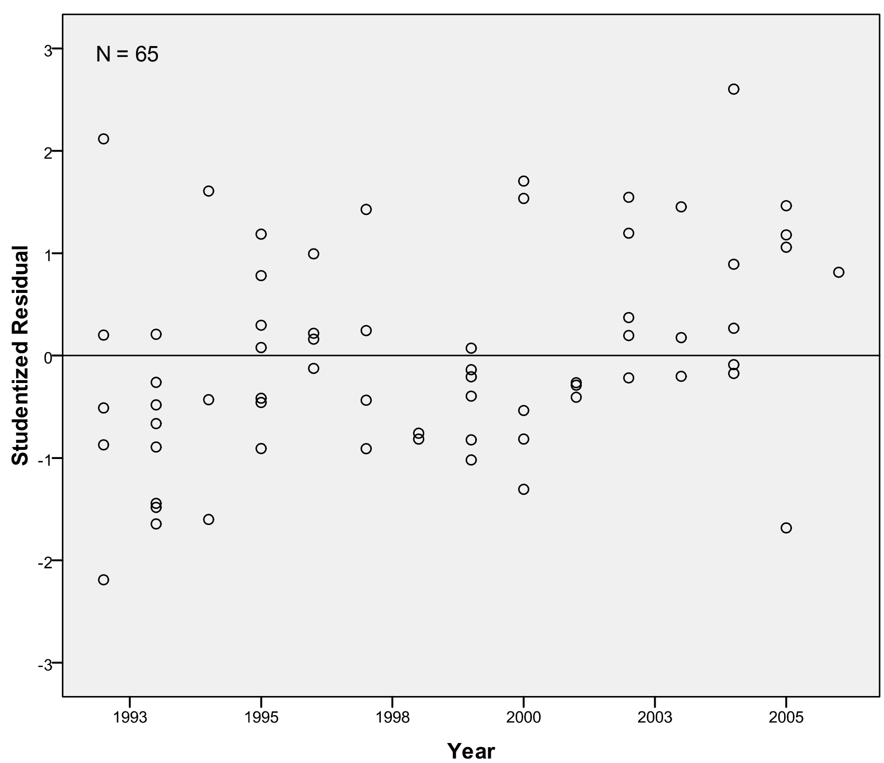


Fig. F- 10. Residual plot for yearly time series model for type "L" curb and gutter

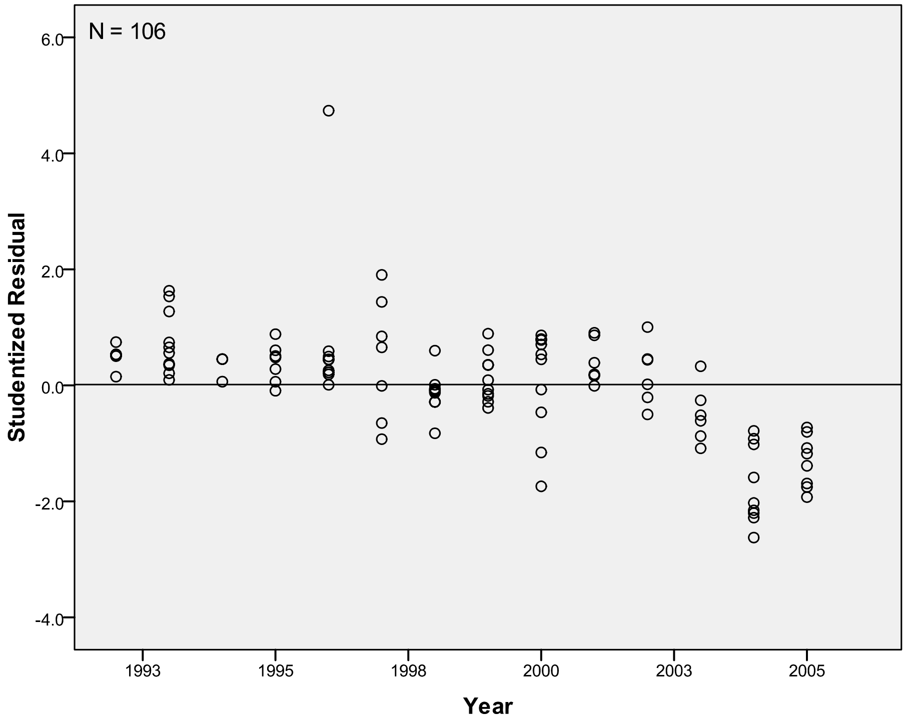


Fig. F- 11. Residual plot for yearly time series model for reflective pavement markers

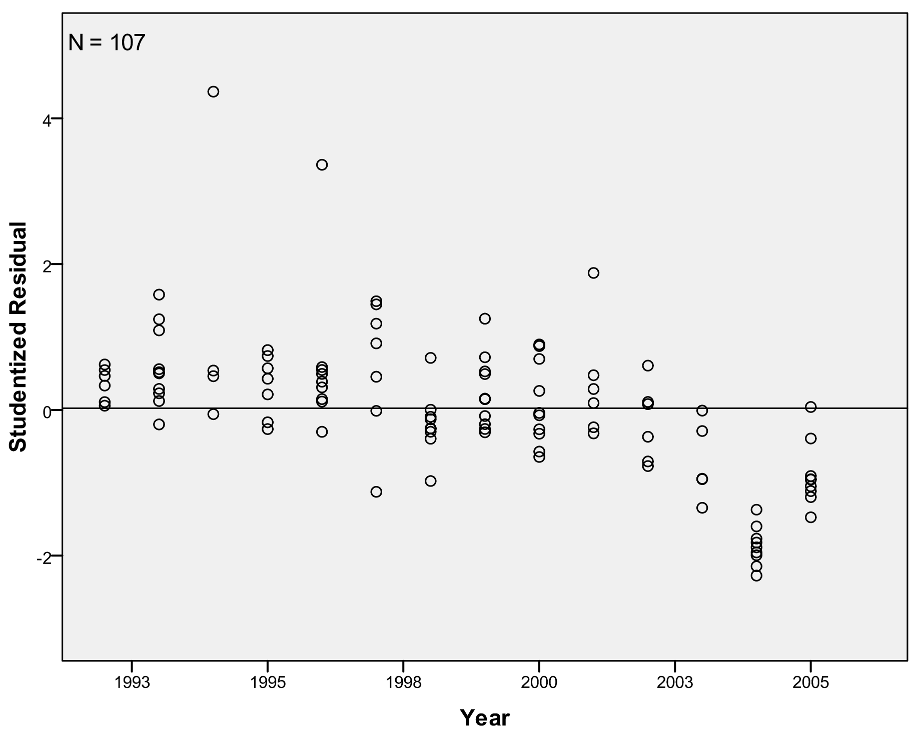


Fig. F- 12. Residual plot for yearly time series model for non reflective pavement markers

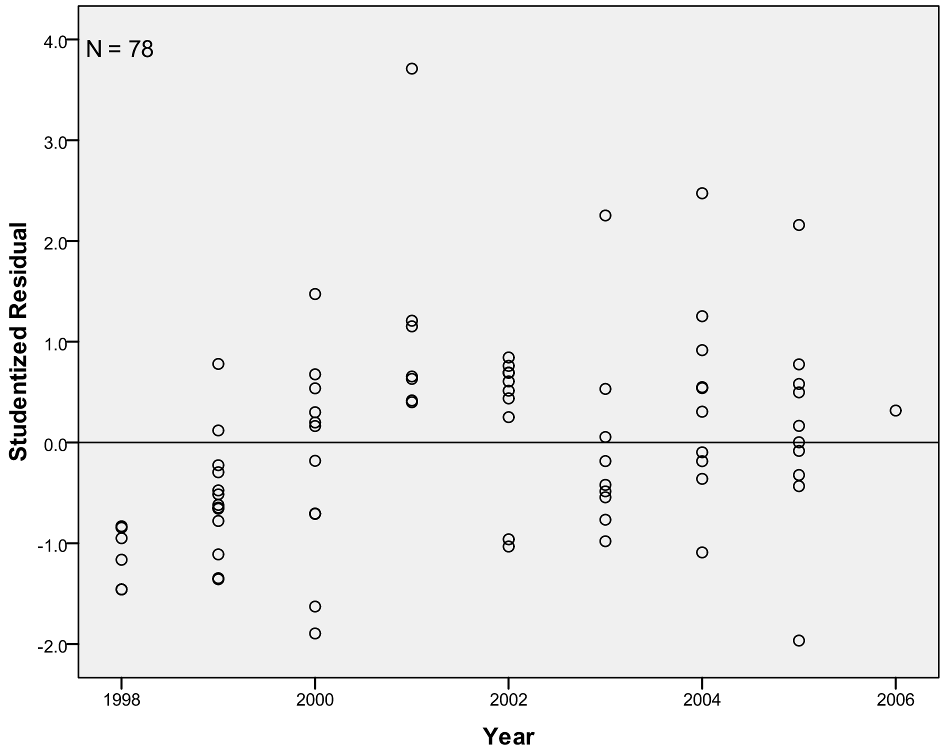


Fig. F- 13. Residual plot for yearly time series model for quality control

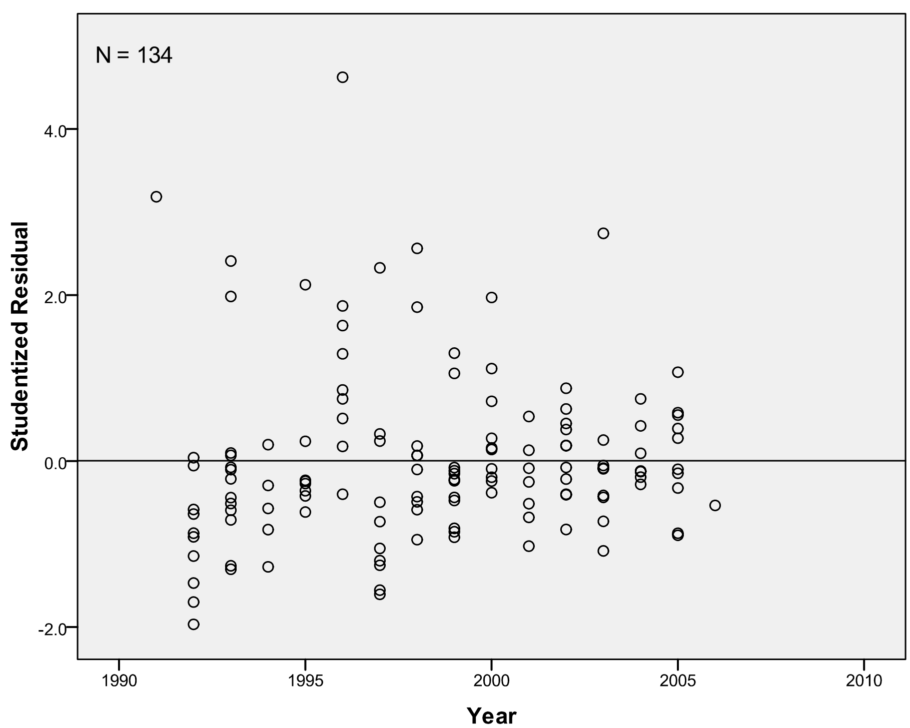


Fig. F- 14. Residual plot for yearly time series model for traffic control

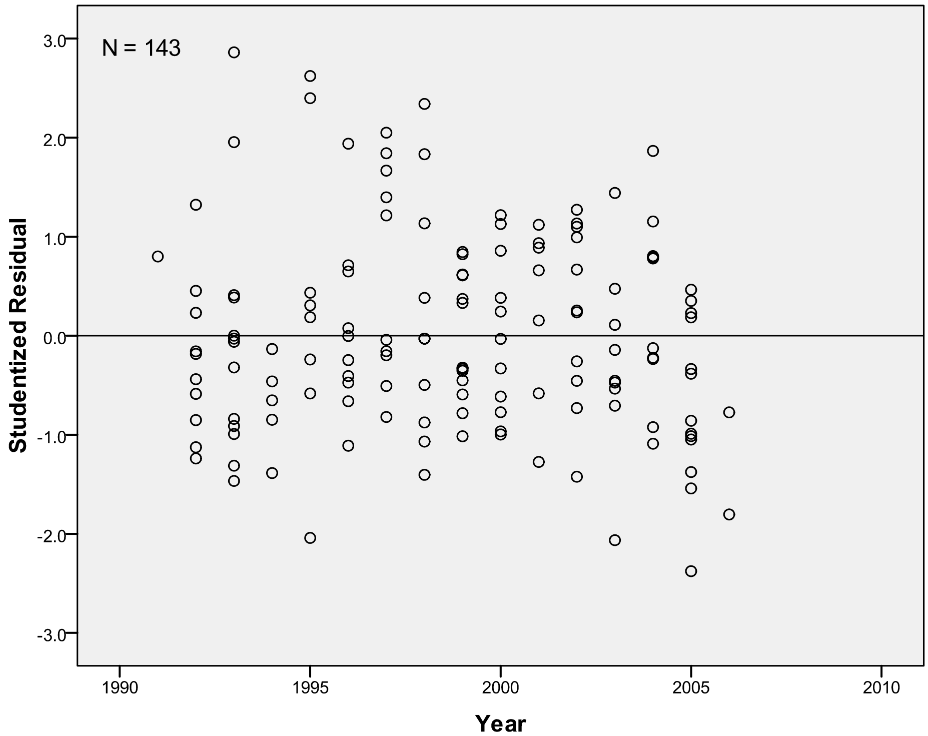


Fig. F- 15. Residual plot for yearly time series model for construction conflicts and additional works

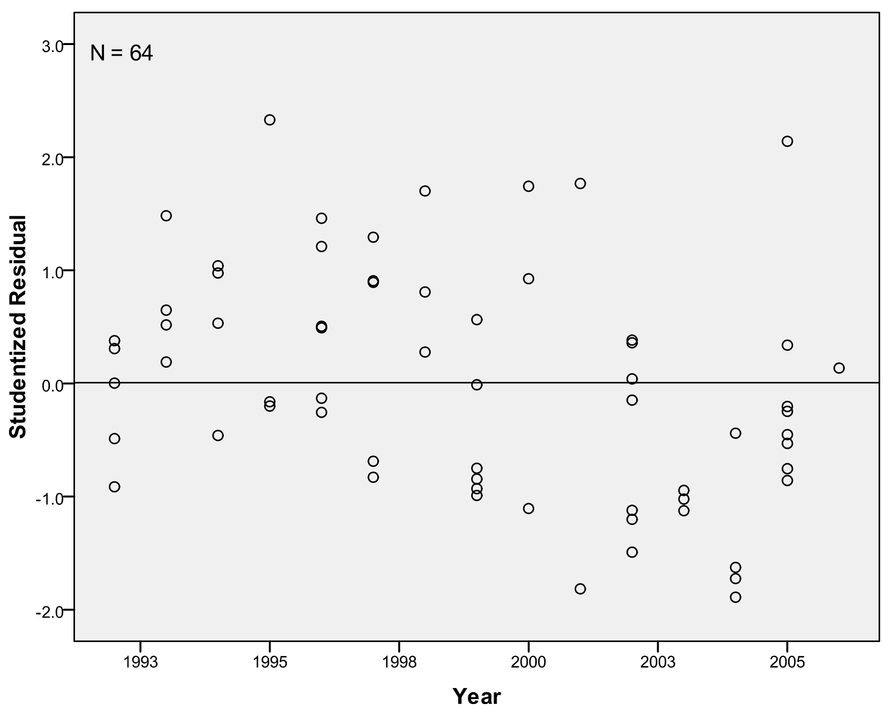


Fig. F- 16. Residual plot for yearly time series model for clearing and grubbing

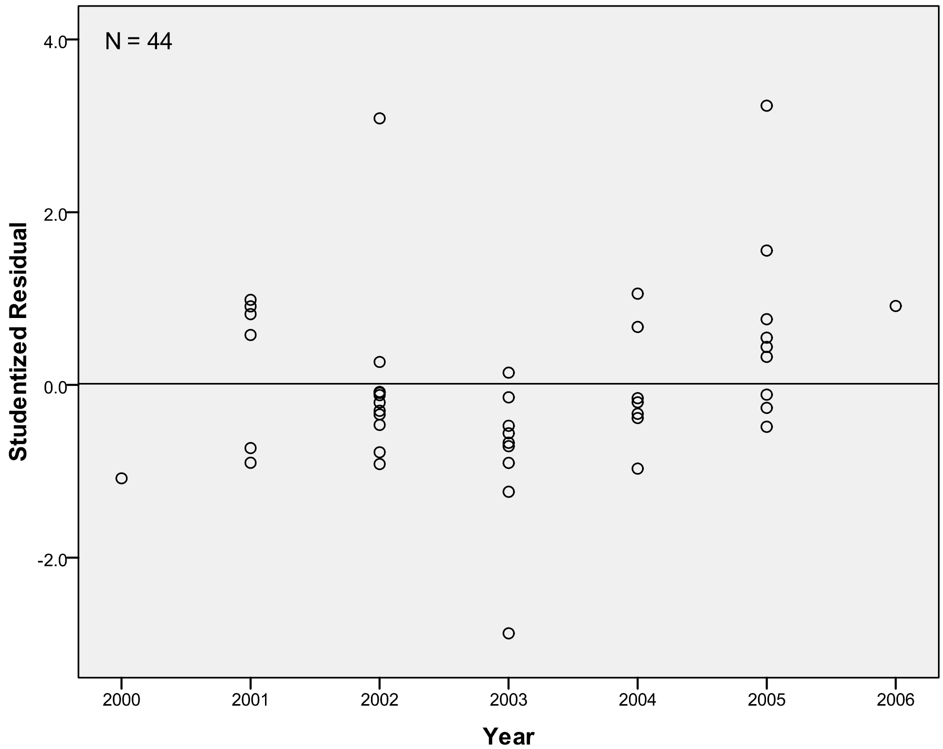


Fig. F- 17. Residual plot for yearly time series model for dust control

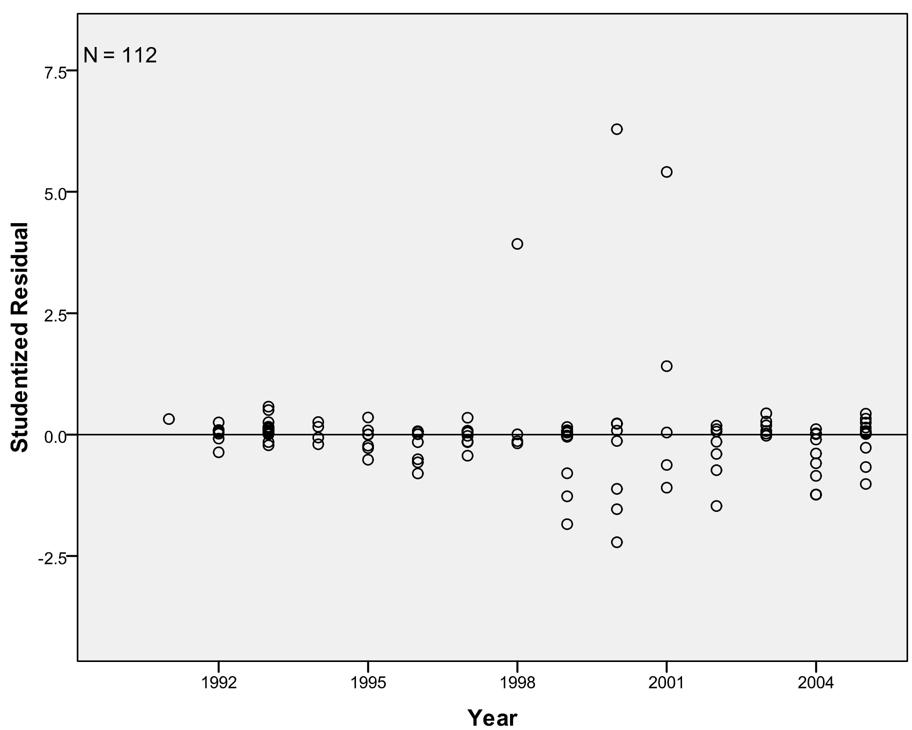


Fig. F- 18. Residual plot for yearly time series model for final completion cost

APPENDIX G

PLOT FOR PREDICTED VALUES AGAINST ACTUAL VALUES

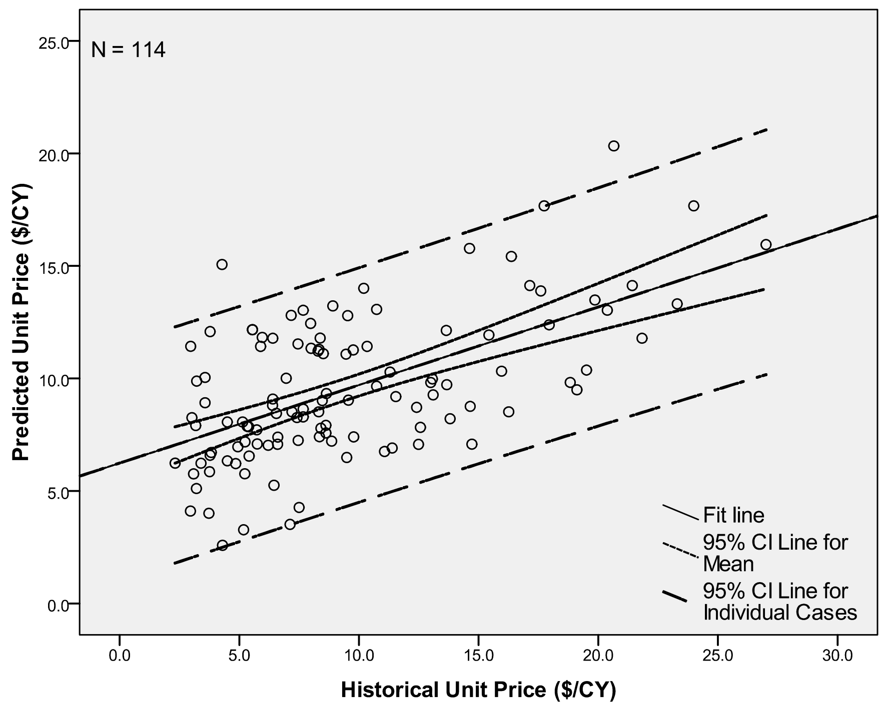


Fig. G-1. Predicted values of unit price vs. historical values of unit prices for roadway excavation

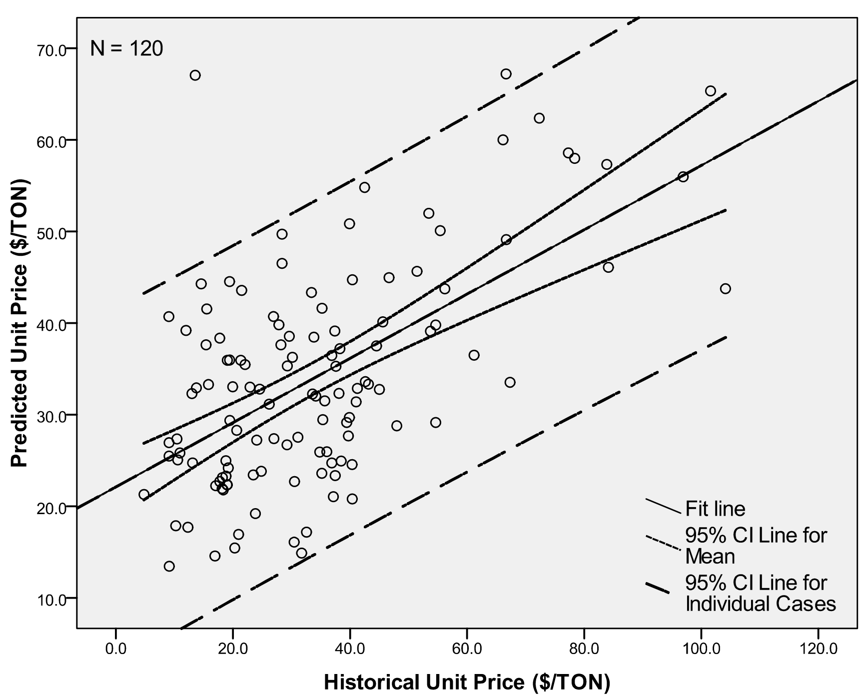


Fig. G-2. Predicted values of unit price vs. historical values of unit prices for type II aggregate base

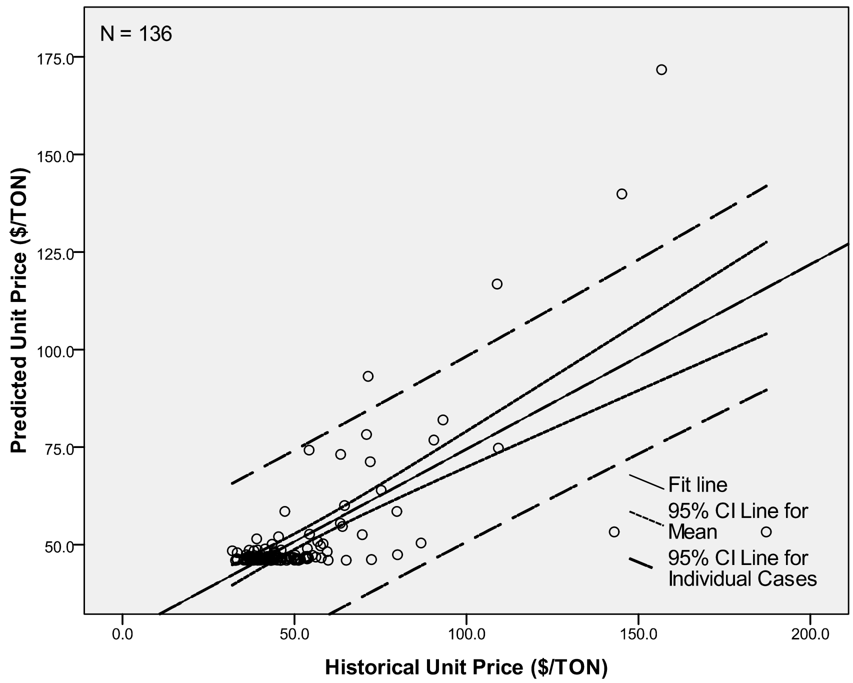


Fig. G-3. Predicted values of unit price vs. historical values of unit prices for plantmix bituminous surface

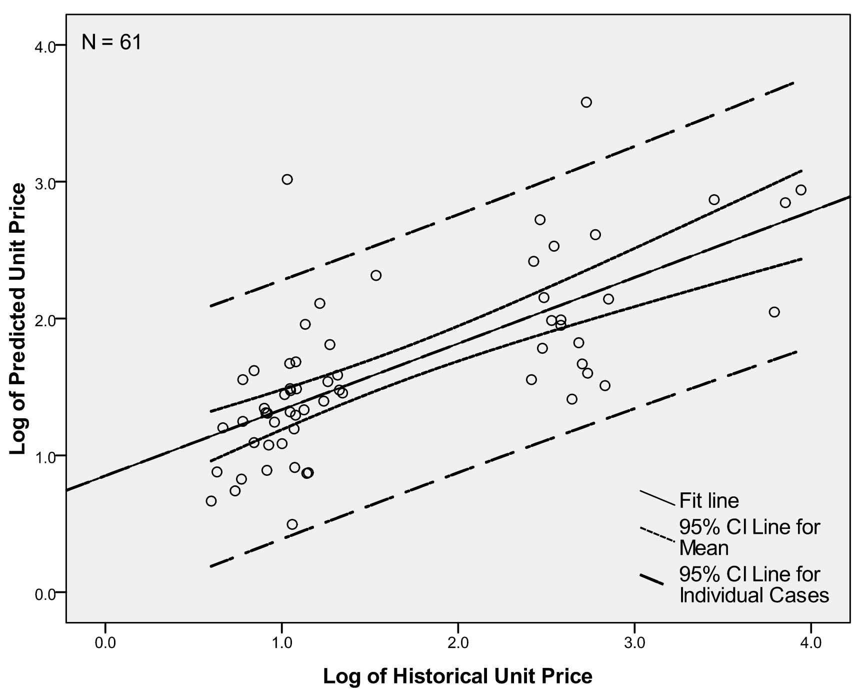


Fig. G-4. Logarithm of predicted values of unit price vs. logarithm of historical values of unit prices for plantmix bituminous open-graded surface (3/4" depth)

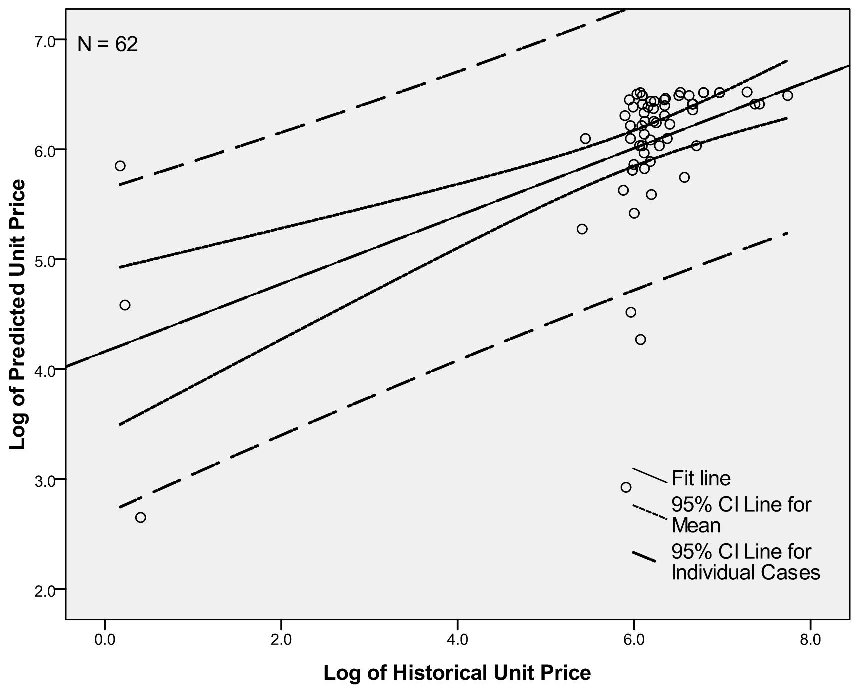


Fig. G-5. Logarithm of predicted values of unit price vs. logarithm of historical values of unit prices for prime coat

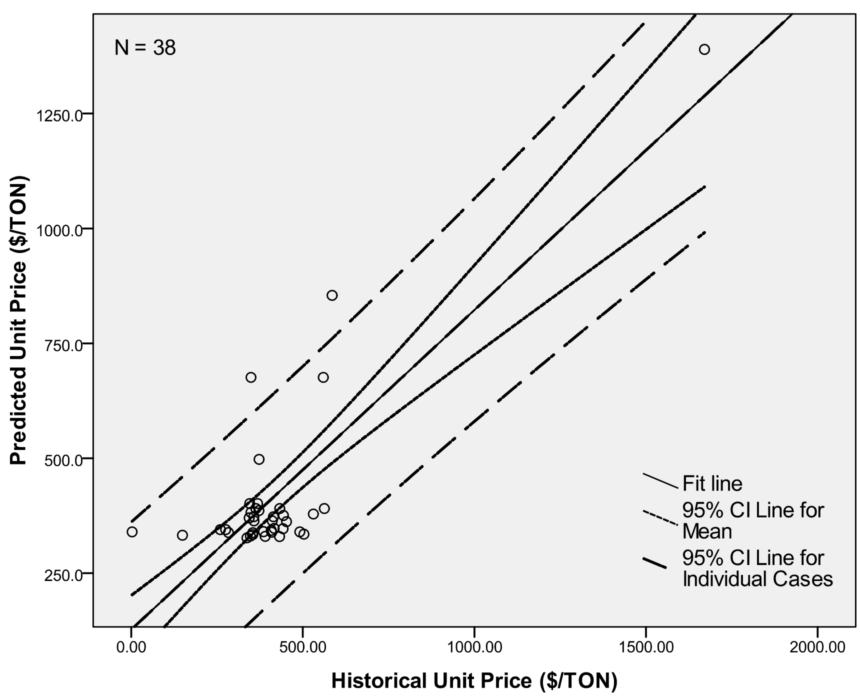


Fig. G-6. Predicted values of unit price vs. historical values of unit prices for tack coat

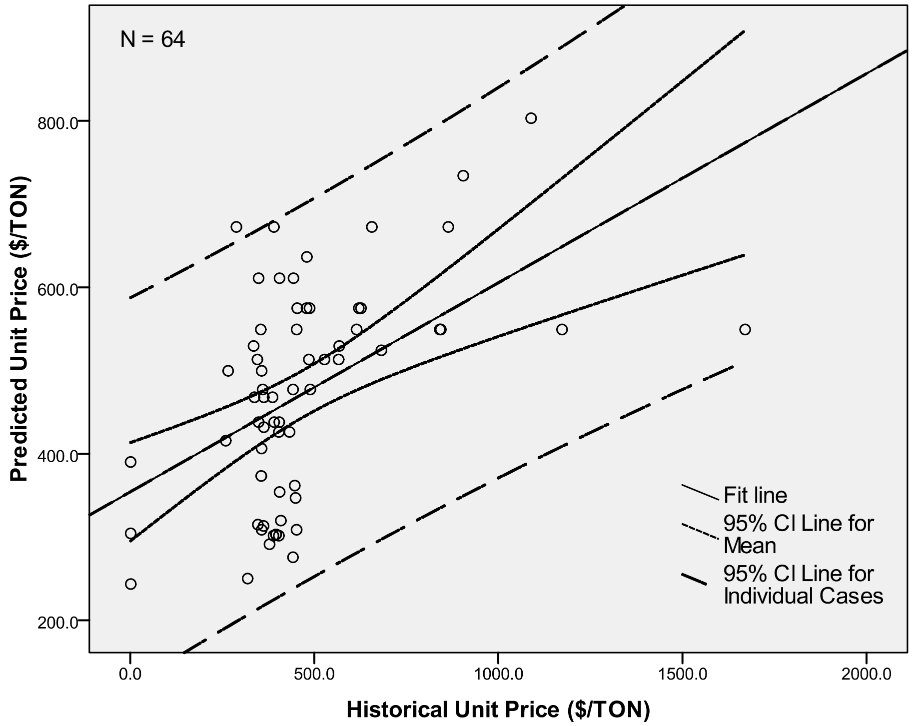


Fig. G-7. Predicted values of unit price vs. historical values of unit prices for seal coat

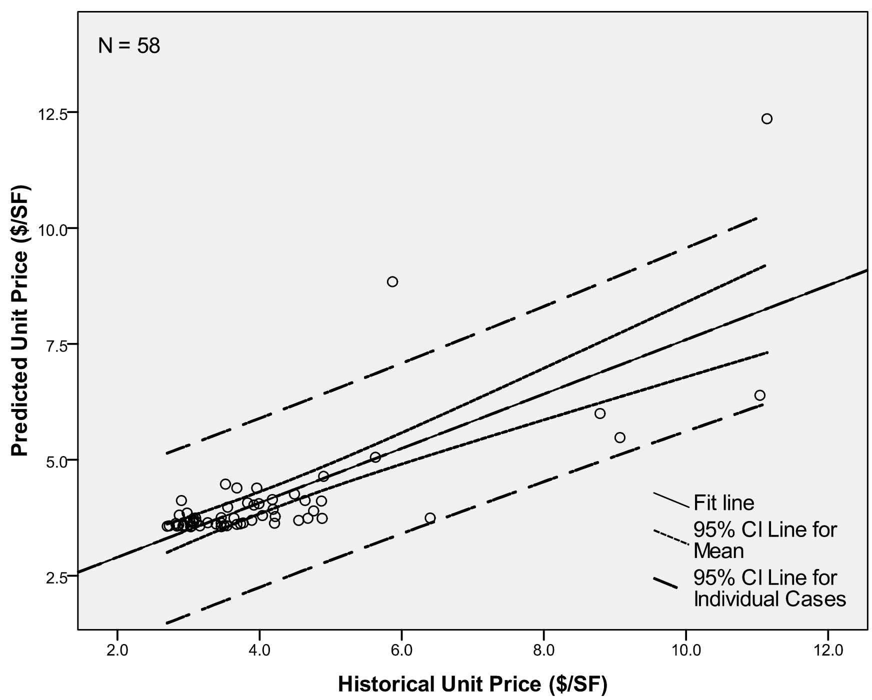


Fig. G-8. Predicted values of unit price vs. historical values of unit prices for concrete sidewalk

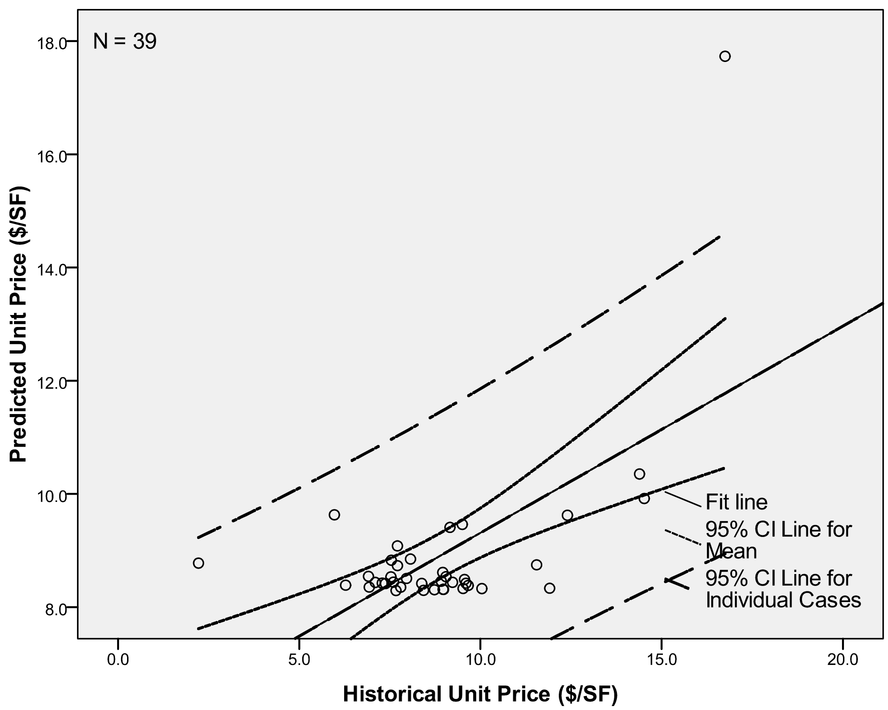


Fig. G-9. Predicted values of unit price vs. historical values of unit prices for concrete valley gutter

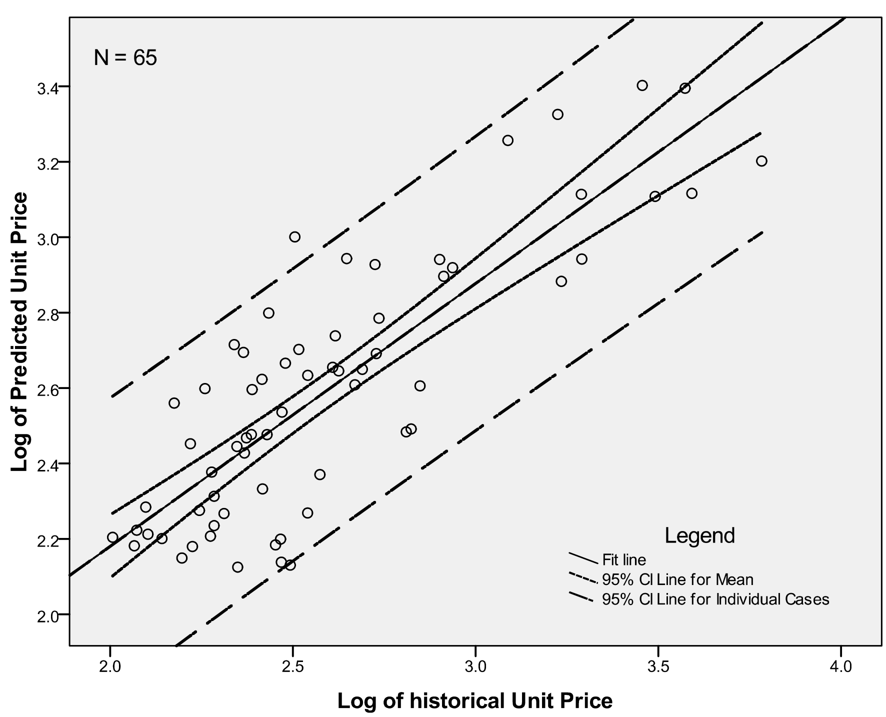


Fig. G-10. Logarithm of predicted values of unit price vs. logarithm of historical values of unit prices for type “L” curb and Gutter

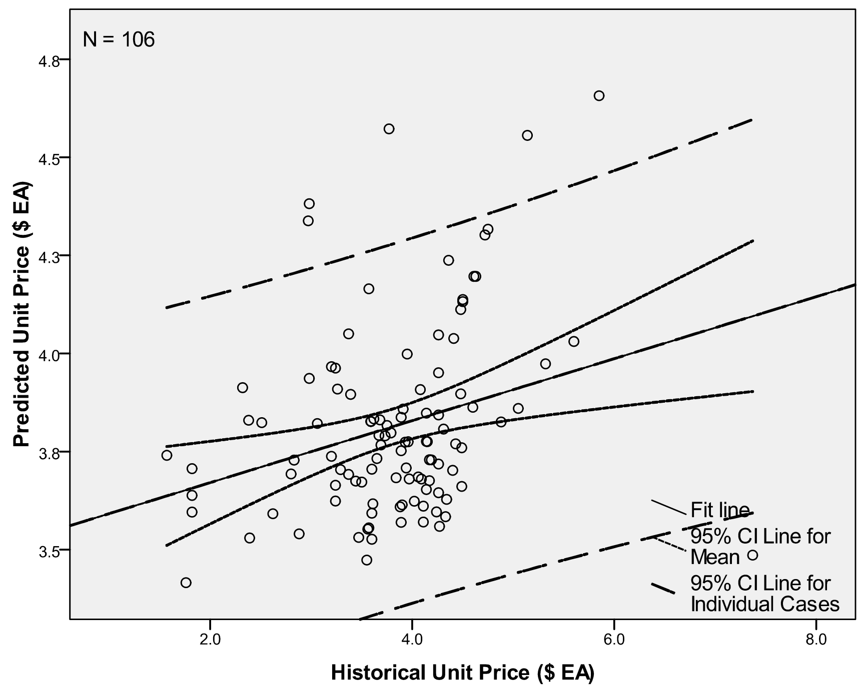


Fig. G-11. Predicted values of unit price vs. historical values of unit prices for reflective pavement markers

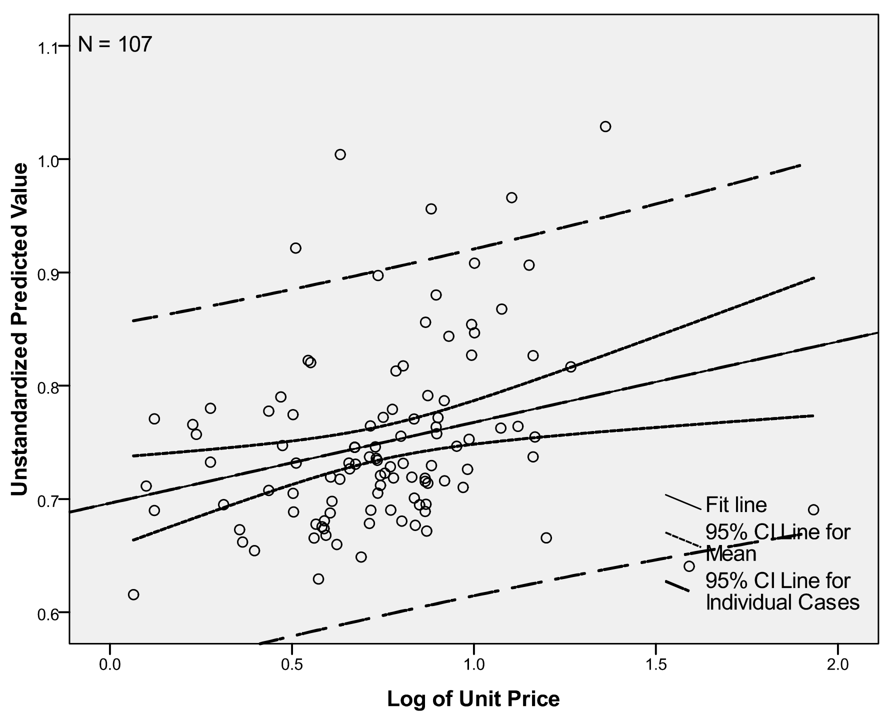


Fig. G-12. Logarithm of predicted values of unit price vs. logarithm of historical values of unit prices for non reflective pavement markers

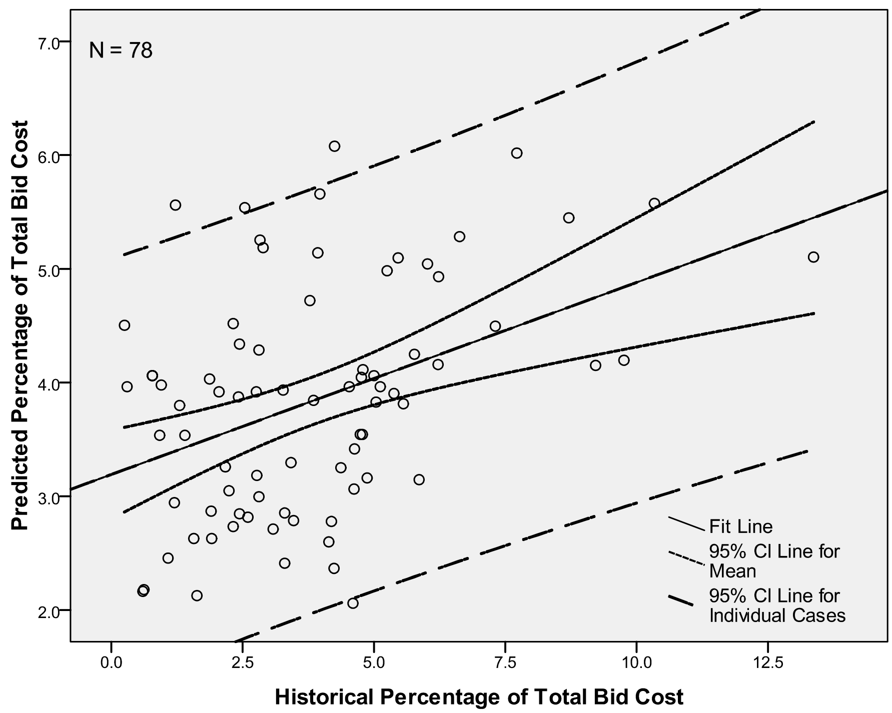


Fig. G-13. Historical percentage of total bid cost vs. predicted percentage of total bid cost for quality control

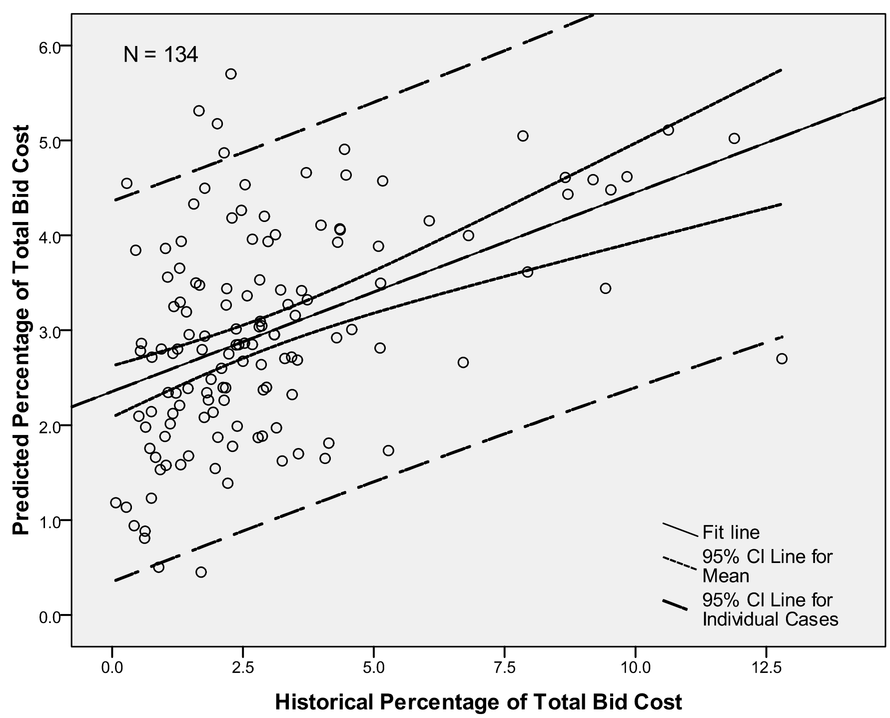


Fig. G-14. Historical percentage of total bid cost vs. predicted percentage of total bid cost for traffic control

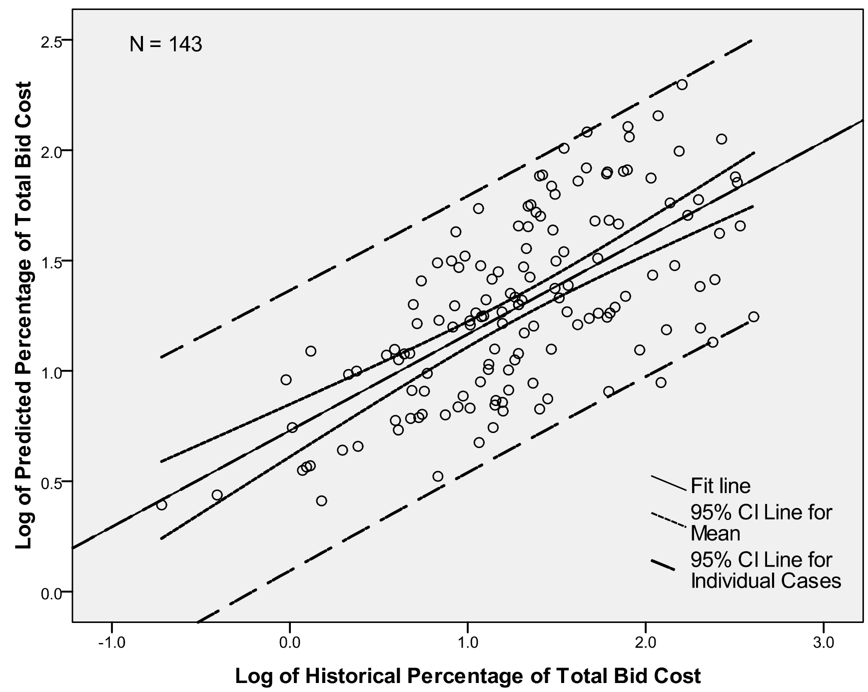


Fig. G-15. Historical percentage of total bid cost vs. predicted percentage of total bid cost for construction conflicts and additional works

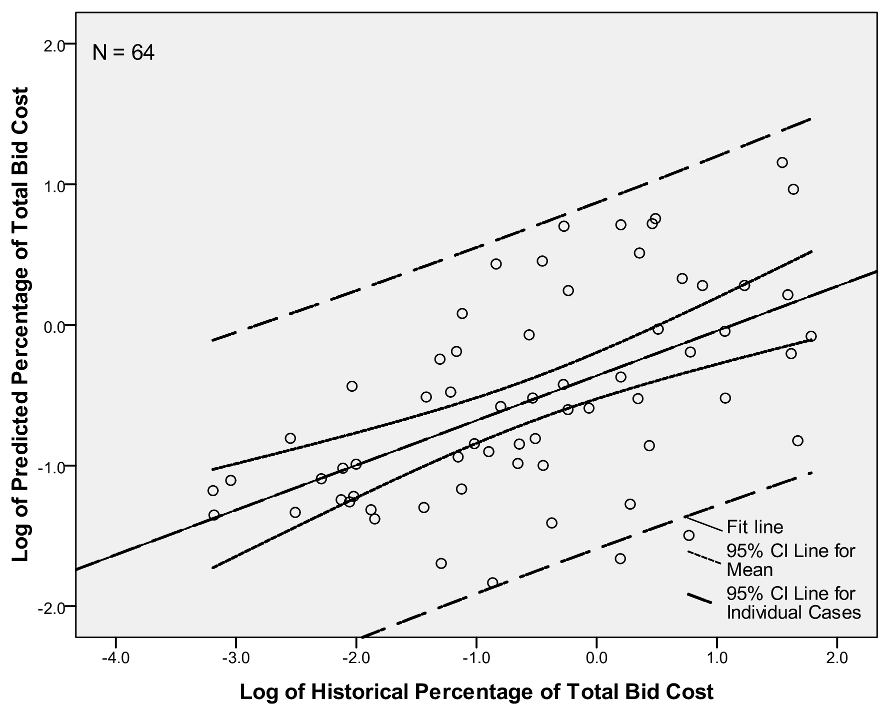


Fig. G-16. Logarithm of historical percentage of total bid cost vs. logarithm of predicted percentage of total bid cost for clearing and grubbing

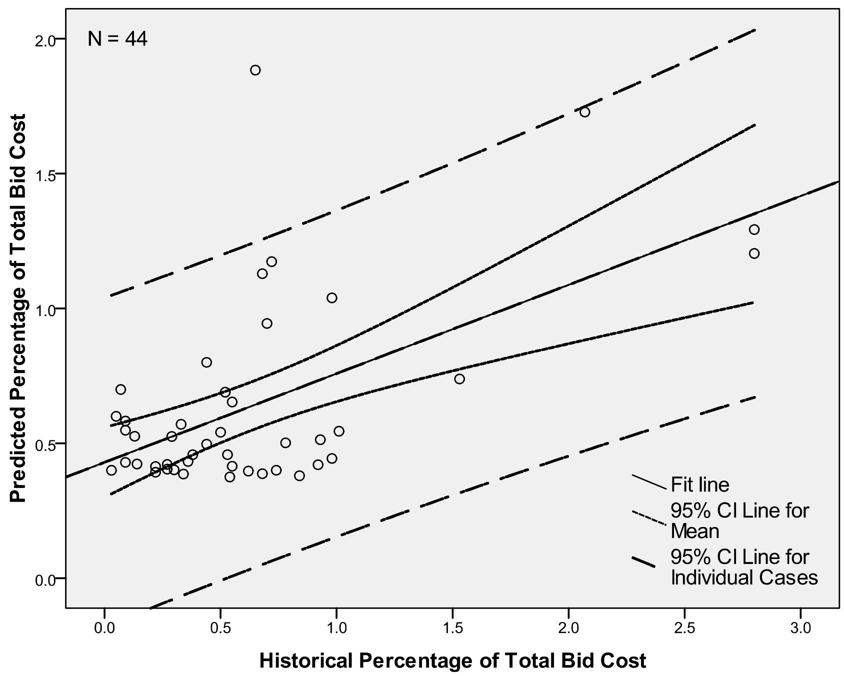


Fig. G-17. Historical percentage of total bid cost vs. predicted percentage of total bid cost for dust control

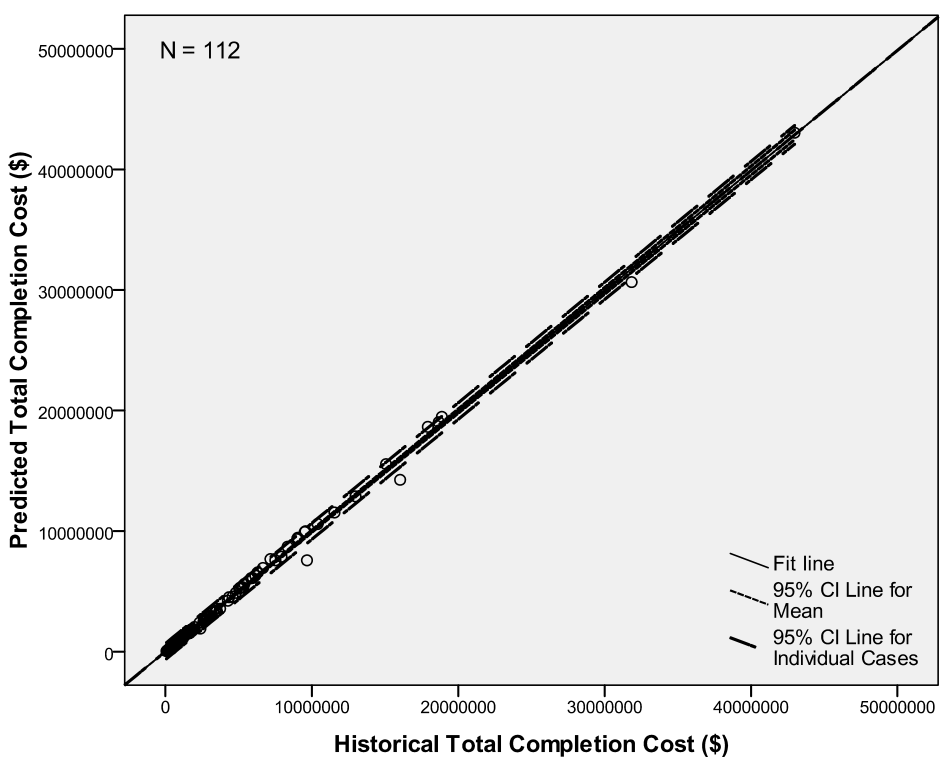


Fig. G-18. Historical total completion cost vs. predicted total completion cost

APPENDIX H

DATA IN TABULAR FORM

Table H-1. Data for Roadway Excavation (n = 114)

SN	Year	Quantity (CY)	Bid ($/CY)	Bid 08 ($/CY)
1	2003	1766.00	7.86	10.74
2	2002	606.00	3.05	4.28
3	2004	1000.00	13.65	17.14
4	2005	1000.00	18.00	21.42
5	1993	16316.00	2.01	3.57
6	1992	28095.00	1.75	3.18
7	2003	40760.00	6.48	8.86
8	1994	13109.00	5.00	8.64
9	1993	4020.00	4.20	7.45
10	1999	9746.00	2.10	3.22
11	1999	84440.00	2.45	3.76
12	1995	18220.00	7.40	12.41
13	1996	500.00	10.00	16.37
14	1997	4465.00	5.00	8.00
15	2000	227500.00	2.50	3.73
16	2004	28917.00	4.29	5.39
17	1998	33550.00	5.50	8.62
18	2006	1626.00	8.00	8.91
19	1993	7703.00	9.00	15.96
20	1994	4769.00	4.80	8.29
21	1996	9105.00	4.25	6.96
22	1992	2037.00	3.95	7.17
23	1993	1069.00	5.75	10.20
24	2004	7859.00	9.00	11.30
25	2003	37000.00	4.84	6.61
26	1993	88753.00	2.95	5.23
27	1995	20258.00	9.70	16.26
28	1997	20256.00	5.20	8.32
29	1997	36837.20	6.12	9.78
30	2002	30000.00	6.00	8.41
31	1998	2863.00	3.54	5.55
32	1993	60120.00	5.35	9.49
33	1992	53400.00	2.11	3.83
34	2002	4265.00	4.20	5.89
35	2002	4265.00	7.38	10.34
36	1997	150.00	15.00	23.99
37	1997	23300.00	1.89	3.02
38	1996	3440.00	3.64	5.96
39	1996	13522.00	8.00	13.10
40	2001	10617.00	9.48	13.67

SN	Year	Quantity (CY)	Bid ($/CY)	Bid 08 ($/CY)
41	1998	17360.00	4.08	6.39
42	2002	3498.00	5.98	8.38
43	1993	3250.00	8.70	15.43
44	2005	1412.00	16.69	19.86
45	2000	15353.00	6.41	9.56
46	2003	1803.00	14.91	20.38
47	2005	25846.00	3.78	4.50
48	2001	3000.00	2.62	3.78
49	1997	14941.00	4.00	6.40
50	1999	11010.00	7.00	10.74
51	1993	4647.00	5.50	9.76
52	1999	25825.00	3.35	5.14
53	1998	2863.00	3.54	5.55
54	2005	197710.00	6.30	7.50
55	1993	43801.00	8.30	14.72
56	2005	41469.00	4.40	5.24
57	1993	2469.00	4.50	7.98
58	1999	1804.00	5.00	7.67
59	1993	45000.00	3.50	6.21
60	1993	150.00	10.00	17.74
61	2001	14112.00	8.00	11.54
62	2005	8940.00	3.00	3.57
63	2004	2554.00	14.30	17.95
64	2003	69595.00	3.55	4.85
65	2004	23238.00	5.90	7.41
66	2003	10074.00	9.51	13.00
67	2000	40062.00	5.00	7.46
68	2001	48010.00	7.90	11.39
69	1994	2916.00	7.90	13.65
70	1999	17800.00	9.55	14.65
71	1998	27937.00	5.50	8.62
72	2005	5067.00	7.15	8.51
73	2002	57000.00	2.70	3.78
74	2006	36700.00	7.50	8.35
75	2005	4571.00	7.00	8.33
76	1995	1138.00	10.50	17.60
77	2001	23883.00	9.58	13.81
78	2000	413.00	9.80	14.62
79	1992	126000.00	1.77	3.21
80	1996	20256.00	4.40	7.20
81	1997	3515.00	4.00	6.40

SN	Year	Quantity (CY)	Bid ($/CY)	Bid 08 ($/CY)
82	1992	2050.00	5.25	9.53
83	1999	19000.00	5.00	7.67
84	1995	12000.00	11.40	19.11
85	2005	46611.00	4.15	4.94
86	1998	43849.00	4.21	6.60
87	2004	44000.00	9.95	12.49
88	2004	10060.00	15.00	18.83
89	1995	29360.00	7.50	12.57
90	1992	9270.00	7.20	13.07
91	1996	31163.00	3.50	5.73
92	1994	336665.00	3.00	5.18
93	2001	215616.00	2.05	2.96
94	2001	88900.00	2.14	3.09
95	2002	52147.00	7.90	11.07
96	2002	36.00	14.73	20.65
97	2004	69019.00	2.71	3.40
98	2002	28585.00	3.80	5.33
99	1999	68800.00	1.51	2.32
100	2005	58132.00	4.55	5.41
101	2003	3514.00	15.97	21.83
102	1996	65205.00	2.75	4.50
103	1995	43580.00	3.43	5.75
104	2000	5130.00	6.34	9.46
105	1999	22862.00	5.00	7.67
106	1996	21032.00	4.00	6.55
107	1996	377.00	16.50	27.01
108	1993	7500.00	11.00	19.51
109	1995	1550.00	13.90	23.30
110	1999	487650.00	2.80	4.30
111	2004	116600.00	5.14	6.45
112	1999	296136.00	4.64	7.12
113	2005	4260.00	2.50	2.97
114	1994	15500.00	4.90	8.47

Table H-2. Data for Type II Aggregate Base (n = 120)

SN	Year	Quantity (TON)	Bid ($/TON)	Bid 08 ($/CY)
1	2003	4462.00	10.06	13.75
2	2002	4252.00	11.28	15.81
3	2004	3000.00	17.00	21.34
4	2005	3000.00	16.00	19.04
5	1993	12700.00	10.59	18.79
6	1992	18968.00	10.00	18.15
7	2003	13420.63	29.53	40.35
8	1994	4232.10	24.97	43.15
9	1993	2183.00	10.00	17.74
10	1998	165.00	50.00	78.37
11	1999	9288.00	6.80	10.43
12	1995	16188.00	10.85	18.19
13	1996	5638.00	16.00	26.19
14	1997	4873.00	21.00	33.59
15	1992	968.00	10.70	19.42
16	2004	7121.00	15.50	19.46
17	2006	1133.00	30.00	33.41
18	1993	2873.00	17.00	30.16
19	1994	2990.00	11.25	19.44
20	1996	4542.00	15.00	24.56
21	1992	1435.00	8.55	15.52
22	1993	746.00	16.00	28.38
23	2004	4411.00	18.25	22.91
24	1993	35420.39	18.36	32.57
25	1995	15579.00	14.00	23.47
26	1997	14090.00	12.00	19.19
27	1997	19325.70	11.47	18.34
28	2002	6824.96	28.46	39.89
29	1998	17962.00	12.13	19.01
30	1993	15221.63	19.83	35.18
31	1992	18200.00	9.40	17.06
32	2002	1970.00	26.68	37.40
33	2002	1072.87	74.29	104.14
34	1997	1600.00	16.83	26.92
35	1997	5375.22	22.31	35.68
36	1996	2153.36	20.66	33.82
37	1996	1602.00	5.53	9.05
38	1997	20638.00	3.00	4.80

SN	Year	Quantity (TON)	Bid ($/TON)	Bid 08 ($/CY)
39	1999	1000.00	9.50	14.57
40	1996	4117.74	41.13	67.33
41	2001	3192.00	15.30	22.06
42	1998	15858.00	12.00	18.81
43	2002	4840.00	9.27	12.99
44	1993	2125.00	16.70	29.62
45	1995	62.63	60.59	101.59
46	2005	529.90	56.04	66.69
47	2000	9250.61	18.09	26.99
48	2003	1803.00	20.37	27.84
49	1992	49.01	36.72	66.65
50	2000	152.49	51.80	77.29
51	2005	13101.00	11.01	13.10
52	2001	11360.00	7.58	10.93
53	1997	7690.00	30.00	47.98
54	1991	180.00	45.00	83.86
55	1999	3255.09	19.10	29.29
56	1993	1726.93	25.71	45.60
57	1999	5017.97	22.25	34.14
58	2000	50.00	9.08	13.55
59	1998	17962.00	12.13	19.01
60	2000	363.25	35.82	53.45
61	1993	15723.76	21.12	37.46
62	2005	21301.57	31.22	37.15
63	1993	836.00	29.00	51.44
64	1999	1099.00	14.00	21.48
65	1993	17111.00	10.00	17.74
66	1993	490.00	16.00	28.38
67	2001	5450.38	28.46	41.04
68	2005	4079.07	35.81	42.61
69	2004	789.67	67.02	84.14
70	2003	33063.00	9.00	12.30
71	2004	7043.89	28.15	35.34
72	2003	8213.00	15.10	20.64
73	2001	2439.82	30.87	44.51
74	1994	12562.00	6.11	10.56
75	1999	4830.62	24.84	38.11
76	1998	11212.82	22.22	34.82
77	2005	2787.27	51.41	61.18
78	2002	11164.35	25.71	36.03
79	2003	943.80	29.56	40.40

SN	Year	Quantity (TON)	Bid ($/TON)	Bid 08 ($/CY)
80	2005	1806.99	45.91	54.63
81	1995	466.18	33.05	55.41
82	2001	4560.50	31.22	45.01
83	2000	92.58	48.48	72.33
84	1992	10110.54	16.10	29.23
85	1997	1977.45	33.60	53.74
86	1997	3272.51	23.50	37.59
87	1992	914.93	25.71	46.66
88	1999	7335.79	25.71	39.43
89	1995	8898.80	23.69	39.71
90	2005	7331.98	45.91	54.63
91	1998	17133.73	19.46	30.51
92	2004	13114.57	29.38	36.88
93	2004	2799.26	29.38	36.88
94	1995	12762.75	22.95	38.48
95	1992	250.52	23.41	42.49
96	1999	422.00	26.01	39.90
97	2003	2539.00	28.00	38.27
98	1997	215.12	60.59	96.91
99	1996	9068.00	19.00	31.10
100	1994	47893.96	18.36	31.73
101	2001	40899.63	21.12	30.45
102	1992	11884.00	5.00	9.07
103	1992	9812.00	5.00	9.07
104	2002	27159.00	17.00	23.83
105	2002	1954.00	8.55	11.98
106	2004	32331.00	8.15	10.23
107	2002	57909.00	6.50	9.11
108	1999	49900.00	11.03	16.92
109	2005	21997.03	33.93	40.38
110	1996	44492.00	12.40	20.30
111	1995	36610.00	12.50	20.96
112	2000	2403.00	18.90	28.20
113	1999	14793.00	16.19	24.84
114	1996	9454.29	14.69	24.05
115	1996	126.35	40.40	66.13
116	1993	1075.59	31.67	56.19
117	1995	4391.00	11.90	19.95
118	1999	2402.00	10.04	15.40
119	1999	1420.87	22.95	35.21
120	1994	4493.51	23.87	41.25

Table H-3. Data for Plantmix Bituminous Surface (n = 136)

SN	Year	Quantity (TON)	Bid ($/TON)	Bid 08 ($/CY)
1	2003	53506.00	30.81	42.11
2	2002	33448.00	27.81	38.98
3	2004	52020.00	38.00	47.70
4	2005	47710.00	50.25	59.80
5	1993	8017.00	20.66	36.65
6	1992	13870.00	21.00	38.11
7	2003	24316.00	31.00	42.36
8	1994	5142.00	23.30	40.26
9	1993	3027.00	18.00	31.93
10	1998	62.00	100.00	156.73
11	1999	5770.00	25.00	38.35
12	1999	35770.00	29.30	44.95
13	1995	14225.00	19.85	33.28
14	1996	5176.00	27.08	44.32
15	1997	2023.00	36.00	57.57
16	2000	6650.00	36.00	53.72
17	1992	616.00	26.00	47.19
18	2004	17543.00	35.20	44.19
19	1998	14005.00	28.00	43.89
20	2006	1703.00	77.95	86.80
21	1993	2804.00	26.00	46.12
22	1994	3721.00	19.30	33.35
23	1996	3290.00	27.00	44.20
24	1992	1261.00	25.00	45.37
25	1993	286.00	35.75	63.41
26	2004	7485.00	39.00	48.96
27	2003	5345.00	40.38	55.19
28	1993	47017.00	21.50	38.14
29	1995	15150.00	26.30	44.09
30	1997	13599.00	26.40	42.22
31	1997	13780.00	30.00	47.98
32	2002	27206.00	25.80	36.16
33	1998	21887.00	24.48	38.37
34	1993	48697.00	20.30	36.01
35	2005	165.00	60.00	71.40
36	1992	15300.00	23.00	41.74
37	2002	1050.00	102.00	142.97
38	2002	1050.00	133.53	187.17
39	1997	2462.00	33.60	53.74

SN	Year	Quantity (TON)	Bid ($/TON)	Bid 08 ($/CY)
40	1997	8030.00	24.30	38.86
41	1996	2844.00	22.50	36.83
42	1996	8685.00	24.64	40.34
43	1997	27878.00	26.00	41.58
44	1999	41411.00	23.00	35.28
45	1996	13610.00	32.70	53.53
46	2001	11180.00	29.00	41.82
47	1998	12795.00	23.00	36.05
48	2002	2800.00	28.03	39.29
49	1993	1825.00	24.50	43.46
50	1995	9855.00	24.25	40.66
51	2005	275.00	45.59	54.25
52	2000	10978.00	30.00	44.76
53	1998	252.00	57.75	90.51
54	1992	83.00	80.00	145.19
55	2000	270.00	73.24	109.28
56	2005	8108.00	33.05	39.33
57	1997	4918.00	50.00	79.96
58	1991	216.00	50.00	93.18
59	1999	8542.00	32.40	49.70
60	1993	1382.00	22.00	39.02
61	1999	7840.00	24.25	37.20
62	2000	20548.00	34.66	51.72
63	1998	21887.00	24.48	38.37
64	2000	10583.00	36.25	54.09
65	2005	49113.00	54.66	65.04
66	1993	20765.00	20.00	35.48
67	2005	28559.00	37.00	44.03
68	1993	431.00	42.40	75.21
69	1999	616.00	52.00	79.77
70	1993	45800.00	22.15	39.29
71	1993	241.00	40.00	70.95
72	2001	7670.00	26.00	37.49
73	2005	10915.00	39.00	46.41
74	2004	1561.00	45.20	56.74
75	2003	15975.00	30.70	41.96
76	2004	20050.00	34.00	42.68
77	2003	5465.00	32.77	44.79
78	2000	10179.00	35.67	53.23
79	2001	9902.00	40.08	57.79
80	1994	11801.00	23.95	41.38

SN	Year	Quantity (TON)	Bid ($/TON)	Bid 08 ($/CY)
81	1999	15570.00	26.65	40.88
82	1998	12930.00	25.00	39.18
83	2005	3299.00	50.00	59.50
84	2002	13400.00	36.26	50.82
85	2003	4009.00	32.39	44.27
86	2006	23300.00	65.00	72.38
87	2005	1781.00	49.00	58.31
88	1995	550.00	38.50	64.55
89	2001	26152.00	26.00	37.49
90	2000	110.00	73.00	108.93
91	1992	30761.00	22.05	40.02
92	1996	27808.00	23.20	37.98
93	1997	1143.00	34.00	54.38
94	1997	4890.00	22.50	35.98
95	1992	810.00	34.90	63.34
96	1999	9500.00	24.00	36.82
97	2000	14500.00	36.00	53.72
98	1995	29340.00	23.75	39.82
99	2005	7217.00	44.69	53.18
100	1998	13334.00	23.46	36.77
101	2004	25619.00	33.17	41.64
102	2004	5270.00	40.00	50.22
103	1995	26135.00	23.70	39.73
104	2000	33751.00	27.00	40.29
105	1992	6333.00	20.20	36.67
106	1999	885.00	41.69	63.95
107	2003	1162.00	51.00	69.70
108	1996	12606.00	29.00	47.47
109	1994	66228.00	19.00	32.83
110	2001	53410.00	35.47	51.15
111	2001	43625.00	32.00	46.15
112	1992	14648.00	22.64	41.09
113	1992	13388.00	23.50	42.65
114	2002	26610.00	30.00	42.05
115	2002	23553.00	27.34	38.33
116	2004	17511.00	32.55	40.86
117	1999	43500.00	24.48	37.55
118	2005	37986.00	33.54	39.91
119	1998	67000.00	27.54	43.16
120	2003	7826.00	41.13	56.21
121	2005	36132.00	28.00	33.32

SN	Year	Quantity (TON)	Bid ($/TON)	Bid 08 ($/CY)
122	1997	21400.00	31.90	51.02
123	1998	55138.00	29.25	45.84
124	1996	41959.00	24.43	39.99
125	1995	34270.00	22.40	37.56
126	2000	6852.00	28.17	42.03
127	1999	12704.00	23.00	35.28
128	1996	307.00	44.00	72.03
129	1993	7700.00	27.40	48.60
130	1995	2991.00	22.80	38.23
131	2002	22800.00	30.00	42.05
132	2000	37534.00	33.60	50.14
133	1999	37194.00	32.60	50.01
134	2004	7384.00	38.50	48.33
135	1999	23214.00	33.00	50.62
136	1994	2543.00	24.00	41.47

Table H-4. Data for Plantmix Bituminous Open Graded Surface (3/4”) (n = 61)

SN	Year	Quantity (SY)	Bid ($/SY)	Bid 08 ($/SY)
1	2003	46486.00	2.15	2.94
2	1993	3001.28	6.62	11.75
3	1992	2363.00	26.00	47.19
4	2003	32928.00	2.09	2.86
5	1994	4351.67	7.36	12.72
6	1999	56350.00	1.90	2.91
7	1995	50729.00	1.30	2.18
8	1996	9700.00	2.06	3.37
9	2000	3701.20	10.78	16.08
10	2004	68265.00	1.85	2.32
11	1998	38191.00	2.20	3.45
12	1996	1977.00	31.50	51.57
13	2003	22520.00	2.08	2.84
14	1993	25817.10	8.68	15.39
15	1995	44458.00	1.70	2.85
16	2002	154944.00	1.30	1.82
17	1993	28247.79	6.31	11.19
18	1992	69268.00	1.50	2.72
19	1996	16832.28	8.94	14.63
20	1995	28246.00	1.30	2.18
21	1998	578.00	9.75	15.28

SN	Year	Quantity (SY)	Bid ($/SY)	Bid 08 ($/SY)
22	1997	2267.13	19.72	31.53
23	1999	29041.00	2.30	3.53
24	2005	30712.72	14.27	16.98
25	1993	10943.83	25.00	44.35
26	1993	44914.00	1.40	2.48
27	1993	12317.04	7.07	12.54
28	2001	113868.00	1.50	2.16
29	2004	34801.00	2.20	2.76
30	2004	103021.00	1.50	1.88
31	2000	42200.00	1.65	2.46
32	2001	34090.00	2.66	3.84
33	1999	8939.17	7.83	12.01
34	1998	45265.00	1.60	2.51
35	2005	17288.00	3.00	3.57
36	2002	43100.00	2.20	3.08
37	2003	24873.00	1.70	2.32
38	2001	55456.00	1.35	1.95
39	1992	18194.07	6.56	11.91
40	1997	6550.00	2.90	4.64
41	2000	26500.00	2.50	3.73
42	1995	13191.94	7.89	13.22
43	2004	32690.00	3.00	3.77
44	1995	12214.34	7.89	13.22
45	2000	96776.00	1.96	2.92
46	1992	5382.52	6.24	11.33
47	1994	37152.73	8.15	14.08
48	2001	214894.00	2.00	2.88
49	2001	70705.00	1.75	2.52
50	2002	1704.00	2.00	2.80
51	1999	134300.00	1.36	2.09
52	2005	100760.00	2.10	2.50
53	1997	9129.37	10.83	17.32
54	1998	22663.66	9.52	14.92
55	2000	32184.00	1.98	2.95
56	1993	13000.00	1.75	3.10
57	2002	22000.00	2.10	2.94
58	2000	104952.00	2.10	3.13
59	1999	104023.00	2.06	3.16
60	2004	32028.00	2.27	2.85
61	1999	51245.00	1.70	2.61

Table H-5. Data for Prime Coat (n = 62)

SN	Year	Quantity (TON)	Bid ($/TON)	Bid 08 ($/TON)
1	2002	173.00	310.00	434.53
2	2005	60.00	600.00	713.98
3	1993	51.00	226.80	402.31
4	1992	54.00	250.00	453.72
5	1994	23.00	350.00	604.79
6	1993	17.00	205.00	363.64
7	1999	33.00	151.52	232.43
8	1997	13.00	490.00	783.65
9	2004	38.00	342.00	429.34
10	1998	3.00	480.00	752.32
11	2006	9.00	1500.00	1670.37
12	1993	11.00	225.00	399.12
13	1994	21.00	292.00	504.57
14	1992	11.00	260.00	471.87
15	1993	3.00	250.00	443.46
16	1993	1.00	500.00	886.92
17	1997	6.00	356.00	569.35
18	1998	55.00	252.63	395.96
19	1993	1.00	600.00	1064.31
20	2002	9.00	561.11	786.51
21	2002	9.00	1133.33	1588.60
22	1997	34.00	303.69	485.69
23	1999	276.00	240.00	368.16
24	2001	38.00	307.00	442.71
25	2002	24.00	276.14	387.07
26	1993	1.00	600.00	1064.31
27	2000	38.00	360.00	537.17
28	1992	0.53	800.00	1451.91
29	2005	69.00	300.02	357.02
30	2001	85.00	280.15	403.99
31	1999	24.00	287.00	440.26
32	1993	9.00	250.00	443.46
33	1999	33.00	252.58	387.46
34	2000	30.00	303.26	452.51
35	1998	55.00	252.63	395.96
36	2000	43.00	302.97	452.07
37	1993	7.00	275.00	487.81
38	1999	3.00	1500.00	2301.02
39	1993	1.00	500.00	886.92

SN	Year	Quantity (TON)	Bid ($/TON)	Bid 08 ($/TON)
40	2001	1.00	300.00	432.61
41	2005	2.00	350.00	416.49
42	1994	17.00	330.00	570.23
43	2005	10.00	480.00	571.19
44	2001	6.00	265.00	382.14
45	1996	72.00	300.00	491.11
46	1997	5.00	360.00	575.74
47	1997	21.00	285.00	455.80
48	1992	7.00	280.00	508.17
49	2005	52.00	1.00	1.19
50	2000	96.00	150.00	223.82
51	1994	33.00	340.00	587.51
52	2002	154.00	277.61	389.13
53	2004	149.00	1.00	1.26
54	2002	297.00	1.07	1.50
55	2005	0.80	573.34	682.26
56	1996	49.00	296.00	484.56
57	1995	12.00	300.00	502.97
58	2000	15.00	303.13	452.31
59	1999	9.00	508.44	779.95
60	1996	38.00	500.00	818.51
61	1995	3.00	400.00	670.63
62	1994	22.00	300.00	518.39

Table H-6. Data for Tack Coat (n = 38)

SN	Year	Quantity (TON)	Bid ($/TON)	Bid 08 ($/TON)
1	2003	39.00	323.57	442.21
2	2004	20.00	330.00	414.28
3	2005	20.00	300.00	356.99
4	1993	24.00	201.60	357.61
5	1992	15.00	200.00	362.98
6	1994	13.00	213.00	368.06
7	2004	52.00	2.00	2.51
8	1998	57.00	226.00	354.22
9	2006	1.00	1500.00	1670.37
10	1996	21.00	210.00	343.77
11	1993	142.00	190.00	337.03
12	1997	42.00	172.00	275.08
13	1993	45.00	230.00	407.98
14	2001	16.00	258.00	372.05

SN	Year	Quantity (TON)	Bid ($/TON)	Bid 08 ($/TON)
15	1998	15.00	358.91	562.53
16	1993	2.00	330.00	585.37
17	1995	24.00	245.00	410.76
18	2000	15.00	290.00	432.72
19	1999	13.00	225.00	345.15
20	1999	3.00	227.35	348.76
21	1993	19.00	250.00	443.46
22	1993	98.00	220.00	390.25
23	2001	56.00	196.43	283.26
24	2005	38.00	350.00	416.49
25	2003	17.00	255.00	348.50
26	2001	42.00	180.00	259.57
27	1996	54.00	250.00	409.26
28	1997	3.00	350.00	559.75
29	1995	69.00	300.00	502.97
30	2000	81.00	100.00	149.21
31	1994	103.00	250.00	431.99
32	1999	51.00	251.17	385.30
33	1996	74.00	216.00	353.60
34	1995	92.00	207.00	347.05
35	2000	25.00	303.13	452.31
36	1999	18.00	345.98	530.74
37	1996	52.00	300.00	491.11
38	1993	6.00	210.00	372.51

Table H-7. Data for Seal Coat (n = 64)

SN	Year	Quantity (TON)	Bid ($/TON)	Bid 08 ($/TON)
1	2003	87.00	323.57	442.21
2	2002	73.00	270.00	378.46
3	2004	60.00	360.00	451.94
4	2005	60.00	300.00	356.99
5	1993	33.00	252.00	447.01
6	1992	10.00	200.00	362.98
7	1994	3.00	282.00	487.29
8	1993	7.00	150.00	266.08
9	1999	14.00	255.00	391.17
10	1997	6.00	330.00	527.77
11	2004	2.00	323.00	405.49
12	1998	3.00	400.00	626.93
13	2006	4.00	1500.00	1670.37
14	1993	5.00	320.00	567.63

SN	Year	Quantity (TON)	Bid ($/TON)	Bid 08 ($/TON)
15	1994	9.00	283.00	489.02
16	1993	2.00	250.00	443.46
17	1993	1.00	370.00	656.32
18	1997	6.00	216.00	345.45
19	1998	64.00	252.63	395.96
20	2002	4.00	600.00	841.03
21	2002	4.00	836.88	1173.06
22	1997	14.00	253.08	404.75
23	1996	10.00	206.20	337.55
24	1999	116.00	208.00	319.07
25	2001	16.00	280.00	403.77
26	1998	15.00	231.50	362.84
27	2002	10.00	275.85	386.66
28	1993	3.00	270.00	478.94
29	2000	16.00	290.00	432.72
30	2003	6.00	355.00	485.17
31	1992	0.23	600.00	1088.93
32	2005	29.00	299.04	355.85
33	2001	36.00	281.38	405.76
34	1993	4.00	200.00	354.77
35	1999	14.00	227.32	348.71
36	2000	65.00	270.57	403.73
37	1998	64.00	252.63	395.96
38	1993	3.00	350.00	620.85
39	1993	1.00	220.00	390.25
40	2001	1.00	200.00	288.41
41	2003	57.00	265.00	362.17
42	1994	39.00	260.00	449.27
43	2005	4.00	380.00	452.19
44	2001	18.00	180.00	259.57
45	1996	53.00	250.00	409.26
46	1997	9.00	225.00	359.84
47	1992	3.00	250.00	453.72
48	1995	2.00	208.00	348.73
49	2005	24.00	1.00	1.19
50	1999	4.00	550.00	843.71
51	2003	4.00	450.00	615.00
52	1997	1.50	300.00	479.79
53	1994	1.00	500.00	863.98
54	2002	65.00	277.61	389.13
55	2004	63.00	1.00	1.26

SN	Year	Quantity (TON)	Bid ($/TON)	Bid 08 ($/TON)
56	2002	125.00	1.07	1.50
57	1999	56.00	226.05	346.76
58	2005	5.30	573.34	682.26
59	1996	20.00	218.00	356.87
60	1995	7.00	213.00	357.11
61	2000	0.50	606.26	904.63
62	1999	6.00	369.05	566.13
63	1995	5.00	200.00	335.32
64	1994	9.00	256.00	442.36

Table H-8. Concrete Sidewalk (*n* = 58)

SN	Year	Quantity (SF)	Bid ($/SF)	Bid 08 ($/SF)
1	1993	46836.00	1.66	2.94
2	1992	56531.00	1.68	3.05
3	2003	33865.00	2.48	3.39
4	1994	22967.00	1.75	3.02
5	1995	14131.00	1.85	3.10
6	2000	9525.00	2.00	2.98
7	1998	6245.00	2.50	3.92
8	2003	18346.00	3.33	4.55
9	1993	11020.00	1.62	2.87
10	1995	30520.00	1.68	2.82
11	1997	37068.00	2.30	3.68
12	1997	355.21	6.97	11.14
13	1993	58744.00	1.54	2.73
14	1992	5242.00	1.60	2.90
15	2004	1267.00	7.00	8.79
16	1996	46050.00	1.75	2.86
17	2001	13616.00	2.40	3.46
18	1995	7655.00	2.50	4.19
19	2005	12360.00	3.55	4.22
20	1992	1604.00	5.00	9.07
21	1997	14131.00	4.00	6.40
22	1999	20050.00	2.00	3.07
23	1993	6892.00	2.00	3.55
24	1999	32622.00	2.43	3.73
25	2000	5234.00	3.11	4.64
26	1993	14810.00	1.73	3.07
27	2005	8353.00	4.00	4.76
28	1999	3605.00	2.40	3.68
29	1993	65675.00	1.60	2.84

SN	Year	Quantity (SF)	Bid ($/SF)	Bid 08 ($/SF)
30	2001	27636.00	2.40	3.46
31	2005	14612.00	4.10	4.88
32	2004	27000.00	3.00	3.77
33	2003	5331.00	3.56	4.87
34	2002	28610.00	3.00	4.21
35	2003	2048.00	4.12	5.63
36	1995	590.00	3.50	5.87
37	2001	17996.00	2.70	3.89
38	2000	1094.00	7.40	11.04
39	1992	71500.00	1.49	2.70
40	1996	3615.00	2.42	3.96
41	1999	27000.00	2.00	3.07
42	2000	5065.00	2.80	4.18
43	1998	5715.00	2.44	3.83
44	2004	2800.00	3.90	4.90
45	1995	25847.00	1.95	3.27
46	1992	5900.00	2.20	3.99
47	1994	89755.00	2.00	3.46
48	2002	54310.00	2.50	3.50
49	1999	59468.00	2.06	3.16
50	2005	14434.00	3.93	4.68
51	1996	97880.00	1.85	3.03
52	1995	64800.00	1.74	2.92
53	2000	11389.00	2.71	4.04
54	1999	56619.00	2.31	3.54
55	1993	14320.00	2.05	3.64
56	1995	3295.00	2.10	3.52
57	2002	4250.00	3.20	4.49
58	1994	22557.00	1.80	3.11

Table H-9. Data for Concrete Valley Gutter (n = 39)

SN	Year	Quantity (SF)	Bid ($/SF)	Bid 08 ($/SF)
1	1993	4840.00	3.54	6.28
2	1992	6474.00	3.82	6.93
3	2003	2323.00	6.62	9.05
4	1994	3478.00	4.40	7.60
5	1995	3834.00	4.35	7.29
6	1997	320.00	9.00	14.39
7	1998	2800.00	6.10	9.56
8	1993	1162.00	4.25	7.54

SN	Year	Quantity (SF)	Bid ($/SF)	Bid 08 ($/SF)
9	1995	4001.00	4.40	7.38
10	1997	1847.00	5.60	8.96
11	2002	10283.00	6.40	8.97
12	1993	3582.00	4.00	7.10
13	1992	2349.00	4.15	7.53
14	2005	71.00	14.08	16.75
15	2000	487.00	4.00	5.97
16	1992	403.00	8.00	14.52
17	1997	3865.00	6.00	9.60
18	1993	1120.00	4.55	8.07
19	2000	490.00	8.31	12.40
20	2005	8409.00	8.00	9.52
21	1993	1272.00	1.25	2.22
22	2001	3546.00	6.40	9.23
23	2005	3230.00	7.50	8.92
24	2004	8482.00	8.00	10.04
25	1994	580.00	5.30	9.16
26	2003	1349.00	8.45	11.55
27	2001	5042.00	6.70	9.66
28	1992	808.00	4.25	7.71
29	1999	14952.00	5.00	7.67
30	1995	2602.00	4.75	7.96
31	1995	3963.00	5.00	8.38
32	1992	6510.00	4.30	7.80
33	1994	2280.00	4.00	6.91
34	2002	7954.00	8.50	11.91
35	1999	11500.00	5.69	8.73
36	2005	10485.00	7.55	8.98
37	1996	14061.00	5.15	8.43
38	1995	1390.00	4.60	7.71
39	1999	555.00	6.19	9.50

Table H-10. Data for Type “L” Curb and Gutter (n = 65)

SN	Year	Quantity (LF)	Bid ($/LF)	Bid 08 ($/LF)
1	1993	13059.00	4.62	8.20
2	1992	14991.00	5.10	9.26
3	1994	4881.00	6.05	10.45
4	1998	158.00	14.00	21.94
5	1995	2579.00	6.50	10.90
6	1997	4147.00	10.39	16.61
7	1992	466.00	6.75	12.25

SN	Year	Quantity (LF)	Bid ($/LF)	Bid 08 ($/LF)
8	1998	1645.00	7.90	12.38
9	2006	88.00	32.00	35.63
10	1993	635.00	8.60	15.26
11	2004	2446.00	11.50	14.44
12	2003	4013.00	12.32	16.84
13	1993	17053.00	5.07	8.99
14	1995	4431.00	6.40	10.73
15	1997	6507.00	6.10	9.76
16	1997	85.28	19.82	31.69
17	2002	10359.00	7.20	10.09
18	1993	12482.00	4.48	7.95
19	1992	14870.00	4.35	7.89
20	2004	199.00	35.00	43.94
21	1996	8537.00	6.00	9.82
22	2001	2200.00	8.80	12.69
23	2002	767.00	18.12	25.40
24	1995	289.00	16.00	26.83
25	2005	2475.00	14.50	17.25
26	2000	597.00	18.00	26.86
27	1992	286.00	20.00	36.30
28	1997	2300.00	7.00	11.20
29	1999	4275.00	7.40	11.35
30	1993	1701.00	6.00	10.64
31	1999	4269.00	7.09	10.88
32	2000	594.00	9.46	14.12
33	1993	2553.00	5.40	9.58
34	2005	13794.00	9.90	11.78
35	1999	725.00	12.00	18.41
36	1993	13720.00	4.80	8.51
37	2001	5251.00	7.40	10.67
38	2005	3002.00	7.40	8.81
39	2004	6692.00	10.45	13.12
40	2003	2055.00	10.78	14.73
41	1994	1094.00	6.60	11.40
42	2002	7860.00	8.00	11.21
43	2003	2009.00	9.94	13.58
44	1995	118.00	15.00	25.15
45	2001	3322.00	8.20	11.82
46	2000	296.00	22.00	32.83
47	1992	13520.00	4.10	7.44
48	1996	1723.00	9.35	15.31

SN	Year	Quantity (LF)	Bid ($/LF)	Bid 08 ($/LF)
49	1999	4736.00	6.00	9.20
50	2000	1920.00	8.00	11.94
51	1995	14710.00	6.93	11.62
52	2004	600.00	14.50	18.20
53	2004	2093.00	11.00	13.81
54	1994	18469.00	7.00	12.10
55	2002	10289.00	9.05	12.69
56	1999	9637.00	5.31	8.15
57	2005	17874.00	9.92	11.80
58	1996	18889.00	6.40	10.48
59	1995	13344.00	5.80	9.72
60	2000	1413.00	9.17	13.68
61	1999	10000.00	6.15	9.43
62	1996	11860.00	6.00	9.82
63	1993	1560.00	5.85	10.38
64	1995	658.00	11.25	18.86
65	2002	1160.00	11.00	15.42

Table H-11. Data for Reflective Pavement Markers (n = 106)

SN	Year	Quantity (EA)	Bid ($/EA)	Bid 08 ($/EA)
1	2003	1882.00	2.37	3.24
2	2002	1555.00	2.35	3.29
3	2004	6204.00	1.40	1.76
4	2005	3412.00	2.42	2.88
5	1993	1380.00	2.36	4.19
6	1992	2062.00	2.35	4.26
7	2003	1384.00	2.07	2.83
8	1994	820.00	2.25	3.89
9	1993	584.00	2.30	4.08
10	1999	3645.00	2.35	3.60
11	1995	1150.00	2.20	3.69
12	1996	299.00	2.60	4.26
13	1997	324.00	3.50	5.60
14	2000	1029.00	2.50	3.73
15	2004	1536.00	1.45	1.82
16	1998	1357.00	2.33	3.65
17	1993	426.00	3.00	5.32
18	1994	1104.00	2.40	4.15
19	1996	1105.00	2.42	3.96
20	1992	146.00	2.55	4.63

SN	Year	Quantity (EA)	Bid ($/EA)	Bid 08 ($/EA)
21	1993	26.00	2.90	5.14
22	2004	580.00	2.60	3.26
23	2003	835.00	2.65	3.62
24	1993	4700.00	2.00	3.55
25	1995	1190.00	2.68	4.49
26	1997	1568.00	2.75	4.40
27	1997	1321.00	2.00	3.20
28	2002	3171.00	2.55	3.57
29	1998	862.00	2.29	3.59
30	2005	170.00	3.00	3.57
31	1992	1378.00	2.30	4.17
32	2004	24.00	3.00	3.77
33	1997	735.00	3.16	5.05
34	1996	194.00	2.75	4.50
35	1997	991.00	2.37	3.79
36	1999	1649.00	2.20	3.37
37	1996	2650.00	2.20	3.60
38	2001	1234.00	2.70	3.89
39	1998	906.00	2.39	3.75
40	1995	741.00	2.33	3.91
41	2000	1134.00	2.97	4.43
42	1998	295.00	2.15	3.37
43	2000	60.00	2.00	2.98
44	1997	441.00	2.00	3.20
45	1999	779.00	2.70	4.14
46	1999	1022.00	2.39	3.67
47	2000	82.00	3.18	4.75
48	1998	862.00	2.29	3.59
49	2000	3113.00	2.86	4.27
50	1993	1452.00	2.40	4.26
51	1993	867.00	2.75	4.88
52	1993	16.00	3.30	5.85
53	1993	2392.00	2.20	3.90
54	2001	2966.00	2.70	3.89
55	2005	1640.00	2.35	2.80
56	2004	1305.00	1.25	1.57
57	2004	2614.00	1.45	1.82
58	2003	449.00	2.37	3.24
59	2000	509.00	2.00	2.98
60	2001	1718.00	2.66	3.84
61	1994	312.00	2.55	4.41

SN	Year	Quantity (EA)	Bid ($/EA)	Bid 08 ($/EA)
62	1999	1789.00	2.24	3.44
63	1998	1546.00	2.30	3.60
64	2005	570.00	1.95	2.32
65	2002	1700.00	2.90	4.06
66	2003	619.00	2.48	3.39
67	2005	74.00	2.50	2.97
68	1995	146.00	2.75	4.61
69	2001	2362.00	2.50	3.61
70	2000	219.00	3.00	4.48
71	1996	1744.00	2.50	4.09
72	1992	88.00	2.60	4.72
73	1999	725.00	3.00	4.60
74	1995	2430.00	2.45	4.11
75	2005	850.00	2.00	2.38
76	2004	2131.00	1.45	1.82
77	2004	875.00	2.00	2.51
78	1995	1523.00	2.35	3.94
79	2000	2608.00	2.84	4.24
80	1992	796.00	2.35	4.26
81	1996	1110.00	2.40	3.93
82	2001	2238.00	3.01	4.34
83	2001	2766.00	3.00	4.33
84	1992	120.00	2.40	4.36
85	2002	1810.00	2.50	3.50
86	2002	1101.00	2.95	4.14
87	1999	1743.00	2.59	3.97
88	2005	3589.00	2.01	2.39
89	1998	3221.00	2.27	3.56
90	2003	2452.00	2.84	3.88
91	2005	2667.00	2.20	2.62
92	1997	2953.00	2.57	4.11
93	1998	1780.00	2.66	4.17
94	1996	1983.00	2.53	4.14
95	1995	2290.00	2.40	4.02
96	2000	615.00	3.00	4.48
97	1999	946.00	2.81	4.31
98	1996	4428.00	4.50	7.37
99	1998	378.00	2.52	3.95
100	1996	199.00	2.75	4.50
101	1993	475.00	2.40	4.26
102	2002	1910.00	3.20	4.49

SN	Year	Quantity (EA)	Bid ($/EA)	Bid 08 ($/EA)
103	2000	2285.00	2.17	3.24
104	1999	3565.00	2.26	3.47
105	2004	884.00	2.44	3.06
106	1999	846.00	2.40	3.68

Table H-12. Data for Non-reflective Pavement Markers (n = 107)

SN	Year	Quantity (EA)	Bid ($/EA)	Bid 08 ($/EA)
1	2003	5229.00	1.00	1.37
2	2002	4527.00	1.18	1.65
3	2004	16477.00	0.85	1.07
4	2005	8421.00	1.21	1.44
5	1993	3734.00	1.34	2.38
6	1992	5704.00	1.31	2.38
7	1994	2502.00	1.20	2.07
8	1993	1752.00	1.30	2.31
9	1999	10195.00	1.30	1.99
10	1995	3075.00	1.15	1.93
11	1996	610.00	1.55	2.54
12	1997	781.00	2.00	3.20
13	2000	3087.00	1.50	2.24
14	2004	4123.00	0.88	1.10
15	1998	3673.00	1.17	1.83
16	1993	901.00	2.00	3.55
17	1994	3174.00	1.40	2.42
18	1996	3223.00	1.32	2.16
19	1992	584.00	1.50	2.72
20	1993	104.00	1.70	3.02
21	2004	1529.00	1.05	1.32
22	2003	1549.00	1.59	2.17
23	1993	13500.00	1.00	1.77
24	1995	2270.00	1.60	2.68
25	1997	4192.00	1.65	2.64
26	1997	2841.00	2.00	3.20
27	2002	8004.00	1.25	1.75
28	1998	2513.00	1.25	1.96
29	2005	510.00	2.00	2.38
30	1992	4514.00	1.15	2.09
31	2004	60.00	1.50	1.88
32	1997	2203.00	2.01	3.21
33	1996	776.00	1.65	2.70
34	1997	2897.00	1.30	2.08

SN	Year	Quantity (EA)	Bid ($/EA)	Bid 08 ($/EA)
35	1999	5009.00	1.20	1.84
36	1996	7100.00	1.10	1.80
37	2001	3311.00	1.34	1.93
38	1998	2970.00	1.33	2.08
39	1995	1915.00	1.22	2.05
40	2000	3331.00	1.79	2.67
41	1998	830.00	1.10	1.72
42	2000	120.00	1.62	2.42
43	1997	1323.00	1.00	1.60
44	1999	2114.00	1.60	2.45
45	1999	2842.00	1.33	2.04
46	2000	246.00	2.12	3.16
47	1998	2513.00	1.25	1.96
48	2000	6930.00	1.20	1.79
49	1993	3978.00	1.35	2.39
50	2005	7191.00	1.20	1.43
51	1993	1968.00	1.65	2.93
52	1993	42.00	2.20	3.90
53	1993	6645.00	1.15	2.04
54	2001	7990.00	2.30	3.32
55	2005	4360.00	1.30	1.55
56	2004	3041.00	1.05	1.32
57	2004	5633.00	0.90	1.13
58	2003	853.00	1.27	1.74
59	2000	890.00	1.50	2.24
60	2001	4807.00	1.60	2.31
61	1994	1387.00	1.45	2.51
62	1999	3119.00	1.28	1.96
63	1998	3778.00	1.20	1.88
64	2005	1585.00	1.30	1.55
65	2002	3600.00	1.50	2.10
66	2003	1658.00	1.21	1.65
67	2005	198.00	1.40	1.67
68	1995	431.00	1.75	2.93
69	2001	6423.00	1.25	1.80
70	2000	281.00	1.40	2.09
71	1996	3681.00	1.40	2.29
72	1992	240.00	1.50	2.72
73	1999	1925.00	2.00	3.07
74	1995	6800.00	1.38	2.31
75	2005	2458.00	1.35	1.61

SN	Year	Quantity (EA)	Bid ($/EA)	Bid 08 ($/EA)
76	2004	1749.00	0.90	1.13
77	2004	1881.00	1.00	1.26
78	1995	3717.00	1.30	2.18
79	2000	7322.00	1.60	2.39
80	1992	1940.00	1.35	2.45
81	1996	3500.00	1.30	2.13
82	1994	5580.00	4.00	6.91
83	2001	5614.00	1.42	2.05
84	2001	5603.00	1.50	2.16
85	1992	360.00	1.35	2.45
86	2002	4086.00	1.50	2.10
87	2002	3076.00	1.19	1.67
88	1999	3885.00	1.55	2.38
89	2005	9403.00	1.25	1.49
90	1998	8690.00	1.19	1.87
91	2003	5815.00	1.34	1.83
92	2005	6706.00	1.48	1.76
93	1997	1722.00	1.54	2.46
94	1998	3857.00	1.60	2.51
95	1996	5242.00	1.43	2.34
96	1995	6452.00	1.33	2.23
97	2000	1715.00	1.42	2.12
98	1999	2482.00	1.69	2.59
99	1996	11482.00	3.00	4.91
100	1998	950.00	1.40	2.19
101	1996	525.00	1.65	2.70
102	1993	1300.00	1.35	2.39
103	2002	5200.00	1.70	2.38
104	2000	5735.00	1.11	1.66
105	1999	7731.00	1.18	1.81
106	2004	2134.00	1.01	1.27
107	1999	2184.00	1.45	2.22

Table H-13. Data for Quality Control (n = 78)

SN	Year	% of Bid Cost	Bid Cost ($)	Bid Cost 08 ($)
1	2003	4.74	3162194.15	4321665.34
2	2002	5.12	1757651.00	2463715.93
3	2004	4.63	4069782.00	5109176.57
4	2005	4.37	5392070.00	6416421.03
5	2003	3.42	4389372.21	5998808.69
6	2002	1.87	1607900.00	2253808.55

SN	Year	% of Bid Cost	Bid Cost ($)	Bid Cost 08 ($)
7	1998	4.25	94074.32	147445.76
8	1999	5.25	415012.86	636635.37
9	1999	1.57	9568470.38	14678163.75
10	2000	3.30	7265265.00	10840808.98
11	2004	4.78	3451154.00	4332555.20
12	1998	2.05	1681215.53	2635024.17
13	2006	4.76	1979979.00	2204865.50
14	2004	7.31	967090.00	1214078.19
15	2003	2.77	5107209.00	6979852.30
16	2002	4.87	5138230.65	7202306.21
17	1998	0.78	1381848.75	2165816.81
18	2005	6.23	570000.00	678284.96
19	2002	2.89	346295.00	485404.96
20	2004	2.83	353971.65	444373.60
21	2002	6.02	415567.18	582504.42
22	1999	0.95	1579186.97	2422494.30
23	2001	5.00	1499000.00	2161627.50
24	1998	2.44	954908.59	1496659.51
25	2002	6.63	301749.25	422964.76
26	2005	10.34	241700.00	287616.62
27	2000	0.25	806404.00	1203269.49
28	2003	3.93	375991.00	513854.37
29	2000	5.46	366554.00	546950.72
30	2001	13.37	374042.73	539386.96
31	1999	2.42	1817614.45	2788245.30
32	1999	2.81	1046233.13	1604935.86
33	2000	4.79	1356378.93	2023910.33
34	1998	0.78	1381848.75	2165816.81
35	2000	5.04	1983741.02	2960023.82
36	2005	1.91	12326412.67	14668105.84
37	2005	2.81	7553178.60	8988083.24
38	1999	2.54	197014.00	302222.16
39	2001	5.38	1858981.95	2680738.16
40	2005	5.56	2540000.00	3022532.98
41	2004	6.22	1515611.20	1902687.96
42	2003	9.22	1409939.00	1926916.63
43	2004	2.60	9048811.75	11359816.56
44	2003	2.17	4618921.00	6312525.37
45	2000	2.44	7367367.00	10993159.69
46	2001	4.19	8346355.73	12035831.92
47	1999	1.30	1999948.00	3067947.44

SN	Year	% of Bid Cost	Bid Cost ($)	Bid Cost 08 ($)
48	1998	0.92	2798757.60	4386584.46
49	2005	3.08	11048109.00	13146958.20
50	2002	4.14	10868888.00	15235022.50
51	2003	3.78	661724.00	904356.13
52	2001	5.86	5100904.95	7355741.43
53	2000	8.71	229633.77	342646.25
54	1999	2.76	1703442.00	2613103.20
55	2000	0.62	17827513.00	26601185.65
56	2005	3.85	2445170.00	2909687.78
57	1998	1.40	2775317.72	4349846.37
58	2004	2.24	6661744.20	8363108.24
59	2004	3.47	9507073.00	11935114.61
60	2000	0.30	1654691.88	2469035.69
61	1999	7.72	103843.62	159297.53
62	2003	3.97	188854.00	258100.47
63	2001	4.60	21749072.82	31363171.36
64	2001	3.30	13635579.25	19663137.46
65	2002	4.62	5847510.00	8196509.74
66	2002	4.53	1765948.21	2475346.21
67	2004	9.76	1447468.00	1817141.46
68	1999	1.20	6281914.72	9636542.65
69	2005	1.90	8938552.79	10636641.97
70	2003	2.32	862405.00	1178620.17
71	2000	5.77	1126904.59	1681501.97
72	1999	3.27	1682066.79	2580313.34
73	2002	4.24	14875945.50	20851752.67
74	2000	0.60	18199683.95	27156517.66
75	1999	1.63	18627063.31	28574168.55
76	2004	2.32	10144655.70	12735531.58
77	1999	1.08	12077777.00	18527474.24
78	2005	1.22	245730.00	292412.22

Table H-14. Data for Traffic Control (n = 134)

SN	Year	% of Bid Cost	Bid Cost ($)	Bid Cost 08 ($)
1	2003	2.95	3162194.15	4321665.34
2	2002	2.68	1757651.00	2463715.93
3	2004	1.84	4069782.00	5109176.57
4	2005	1.76	5392070.00	6416421.03
5	1993	2.81	1100113.02	1951429.59
6	1992	1.07	2548301.80	4624885.76
7	2003	1.93	4389372.21	5998808.69

SN	Year	% of Bid Cost	Bid Cost ($)	Bid Cost 08 ($)
8	1994	2.37	1162025.05	2007943.67
9	2002	4.29	1607900.00	2253808.55
10	1993	9.84	153363.40	272042.85
11	1998	10.63	94074.32	147445.76
12	1999	2.98	415012.86	636635.37
13	1995	1.89	2320138.45	3889897.55
14	1996	1.01	5034450.72	8241514.61
15	1997	2.18	917381.00	1467158.98
16	2000	0.83	7265265.00	10840808.98
17	1992	1.66	63108.10	114534.22
18	2004	2.12	3451154.00	4332555.20
19	1998	1.72	1681215.53	2635024.17
20	2006	1.77	1979979.00	2204865.50
21	1993	1.02	393254.50	697572.39
22	1994	1.56	225247.81	389221.31
23	1996	5.13	672179.06	1100372.98
24	1992	2.01	74779.30	135716.15
25	1993	2.14	112104.50	198855.97
26	2004	3.62	967090.00	1214078.19
27	2003	1.11	5107209.00	6979852.30
28	1993	1.16	3436160.01	6095214.02
29	1995	0.64	4345730.68	7285964.82
30	1997	3.43	1816269.47	2904743.02
31	1997	0.56	1517517.00	2426950.95
32	2002	2.39	5138230.65	7202306.21
33	1998	3.10	1381848.75	2165816.81
34	1993	2.02	4695369.52	8328856.06
35	2005	5.09	570000.00	678284.96
36	1992	0.75	3276066.04	5945697.32
37	2002	6.06	346295.00	485404.96
38	2002	3.12	415567.18	582504.42
39	1997	9.53	202184.73	323352.17
40	1997	0.45	446896.22	714717.00
41	1996	8.66	167815.27	274717.56
42	1996	6.81	359861.14	589101.18
43	1997	1.16	1729715.39	2766317.88
44	1999	2.53	1579186.97	2422494.30
45	1996	5.28	6055923.75	9913690.06
46	2001	1.47	1499000.00	2161627.50
47	1998	1.18	954908.59	1496659.51
48	2002	2.47	301749.25	422964.76

SN	Year	% of Bid Cost	Bid Cost ($)	Bid Cost 08 ($)
49	1993	4.47	150050.00	266165.39
50	1995	2.58	774858.49	1299112.19
51	2005	5.17	241700.00	287616.62
52	2000	3.22	806404.00	1203269.49
53	2003	3.99	375991.00	513854.37
54	1998	6.71	1989641.05	3118429.59
55	1992	1.30	778080.00	1412129.09
56	2000	4.36	366554.00	546950.72
57	2005	2.82	885850.50	1054138.72
58	2001	4.35	374042.73	539386.96
59	1997	2.30	5866866.00	9382824.70
60	1991	11.89	88327.00	164609.41
61	1999	2.23	1817614.45	2788245.30
62	1993	2.91	258091.70	457814.58
63	1999	1.42	1046233.13	1604935.86
64	2000	4.58	1356378.93	2023910.33
65	1998	3.10	1381848.75	2165816.81
66	2000	3.30	1983741.02	2960023.82
67	1993	2.85	1806688.15	3204784.09
68	2005	4.14	7553178.60	8988083.24
69	1993	7.94	536054.75	950877.85
70	1993	4.44	107063.55	189914.10
71	1999	2.54	197014.00	302222.16
72	1993	1.22	2627448.15	4660684.82
73	2001	0.54	1858981.95	2680738.16
74	2005	3.54	2540000.00	3022532.98
75	2003	2.86	1409939.00	1926916.63
76	2004	3.25	9048811.75	11359816.56
77	2003	0.51	4618921.00	6312525.37
78	2000	4.07	7367367.00	10993159.69
79	2001	1.03	8346355.73	12035831.92
80	1994	2.19	684233.49	1182334.50
81	1999	2.50	1999948.00	3067947.44
82	1998	1.45	2798757.60	4386584.46
83	2002	2.21	10868888.00	15235022.50
84	2003	1.29	661724.00	904356.13
85	2005	2.29	393083.00	467758.40
86	1995	9.19	168698.15	282835.93
87	2001	3.14	5100904.95	7355741.43
88	2000	8.71	229633.77	342646.25
89	1992	2.14	2823247.33	5123881.47

SN	Year	% of Bid Cost	Bid Cost ($)	Bid Cost 08 ($)
90	1996	3.44	2904680.26	4755030.12
91	1997	1.77	197979.30	316626.47
92	1997	1.32	397692.20	636025.47
93	1992	0.28	163547.62	296820.83
94	1999	0.94	1703442.00	2613103.20
95	2000	0.42	17827513.00	26601185.65
96	1995	1.29	3268335.60	5479625.86
97	2005	0.76	2445170.00	2909687.78
98	1998	2.17	2775317.72	4349846.37
99	2004	2.79	6661744.20	8363108.24
100	2004	1.31	9507073.00	11935114.61
101	1995	1.81	2766942.05	4638999.50
102	2000	2.42	1654691.88	2469035.69
103	1992	3.36	802643.05	1456708.31
104	1999	7.85	103843.62	159297.53
105	2003	3.71	188854.00	258100.47
106	1997	2.27	44110.50	70545.52
107	1996	12.80	1813132.11	2968140.04
108	1994	1.97	7266000.00	12555425.29
109	2001	0.62	21749072.82	31363171.36
110	2001	0.07	13635579.25	19663137.46
111	1992	1.60	604559.55	1097208.68
112	1992	1.06	560434.34	1017126.31
113	2002	2.87	5847510.00	8196509.74
114	2002	2.37	1765948.21	2475346.21
115	2004	2.83	1447468.00	1817141.46
116	2002	3.73	976235.00	1368397.78
117	1999	0.72	6281914.72	9636542.65
118	2005	1.46	8938552.79	10636641.97
119	2003	9.43	862405.00	1178620.17
120	2005	1.70	41111111.00	48921137.36
121	1998	0.89	29284650.12	45898791.33
122	1995	2.89	2666042.97	4469834.12
123	2000	3.50	1126904.59	1681501.97
124	1999	5.12	1682066.79	2580313.34
125	1996	3.56	6316316.00	10339958.32
126	1998	2.68	394422.35	618191.07
127	1996	4.31	393086.72	643492.23
128	1993	1.25	1474874.35	2616197.96
129	1995	2.09	2008567.45	3367523.87
130	2002	0.27	14875945.50	20851752.67

SN	Year	% of Bid Cost	Bid Cost ($)	Bid Cost 08 ($)
131	1999	0.63	18627063.31	28574168.55
132	2004	0.92	10144655.70	12735531.58
133	1999	0.75	12077777.00	18527474.24
134	1994	1.67	654191.42	1130422.72

Table H-15. Data for Construction Conflicts and Additional works (*n* = 143)

SN	Year	% of Bid Cost	Bid Cost ($)	Bid Cost 08 ($)
1	2003	3.16	3162194.15	4667666.87
2	2002	2.84	1757651.00	2780470.37
3	2004	1.84	4069782.00	4689604.39
4	2005	1.39	5392070.00	5327873.51
5	1993	4.54	1100113.02	2399529.85
6	1992	1.96	2548301.80	3878462.65
7	2003	3.42	4389372.21	5768115.82
8	1994	3.01	1162025.05	2353223.83
9	2002	6.22	1607900.00	2262520.03
10	1993	6.52	153363.40	309147.77
11	1998	5.31	94074.32	110122.37
12	1999	3.61	415012.86	776016.37
13	1999	3.14	9568470.38	19775899.66
14	1995	10.78	2320138.45	4198495.05
15	1996	1.99	5034450.72	8903079.68
16	1997	10.90	917381.00	1395415.59
17	2000	2.75	7265265.00	12063164.84
18	1992	7.92	63108.10	168884.53
19	2004	4.35	3451154.00	3995697.68
20	1998	5.95	1681215.53	3093913.29
21	2006	2.53	1979979.00	1712373.46
22	1993	2.54	393254.50	789950.67
23	1994	4.44	225247.81	440181.36
24	1996	4.46	672179.06	1162300.50
25	1992	6.69	74779.30	141297.12
26	1993	8.92	112104.50	213454.71
27	2004	2.59	967090.00	1138471.19
28	2003	0.98	5107209.00	7239498.47
29	1993	1.46	3436160.01	6646944.87
30	1995	8.05	4345730.68	6915897.88
31	1997	3.30	1816269.47	2754181.03
32	1997	3.29	1517517.00	2634787.42
33	2002	2.92	5138230.65	10228068.85
34	1998	3.62	1381848.75	2073957.24

SN	Year	% of Bid Cost	Bid Cost ($)	Bid Cost 08 ($)
35	1993	2.13	4695369.52	8771441.79
36	2005	4.39	570000.00	589486.15
37	1992	3.05	3276066.04	7018060.36
38	2002	2.89	346295.00	568245.98
39	2004	8.48	353971.65	401602.79
40	2002	6.02	415567.18	590988.72
41	1997	12.36	202184.73	302977.64
42	1997	11.19	446896.22	888222.11
43	1996	5.96	167815.27	290863.73
44	1996	5.56	359861.14	601204.12
45	1997	2.31	1729715.39	2746781.12
46	1999	4.75	1579186.97	2873755.13
47	1996	3.30	6055923.75	7590859.17
48	2001	2.00	1499000.00	2242446.12
49	1998	2.09	954908.59	1670199.47
50	2002	9.94	301749.25	597053.35
51	1993	6.66	150050.00	268197.33
52	1995	3.23	774858.49	1396170.68
53	2005	4.14	241700.00	332752.32
54	2000	3.72	806404.00	1192335.39
55	2003	3.99	375991.00	437504.17
56	1998	10.05	1989641.05	3128071.74
57	1992	3.86	778080.00	1602541.84
58	2000	4.09	366554.00	522675.05
59	2005	5.64	885850.50	1088761.60
60	2001	9.36	374042.73	755100.54
61	1997	4.26	5866866.00	9802954.09
62	1991	11.32	88327.00	166517.77
63	1999	2.75	1817614.45	2875469.00
64	1993	3.87	258091.70	486474.23
65	1999	4.78	1046233.13	1890056.02
66	2000	3.69	1356378.93	1888533.74
67	1998	3.62	1381848.75	2073955.83
68	2000	5.04	1983741.02	2818427.47
69	2005	1.01	12326412.67	11657202.87
70	1993	8.30	1806688.15	3979026.21
71	2005	2.65	7553178.60	9432374.59
72	1993	4.66	536054.75	784644.12
73	1993	4.67	107063.55	178443.01
74	1999	7.61	197014.00	304521.18
75	1993	1.90	2627448.15	4800726.84

SN	Year	% of Bid Cost	Bid Cost ($)	Bid Cost 08 ($)
76	2001	5.38	1858981.95	3147702.98
77	2005	3.94	2540000.00	3009572.15
78	2004	6.60	1515611.20	1857255.41
79	2003	3.55	1409939.00	2172112.90
80	2004	3.32	9048811.75	11049016.67
81	2003	2.17	4618921.00	2519635.59
82	2000	4.07	7367367.00	12996241.31
83	2001	2.40	8346355.73	13574207.65
84	1994	2.92	684233.49	1134569.12
85	1999	2.50	1999948.00	3931515.75
86	1998	7.15	2798757.60	4828969.46
87	2005	1.81	11048109.00	12873217.51
88	2002	1.84	10868888.00	16062061.18
89	2003	3.78	661724.00	977470.27
90	2006	0.66	37609459.35	32293827.16
91	2005	3.82	393083.00	422714.92
92	1995	5.93	168698.15	257061.95
93	2001	3.92	5100904.95	9062207.20
94	2000	4.35	229633.77	352607.39
95	1992	3.54	2823247.33	6688830.09
96	1996	1.72	2904680.26	4518067.01
97	1997	5.05	197979.30	317625.15
98	1997	12.57	397692.20	709465.38
99	1992	12.23	163547.62	349891.06
100	1999	2.94	1703442.00	2765004.30
101	2000	1.12	17827513.00	34078342.94
102	1995	3.06	3268335.60	5695664.75
103	2005	2.04	2445170.00	2863945.97
104	1998	1.80	2775317.72	3714329.42
105	2004	6.00	6661744.20	8157883.21
106	2004	2.10	9507073.00	10752899.18
107	1995	3.61	2766942.05	4065115.33
108	2000	6.04	1654691.88	2437013.90
109	1992	3.11	802643.05	1639915.86
110	1999	6.74	103843.62	124163.06
111	2003	5.30	188854.00	238879.67
112	1997	9.07	44110.50	79852.59
113	1996	2.76	1813132.11	3016905.32
114	1994	2.06	7266000.00	12701952.51
115	2001	2.30	21749072.82	44589920.80
116	2001	1.47	13635579.25	22219592.21

SN	Year	% of Bid Cost	Bid Cost ($)	Bid Cost 08 ($)
117	1992	2.48	604559.55	1238464.15
118	1992	2.68	560434.34	1058379.94
119	2002	3.42	5847510.00	8846358.34
120	2002	5.66	1765948.21	2737401.94
121	2004	3.45	1447468.00	2067523.32
122	2002	7.68	976235.00	2229082.11
123	1999	3.18	6281914.72	10465922.11
124	2005	2.57	8938552.79	10002047.89
125	2003	8.70	862405.00	1167609.62
126	2005	0.49	41111111.00	54387216.07
127	1998	1.20	29284650.12	48192602.53
128	1996	10.03	997380.05	1421641.22
129	1995	1.13	2666042.97	4293690.17
130	2000	4.44	1126904.59	1856498.04
131	1999	2.97	1682066.79	2944245.97
132	1996	3.17	6316316.00	8664037.00
133	1998	6.34	394422.35	618982.02
134	1996	3.82	393086.72	654600.23
135	1993	13.56	1474874.35	2657913.73
136	1995	3.73	2008567.45	2829521.86
137	2002	1.34	14875945.50	25200034.13
138	2000	1.10	18199683.95	27734859.42
139	1999	1.07	18627063.31	37441570.76
140	2004	1.97	10144655.70	11663433.40
141	1999	2.90	12077777.00	18208121.76
142	2005	4.07	245730.00	236780.95
143	1994	2.29	654191.42	1005229.32

Table H-16. Data for Clearing and Grubbing (n = 64)

SN	Year	% of Bid Cost	Bid Cost ($)	Bid Cost 08 ($)
1	2003	0.14	4389372.21	5998808.69
2	1994	1.22	1162025.05	2007943.67
3	2002	0.13	1607900.00	2253808.55
4	1999	2.41	415012.86	636635.37
5	1997	2.18	917381.00	1467158.98
6	2004	0.08	3451154.00	4332555.20
7	1998	1.41	1681215.53	2635024.17
8	2006	0.76	1979979.00	2204865.50
9	1996	1.67	672179.06	1100372.98
10	1992	4.68	74779.30	135716.15
11	1993	0.64	3436160.01	6095214.02

SN	Year	% of Bid Cost	Bid Cost ($)	Bid Cost 08 ($)
12	1997	0.30	1517517.00	2426950.95
13	2002	0.10	5138230.65	7202306.21
14	2005	0.79	570000.00	678284.96
15	1992	0.52	3276066.04	5945697.32
16	2002	0.43	346295.00	485404.96
17	2002	2.04	415567.18	582504.42
18	1997	4.90	446896.22	714717.00
19	1996	1.63	167815.27	274717.56
20	1996	1.32	6055923.75	9913690.06
21	1998	5.04	954908.59	1496659.51
22	2002	1.43	301749.25	422964.76
23	2000	5.95	806404.00	1203269.49
24	1997	0.12	5866866.00	9382824.70
25	1999	0.27	1046233.13	1604935.86
26	2005	2.15	12326412.67	14668105.84
27	2005	0.13	7553178.60	8988083.24
28	1993	5.14	107063.55	189914.10
29	1999	0.76	197014.00	302222.16
30	1993	0.53	2627448.15	4660684.82
31	2005	0.79	2540000.00	3022532.98
32	2004	0.04	9048811.75	11359816.56
33	2003	0.12	4618921.00	6312525.37
34	2000	0.08	7367367.00	10993159.69
35	1994	0.57	684233.49	1182334.50
36	2003	0.33	661724.00	904356.13
37	2005	0.64	393083.00	467758.40
38	2001	0.05	5100904.95	7355741.43
39	1992	0.41	2823247.33	5123881.47
40	1996	1.55	2904680.26	4755030.12
41	1997	3.42	397692.20	636025.47
42	1992	1.22	163547.62	296820.83
43	1999	0.59	1703442.00	2613103.20
44	2000	0.42	17827513.00	26601185.65
45	1995	0.32	3268335.60	5479625.86
46	2005	0.45	2445170.00	2909687.78
47	1998	0.60	2775317.72	4349846.37
48	2004	0.04	6661744.20	8363108.24
49	2004	0.16	9507073.00	11935114.61
50	1995	0.36	2766942.05	4638999.50
51	1992	0.31	802643.05	1456708.31
52	1996	0.94	1813132.11	2968140.04

SN	Year	% of Bid Cost	Bid Cost ($)	Bid Cost 08 ($)
53	1994	0.69	7266000.00	12555425.29
54	2001	1.22	13635579.25	19663137.46
55	2002	0.32	5847510.00	8196509.74
56	1999	0.13	6281914.72	9636542.65
57	2005	0.15	8938552.79	10636641.97
58	1995	5.33	2666042.97	4469834.12
59	1999	0.24	1682066.79	2580313.34
60	1996	0.24	6316316.00	10339958.32
61	1993	2.92	1474874.35	2616197.96
62	2002	0.27	14875945.50	20851752.67
63	2005	1.59	245730.00	292412.22
64	1994	2.90	654191.42	1130422.72

Table H-17. Data for Dust Control (n = 44)

SN	Year	% of Bid Cost	Bid Cost ($)	Bid Cost 08 ($)
1	2003	0.53	3162194.15	4321665.34
2	2002	0.13	1757651.00	2463715.93
3	2004	0.98	4069782.00	5109176.57
4	2003	0.36	4389372.21	5998808.69
5	2002	0.50	1607900.00	2253808.55
6	2004	0.38	3451154.00	4332555.20
7	2006	1.01	1979979.00	2204865.50
8	2004	0.52	967090.00	1214078.19
9	2003	0.14	5107209.00	6979852.30
10	2002	0.27	5138230.65	7202306.21
11	2005	0.70	570000.00	678284.96
12	2002	0.72	346295.00	485404.96
13	2002	0.98	415567.18	582504.42
14	2001	0.09	1499000.00	2161627.50
15	2002	2.80	301749.25	422964.76
16	2005	2.07	241700.00	287616.62
17	2003	0.68	375991.00	513854.37
18	2005	1.53	885850.50	1054138.72
19	2001	0.93	1858981.95	2680738.16
20	2005	0.44	2540000.00	3022532.98
21	2003	0.33	1409939.00	1926916.63
22	2004	0.30	9048811.75	11359816.56
23	2003	0.09	4618921.00	6312525.37
24	2001	0.03	8346355.73	12035831.92
25	2005	0.62	11048109.00	13146958.20
26	2002	0.22	10868888.00	15235022.50

SN	Year	% of Bid Cost	Bid Cost ($)	Bid Cost 08 ($)
27	2003	0.44	661724.00	904356.13
28	2005	2.80	393083.00	467758.40
29	2001	0.92	5100904.95	7355741.43
30	2005	0.78	2445170.00	2909687.78
31	2004	0.22	6661744.20	8363108.24
32	2004	0.00	9507073.00	11935114.61
33	2003	0.74	188854.00	258100.47
34	2001	0.65	21749072.82	31363171.36
35	2001	0.84	13635579.25	19663137.46
36	2002	0.68	5847510.00	8196509.74
37	2002	0.55	1765948.21	2475346.21
38	2004	0.29	1447468.00	1817141.46
39	2002	0.09	976235.00	1368397.78
40	2005	0.55	8938552.79	10636641.97
41	2003	0.27	862405.00	1178620.17
42	2005	0.07	41111111.00	48921137.36
43	2000	0.54	1126904.59	1681501.97
44	2002	0.05	14875945.50	20851752.67

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