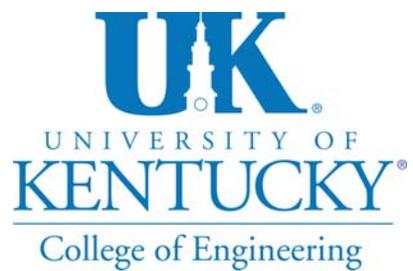




## KENTUCKY TRANSPORTATION CENTER

### CHANGE ORDERS AND LESSONS LEARNED





## **OUR MISSION**

**We provide services to the transportation community**  
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We create and participate in partnerships  
to promote safe and effective  
transportation systems.

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### **Teamwork**

Listening and communicating along with  
courtesy and respect for others.

### **Honesty and Ethical Behavior**

Delivering the highest quality  
products and services.

### **Continuous Improvement**

In all that we do.

**Research Report**  
**KTC-10-18/SPR-384-09-1F**

# **Change Orders and Lessons Learned** **(KYSPR-09-384)**

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## **1.0 Introduction**

Many times, change is necessary for the success of a project. “Change, defined as any event that results in a modification of the original scope, execution time, or cost of work, happens on most projects due to the uniqueness of each project and the limited resources of time and money available for planning” (Hanna, Camlic, Peterson, & Nordheim, 2002). While change orders are necessary to address unforeseen conditions and other unavoidable or unanticipated occurrences, they tend to negatively affect construction. In most public works, change orders are the main reason for construction delays and cost overruns (Wu, Hsieh, & Cheng, 2005). Change orders also lead to a decline in labor efficiency, loss of man hours, and costly disputes (Moselhi, Assem, & El-Rayes, 2005). It is important to understand the impact change orders have on project performance, but it is also important to understand the cause of change orders. Before change orders can be handled properly, owners must be aware of the reasons behind change orders. This research examines change orders on Kentucky Transportation Cabinet projects and focuses on identifying the leading cause of change orders, identifying the types of changes orders that produce the highest risk, and developing a procedure for pricing change orders. This research is intended to help the Kentucky Transportation Cabinet better manage change orders on highway construction projects. From hereafter, the Kentucky Transportation Cabinet is referred to as the Cabinet.

## **1.1 Background and Significance of Work**

An extensive amount of research has examined the causes of change orders in construction and their effects on project performance. However, the majority of research has focused on industrial and commercial construction projects. Research shows that there is a significant positive correlation between percentages of work hours in the field in implementing change order hours to percentage of lost productivity. Furthermore, change orders issued in the later stages of construction have greater negative impacts on labor productivity than change orders issued earlier in the project, as shown in Figure 1 (Chen, 1992).

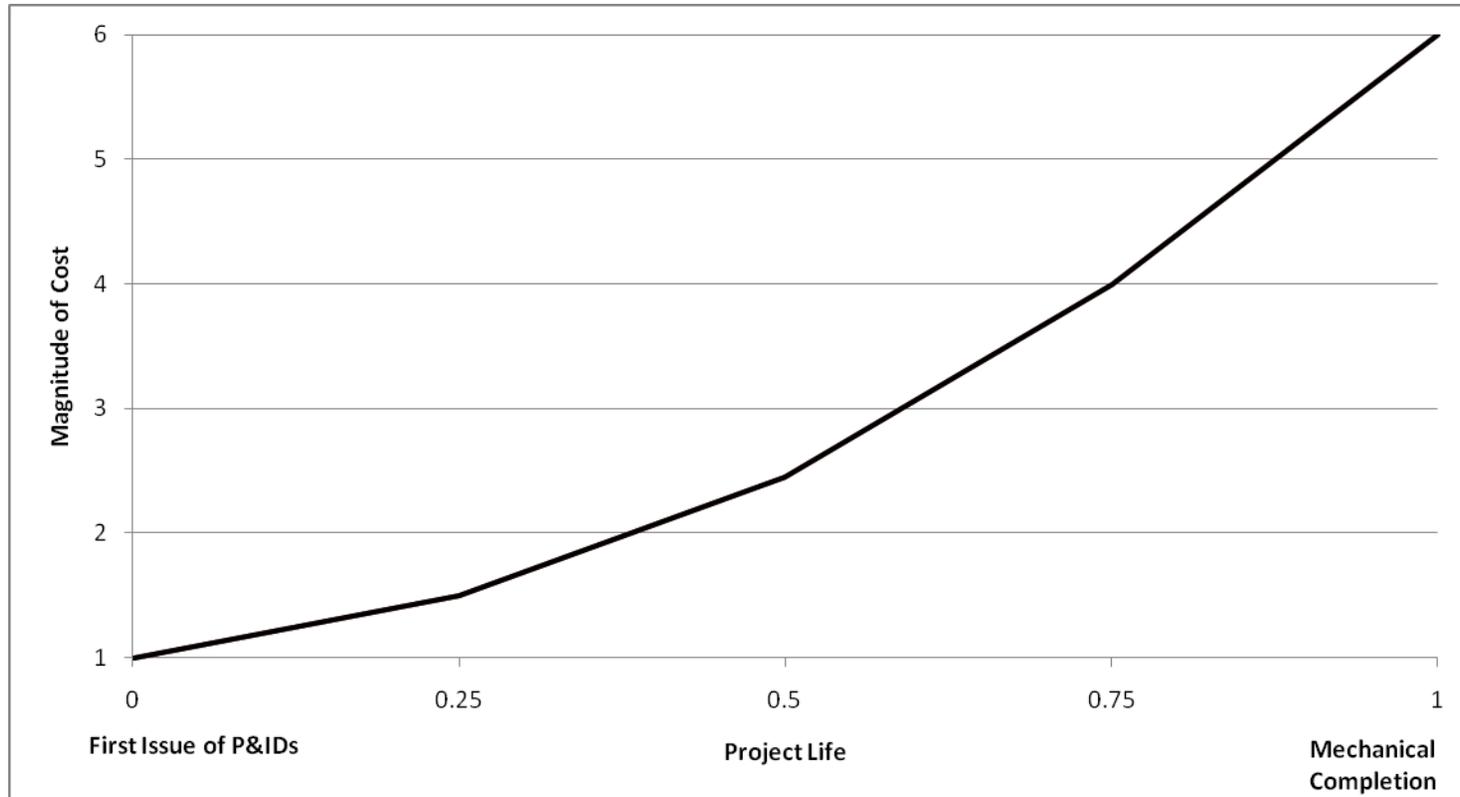


Figure 1: Cost of Changes to a Project vs. Time (Chen 1992)

A study of the Joint Legislative Audit and Review Commission on approximately 300 road construction projects in Virginia revealed that average project change in dollars resulted in an increase of more than 11% (Ibbs, Nguyen, & Lee, 2007). Although it is acknowledged that change orders will likely include the operating performance of a project, a significant disadvantage is that the change orders are not planned to help maximize their performance nor are they competitively bid like the project itself.

Ibbs, Nguyen, & Lee (2007) identified five main causes for change orders on construction projects; change in scope, differing site conditions, delays, suspensions, and acceleration. In Kentucky, there are several reasons that are generally thought to be probable causes of change orders on Kentucky transportation projects. Some of the probable causes include, but are not limited to:

- Unexpected conditions involving existing utilities;
- Unforeseen geotechnical conditions;
- Accelerated project development to meet firm bid dates;
- Unanticipated erosion control needs;
- Unforeseen environmental concerns;
- Errors and omissions in contract documents; and
- Archeological conditions.

It is important to understand the reasons for change orders, because some causes are avoidable. It is unrealistic to expect that all change orders can be eliminated on a construction project, but it is realistic to believe change orders can be managed and minimized. The management of change orders is the management of risks (Cox 1997). Knowing the causes of change orders helps optimize the efforts to minimize the frequency and impacts of change orders. Once focused, the process of managing risk and improving project success can begin.

One element of the risk management process for change orders is a lack of a consistent method for pricing change orders. When field engineers are presented with a price for extra work to be done by the contractor, valuable time and resources are sometimes wasted in finding an appropriate source for pricing the work by the engineer.

Having a standard method for developing a comparable price could provide cost and time savings and allow the engineer to be confident in his estimate.

## **1.2 Goals & Objectives**

The goal of this research is to examine the causes of construction change orders on Kentucky transportation projects. By understanding the causes, the Cabinet will understand where to focus their efforts to minimize construction change orders. The research will help the Cabinet save time and money on future transportation construction projects. Another goal is to provide a method for the Cabinet to use for training and field personnel in the form of a change order pricing flowchart.

The objectives for this research are:

1. Analyze the leading causes of change orders on Kentucky transportation projects;
2. Identify project characteristics that are correlated with higher frequency and magnitude of construction change orders;
3. Deliver Change Order Reference Cards to the Cabinet that identify risk levels of the various reasons for change orders; and
4. Deliver Change Order Pricing flowchart to be used as a quick reference source for pricing change orders.

## **2.0 Change Order Risk Analysis**

One of the main areas of concern to Owners and Architects/Engineers is the uncertainty involved with change orders which can lead to increased project risk. A literature review of reports related to change orders and risk is discussed and an analysis of change order data was performed to assess what risks are more likely to need special attention and could cause the greatest amount of problems.

### **2.1 Other Change Order Topics**

In the course of performing a search for information on change orders, a number of relevant issues on the way change orders affected projects were found. Information regarding risk management was addressed in a number of papers and the legal ramifications of the decisions made by the parties involved were analyzed. Information was also found in relation to the origin of change orders from improper or low bids. Problems with pricing of change orders with regard to rebidding were also addressed. Results from studies looking into the source of claims yielded some surprising results for its authors.

A primary focus of previous research related to change orders involves the legal aspects of change orders and how they have an impact on the owner, architect/engineer, and the contractor. The importance of the different roles of the three main principles was discussed and what their responsibilities should be focused around. Previous research suggests that owners should acknowledge that projects are not guaranteed to be free of changes and select construction methods that will help fulfill their project's goals (Cox 1997). The proper negotiation of construction contracts allows owners to shift risk to the contractor under clauses such as no damage for delays clauses, site condition disclaimers or mechanic's lien waivers. Proactive owners also conduct constructability reviews and other front end planning efforts to help improve the accuracy of the contract documents as a preamble for avoiding change orders during construction. Cox (1997) also addressed the responsibilities of the contractor by suggesting that they be well prepared for the possibility of risk and educate themselves about the conditions of the site before preparing and submitting their bid. The contractor must also be aware of the risk-shifting clauses in the pre-bid documents before submitting their bid. If possible, the contractor

must look to negotiate out of these clauses before they submit their bid or adjust their bid such that they financially cover themselves if a situation occurs (Cox 1997).

When change orders do occur, the level of impact that occurs on a project is difficult to quantify. Disruption has been defined as the increased cost of the *unchanged* work due to the impact of the changed work (Finke 1998). Due to the uncertainty involved with the impact of the disruption, most owners want to know the financial impact of the change prior to approving the change order. Contractors, concerned about profit margins, may claim that they cannot accurately give a monetary impact of delays to the project due to the “interdependency of construction activities” (Moselli, Leonard and Fazio 1991). The difficulties that surround estimating the disruptions caused by change orders can lead to delays and disputes that could be avoided.

The importance of managing the disruption that can occur from a change order is significant to the contractor. To better manage profit margins, they must be able to anticipate, identify, and track the changes that occur to be able to successfully recover any monetary claims from the effects of the disruption on the unchanged work (Finke 1998). The difficulty in pricing a change going forward has been acknowledged by appeals courts. Other boards of appeal have stated their understanding that sometimes the impact of a change can only be determined after the completion of the project.

Claims produced from disputed change orders and modifications were also observed to have an increased occurrence. Diekmann & Nelson, 1985) investigated the increased level of claims and the origins of their dispute. The authors noted that some of the observed claims were resolved without the use of litigation or other resolution procedures. They were able to categorize the claims into one of six different categories:

1. Design Errors
2. Changes (discretionary or mandatory)
3. Differing Site Conditions
4. Weather
5. Strikes; and
6. Value Engineering

Their results showed that commercial designers were better able to avoid claims on their work. The results indicated that they designed 84% of the projects by dollar value, but only had 74% of the claims. This translated to a 5% claims rate compared to a 10% claims rate for the in-house designers. The results also showed that 72% of the claims were due to design errors or changes initiated by the owner and that “uncontrollable” causes such as weather and site conditions accounted for only 28% of change orders. (Diekmann and Nelson 1985).

Problems with the pricing of change orders were also found to originate with the bidding process, or lack thereof. Many state agencies and municipalities have policies that provide for any change order items that exceed certain thresholds of the basis of the original contract will be rebid to allow for competitive pricing. States such as Indiana (InDOT n.d.), Florida (FDOT n.d.), and Nevada (NDOT n.d.) have statutes that put specific dollar or percent of contract limits on change orders. Other states such as Illinois (IDOT 2006), Kansas (KDOT n.d.), and Louisiana (DOTD 2005) have provisions for change orders to be rebid under certain limitations. From a literature review, it was found that many of the complaints and findings from internal audits revealed some public works departments were not following these prescribed guidelines for the rebidding of the change orders items exceeding the established thresholds. The Illinois Public Works Contract Change Order Act was established January 2004 to specifically “require units of local government and school districts to rebid change orders that are over 50 percent or more of the original price”. Many states and municipalities have the same sort of criteria established at differing thresholds. The problem was found in enforcing the provision. Heads of the agencies cite the cost of going through the process of rebidding the portion of the project being greater than the inflated cost of the change order from the contractor. The Missouri Director of the Department of Transportation lamented that “Change orders do not necessarily equate to higher costs. In many instances, the work necessary to avoid all change orders would cost the state more than the change order(s)” (McCaskill 2002). While the validity of the statement can be argued, the questioning of the use of resources to track change orders exceeding prescribed thresholds is valid.

Other problems can arise from lack of consistent and detailed record keeping, lack of post construction reviews to examine causes of project specific change orders,

verification of change order line items to assure they are not being double billed, and other tracking issues. A Mississippi Legislative Review Committee (Bryant 2004) examined the change order process of their state's Bureau of Building, which manages and oversees construction of state owned buildings. Their findings showed a lack of proper documentation and / or identification of a change order request. In their review, over half of the change orders lacked identification of the change order request. In some instances they observed problems in identifying and verifying whether the change order items were already included in the project's original bid or whether the pay items were the responsibility of the design professional. This situation could possibly lead to the issuing of a double payment to the contractor.

## **2.2 Data Acquisition**

Change orders lead to budget changes, schedule changes, or both. Budget changes are measured by the amount of work adjusted by cost. Data related to budget changes is usually objective and reliable. On the other hand, schedule changes are more complicated. Schedule changes consist of time extensions or reductions and are more difficult to quantify (Wu, Hsieh, Cheng, & Lu, 2004). Due to the nature of the data, this study focuses on budget changes and does not examine time related impacts.

The study's data was provided by the Cabinet's data bank of previous road construction projects in Kentucky. The data bank provided through Site Manager consisted of 13,889 projects completed as early as June 1982 and as recently as August 2008. Each project record included:

- District number of the project location;
- County of construction;
- Unique project code id;
- Type of construction;
- Overall project change order amount;
- Original contract amount;
- Project completion date;
- Road name; and

- Brief project description

Unique project code id;

- Brief project description;
- Individual change order amounts; and
- Type of construction

After the raw data was acquired, the data was sorted. The original data had the change order amounts, but did not list the reasons for the change orders. To gather this information, the Cabinet supplied a change order reason code explanation list and HTML files that broke down each individual change order by reason code, item description, and dollar amount. The Cabinet had a list of 30 reason codes that classify change orders; the reason codes and a series of HTML files made it possible to assign causes to each individual change order. Examples of reason codes are Contract Omission, Contract Item Overrun, and Owner Induced Enhancement. There were 1,762 HTML files supplied and they included the unique project code id. The HTML files made it possible to break down each change order item by dollar amount and reason code. The HTML files also verified the change order amounts given in the original Excel files. It is important to note that some of the items in the HTML files did not have reason codes. However, by examining the item description and any additional notes it was possible to classify the item's reason code, which led to the determination of the reason for the change order.

## **2.3 Statistical Methodology**

### **2.3.1 Descriptive Statistics**

The descriptive statistics looked at the following:

- Frequency of change order reason codes;
- Average change order dollar amount by reason code; and
- Average percent change from original contract dollar amount by reason code

From the descriptive statistics, the following information was compiled:

- Ten most frequent reason codes – New Construction & Maintenance Work Combined;
- Ten most frequent reason codes – New Construction Only;
- Ten most frequent reason codes – Maintenance Work Only;
- Ten largest average change order dollar amount by reason code – New Construction at & Maintenance Work combined;
- Ten largest average change order dollar amount by reason code – New Construction Only;
- Ten largest average change order dollar amount by reason code – Maintenance Work Only;
- Ten largest average percent change from original contract dollar amount by reason code – New Construction & Maintenance Work Combined;
- Ten largest average percent change from original contract dollar amount by reason code – New Construction Only; and
- Ten largest average percent change from original contract dollar amount by reason code – Maintenance Work Only

Note: In the report, average change order amount is always in dollars and average percent change refers to the average percent change from original contract.

### 2.3.2 Pearson Chi-Square

The Pearson Chi-Square analysis is used to compare frequency counts. The Chi-Square tests for deviations in the frequencies and the significance level indicates if the difference is statistically significant. In the analyses, a 95% confidence interval is used, which indicates that the difference is unlikely (less than 5%) due to chance.

In this study, the Pearson Chi-Square analysis corresponds with the ten most frequent reason codes. The frequencies are broken down into road types to determine if there is a statistically significant difference for each reason code on the various road types. These analyses highlight specific change order codes that tend to be more common and problematic and warrant corrective action in terms of modified processes and policies within the Cabinet to minimize their occurrences on future projects.

### 2.3.3 Pearson Correlation

The Pearson Correlation Coefficient is a tool used to quantify the linear relationship between variables. The correlation coefficient is a dimensionless quantity that is independent of the units of the variable and ranges between -1 and 1. For random variables that are approximately linearly related, a correlation coefficient of 0 implies independence or that the two variables are uncorrelated. A correlation coefficient close to 1 signifies nearly perfect positive independence. If the correlation coefficient is 1, then one variable can be predicted exactly from the other (Rosner 2005).

In this study, the Pearson's Correlation Coefficient measures the relationship between reason codes and indicates how likely it is that the various reason codes will occur on the same project.

### 2.3.4 One-Way Analysis of Variance

A one-way analysis of variance, or one-way ANOVA analysis, is used to compare means. With this analysis, the means of an arbitrary number of groups, each of which follows a normal distribution with the same variance, can be compared. The one-way analysis of variance determines if the variability in the data is from variability within groups or between groups (Rosner 2005).

For this study, the F test for the one-way ANOVA analysis is used. The F test is for the overall comparison of group means. In the study, the reason codes and road types are compared to determine any statistically significant differences. As mentioned in Section 2.2.2, a statistically significant difference indicates the difference is unlikely due to chance.

The one-way ANOVA analysis corresponds with the ten largest average percent change reason codes. This determines if any of the reason codes are increasing the contract dollar amount by a significant percentage on the various road types.

### 2.3.5 Geographic Information System Mapping

Geographic Information System, GIS, mapping integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. GIS mapping allows users to view, understand, question,

interpret, and visualize data. It reveals patterns, relationships, and trends through maps, globes, reports, and charts (Environmental Systems Research Institute 2009).

In this study, GIS maps are used as a visual tool to quickly share and understand trends that develop in the data. Geological conditions throughout the state of Kentucky and their effects on the average percent change and average change order dollar amount are shown. The GIS maps also show the twelve highway district offices and their descriptive statistics with regards to change order reason codes. The GIS maps are used to provide visual examination if there is any geographic trends among change orders in Kentucky.

### 2.3.6 Control Charts

Control charts indicate the amount and nature of variation in data. The charts include an upper control limit, a lower control limit and the average for the sampled population. Control charts provide the ability to interpret data by monitoring a process, estimating parameters of a process, and then improving the process. The variables of control charts are data based on measurement. The control charts used are a  $\bar{x}$  chart accompanied by a standard deviation chart. The  $\bar{x}$  chart monitors the mean value and the standard deviation measures variability (Swift, Ross and Omachonu 1998).

In this study, control charts are used to create a change order reference card that summarizes the analyses. The change order reference card, which is developed from the control charts, is intended to aid the Cabinet in quickly determining the causes and project characteristics of greatest risk and concern with regards to change orders on current and future construction projects. In this report, the change order reference cards are also referred to as Quick Guides.

### **3.0 Analyses of Causes of Change Orders and Project Characteristics**

#### **3.1 Data Requirements**

With the creation of the master file, requirements were developed so that the data set was an appropriate size. The first criterion for the data was projects completed from the beginning of 2005 until August 21, 2008. The Cabinet started using a new organizational package called Site Manager in 2005, so projects completed that year and after were input into Site Manager. These projects have the HTML files that breakdown each change order, including item descriptions and explanations for the item. The change order breakdown in the HTML files made it possible to assign dollar values to the individual reason codes on each project. Therefore, projects completed in 2005 and later have the most detailed project information. Figure 7 shows an example of an HTML file.

**Commonwealth of Kentucky  
Transportation Cabinet**

|                           |            |                       |                      |
|---------------------------|------------|-----------------------|----------------------|
| <b>Contract ID</b>        | 041125     | <b>District</b>       | FLEMINGSBURG (09316) |
| <b>Change Order No.</b>   | 005        | <b>County</b>         | FLEMING              |
| <b>Contractor</b>         | [REDACTED] | <b>Project Number</b> | [REDACTED]           |
| <b>Contractor Address</b> | [REDACTED] | <b>Road Name</b>      | [REDACTED]           |

| Prj_Nbr       | Catg. | LIN  | Item Code | Item Description                 | Quantity   | Unit | Unit Price | Net Change   |
|---------------|-------|------|-----------|----------------------------------|------------|------|------------|--------------|
| D035001104125 | 0002  | 1250 | 08151M    | STEEL REINF-EPOXY COATED         | -7,457.220 | KG   | 1.720      | \$-12,826.41 |
| D035001104125 | 0001  | 8021 | 10005NS   | RIDE QUALITY ADJUSTMENT ASPH     | 19,667.050 | DOLL | 1.000      | \$19,667.05  |
| D035001104125 | 0001  | 8022 | 02677M    | ASPH PAVE MILLING & TEXTURING    | 650.000    | MTON | 27.120     | \$17,628.00  |
| D035001104125 | 0001  | 8023 | 10000NS   | LOT PAY ADJUSTMENT               | 75,599.180 | DOLL | 1.000      | \$75,599.18  |
| D035001104125 | 0001  | 8024 | 02651     | DIVERSIONS (BY-PASS DETOURS)     | 1.000      | L.S. | 17,914.290 | \$17,914.29  |
| D035001104125 | 0001  | 8025 | 20992MD   | EDGE KEY                         | 37.200     | M    | 116.600    | \$4,337.52   |
| D035001104125 | 0002  | 8026 | 08151M    | STEEL REINFORCEMENT-EPOXY COATED | 7,346.220  | KG   | 0.944      | \$6,941.00   |
| D035001104125 | 0001  | 8027 | 10080NSD  | COST PLUS WORK                   | 29,187.350 | DOLL | 1.000      | \$29,187.35  |

**Change Order Amount: \$158,447.97**

CHANGE ORDER TIME ADJUSTMENT DAYS: 0

**Explanations That Apply To Specific Line Items**

[8021] (002) Ride Quality Adjustment.

[8023] (001) Asphalt Lot Pay Adjustments according to Standard Specifications.

[8024],[8022],[8026],[8025],[1250] (004) Contract Omission - Extra Work is required as a result of a Contract Omission.

[8027] (018) Cost Plus Worksheets (Documentation for cost plus worksheet attached to the change order as supplemental data.)

[8022] ASPHALT MILLING AND TEXTURING - Asphalt milling was needed on this contract due to project phasing and maintenance of traffic. This project contained temporary widening and detours to maintain traffic. Once the proposed roadway was constructed the widened sections and detours were removed. Milling was necessary to remove associated asphalt and to correct cross-slope where permanent pavement was placed as a part of a detour but was installed on a slope that was different than planned slope to provide a safer temporary roadway. Unit price is based on 2006 average bid prices.

[8027] COST PLUS: Cost plus work was needed to correct various problems throughout the project. One portion of the work was cleaning up and replacing channel lining that was displaced during a major flood event. Other cost plus work included correcting a seepage problem in the roadway in which water was seeping up through the asphalt and onto the roadway. This was corrected by using perforated pipe to drain water outside the shoulder area. Cost plus work was also utilized to drain standing water from a property owner's yard by constructing a french drain to the roadway ditch. Cost plus spreadsheets are on file.

[8025] EDGE KEY: Edge key was needed to provide a smooth transition from the new pavement to existing pavement. Unit price is based on 2006 average bid prices.

[8024] DIVERSION/DETOUR: A new detour had to be constructed to accommodate traffic during the part width

**Figure 2: Example of an HTML file**

The second criterion filtered out overall change order amounts between -\$100 and \$100. These cutoffs were selected because it eliminated projects with overall small change orders. There were 1,166 out of the 2,276 projects that had change order amounts between -\$100 and \$100. Out of those 1,166 projects, 1,129 projects had change order magnitudes between -\$1 and \$1. If the -\$100 and \$100 cutoffs were not used the analyses would have been skewed. After sorting the data and HTML files, there were 610 projects that met the above criteria.

After obtaining the desired data set, additional variables were added. For each reason code, a variable was coded for the change order dollar amount. Another variable was created to indicate the percent change from original contract amount for each reason code on each specific project. All data was coded and analyzed using SPSS, a statistical software package. The entire data assembly, including data acquisition and data requirements can be seen in Figure 2 from Section 2.1 Data Acquisition.

The analyses of the causes of change orders first examined the reason codes based on several different factors to establish any trends. The reason codes were identified by road type, new construction vs. maintenance work, type of construction, and district. In addition, GIS Maps were created to display a visual analysis of where the change orders were occurring throughout the state.

For the analyses of the causes of change orders, the reason codes are separated into administrative issues vs. engineering issues. The engineering reasons include:

- Code 1 - Asphalt Lot Pay Adjustment;
- Code 3 - Fuel & Asphalt Adjustment;
- Code 4 - Contract Omission;
- Code 5 - Utility Issue;
- Code 6 - Contract Item Overrun;
- Code 7 - Geotechnical Issue;
- Code 8 - Owner Induced Enhancement; and
- Code 9 - Environmental Issue

Note: Code 30 (The Fuel and Asphalt Adjustment difference between supplemental specification Section 109.07 from 1/1/06 and standard specification Section 109.07 of

applicable specification book will be non-participating Federal Funds) and Code 40 (Fuel and Asphalt Adjustment will be calculated using 1/1/06 Supplemental to the Standard Specification for Section 109.07 Price Adjustments for work performed after 7/1/05 per 5/1/06 memo) were combined with Code 3 (Fuel & Asphalt Adjustment). This was possible because all three codes represent a change order caused by fuel and asphalt adjustments. The only difference is Code 30 and Code 40 provided supplemental information on how the adjustment is calculated. This study focuses on the causes of change orders so the three codes were combined as Code 3 (Fuel & Asphalt Adjustment).

The administrative reasons include:

- Code 2 - Ride Quality Adjustment;
- Code 10 - Contract Incentive;
- Code 11 - Project Renewal for subsequent calendar year;
- Code 12 - Accounting Adjustment;
- Code 13 - Value Engineering Proposal;
- Code 14 - Cost is less than or equal to 110% of the average unit bid price;
- Code 15 - Itemized cost breakdown supplied by the contractor including equipment, labor materials, and time needed to perform proposed work;
- Code 16 - Cost comparison to the competitive bid contracts in an area or district for items similar to scope of work;
- Code 17 - Item special in nature, unit price/cost justified by the contractor;
- Code 18 - Cost Plus Worksheets;
- Code 19 - Formal Partnering;
- Code 20 - Contract Item Underrun;
- Code 21 - Claim Settlement;
- Code 22 - Steel Price Adjustment;
- Code 23 - Liquidated Damages Specifications/Special Note Change;
- Code 24 – Specification/Special Note Change;
- Code 25 - Non-Specification Material to Remain in Place;

- Code 26 - Incorrect Project Wage Rates were included in the contract when let. This item is to reimburse the contractor the difference between wage rates as bid and the correct wage rates that should have been included in the contract;
- Code 27 - This item shall include all labor, equipment, materials and overhead necessary to complete this item of work; and
- Code 50 - Contract renewal as agreed upon in the current contract for the subsequent calendar year. All provisions of the original contract will apply to this renewal

Note: Code 20 (Contract Item Underrun) can be classified as an engineering reason, but for this study it was not. With Contract Item Underrun, the Cabinet is reimbursed for items not needed and this study focuses on change order causes that increase costs for the Cabinet.

### **3.2 Frequency and Impact of Change Order Codes**

The descriptive statistics helped the research team determine which reason codes are occurring most frequently and which reason codes have the greatest dollar impact on projects. A series of lists were created for the most frequent reason codes, the highest average change order dollar amount by reason code, and the highest average percent change by reason code. Each list provided important statistical breakdowns, but the lists are most powerful when compared with one another. Codes that occur frequently across project types represent a greater risk for cost increases on projects than codes that occur on more limited project types. When looking at the lists, it is also important to note which reason codes are engineering issues and which codes are administrative issues. The focus of this study is on engineering issues. The lists are broken down by new construction and maintenance work combined and then new construction only and maintenance work only. The Cabinet is involved in both new construction and maintenance projects, so it is important to understand the different causes for change orders on both types of work. The topic of new construction and maintenance work is discussed in greater detail in Section 3.4 New Construction vs. Maintenance Work. The developed lists are shown in Tables 1 through 9.

Table 1 shows the most frequent reason codes for new construction and maintenance work combined. The Chi-Square analysis shows that the frequency of reason codes for new construction and maintenance work combined has a statistically significant difference. In addition to the statistical significance, the most frequent reason codes are Contract Omission (243), Contract Item Overrun (227), and Fuel & Asphalt Adjustment (218).

**Table 1: Most Frequent Change Order Codes – New Construction & Maintenance Work Combined**

| Reason Code        | Reason Code Explanation                                     | Frequency | Type of Change Order |
|--------------------|---|-----------|----------------------|
| 4                  | Contract Omission   | 243       | Engineering          |
| 6                  | Contract Item Overrun                                       | 227       | Engineering          |
| 3                  | Fuel & Asphalt Adjustment                                   | 218       | Engineering          |
| 1                  | Asphalt Lot Pay Adjustment                                  | 188       | Engineering          |
| 8                  | Owner Induced Enhancement                                   | 186       | Engineering          |
| 20                 | Contract Item Underrun                                      | 165       | Administrative       |
| 7                  | Geotechnical Issue  | 71        | Engineering          |
| 17                 | Item special in nature                                      | 67        | Administrative       |
| 5                  | Utility Issue   | 60        | Engineering          |
| 16                 | Cost comparison to competitive bid in area for similar work | 51        | Administrative       |
| Pearson Chi-Square |   | 474.953   |                      |
| Significance       |   | 0.000     |                      |

Note: The highlighted reason codes are found to be prevalent on all the lists.

Table 2 shows the most frequent reason codes for new construction only. The Chi-Square analysis shows that the frequency of reason codes for new construction only has a statistically significant difference. In addition to the statistical significance, the most frequent reason codes are Contract Omission (150), Contract Item Overrun (113), and Owner Induced Enhancement (113).

**Table 2: Most Frequent Change Order Codes - New Construction Only**

| Reason Code        | Reason Code Explanation                                   | Frequency | Type of Change Order |
|--------------------|---|-----------|----------------------|
| 4                  | Contract Omission   | 150       | Engineering          |
| 6                  | Contract Item Overrun                                     | 113       | Engineering          |
| 8                  | Owner Induced Enhancement                                 | 113       | Engineering          |
| 20                 | Contract Item Underrun                                    | 102       | Administrative       |
| 7                  | Geotechnical Issue  | 64        | Engineering          |
| 3                  | Fuel & Asphalt Adjustment                                 | 60        | Engineering          |
| 1                  | Asphalt Lot Pay Adjustment                                | 54        | Engineering          |
| 5                  | Utility Issue   | 46        | Engineering          |
| 17                 | Item special in nature                                    | 46        | Administrative       |
| 14                 | Cost is less than or equal to 110% of avg. unit bid price | 40        | Administrative       |
| Pearson Chi-Square |   | 238.835   |                      |
| Significance       |   | 0.000     |                      |

Note: The highlighted reason codes are found to be prevalent on all the lists.

Table 3 shows the most frequent reason codes for maintenance work only. The Chi-Square analysis shows that the frequency of reason codes for maintenance work has a statistically significant difference. The most frequent reason codes are Fuel & Asphalt Adjustment (158), Asphalt Lot Pay Adjustment (134), and Contract Item Overrun (114).

**Table 3: Most Frequent Change Order Codes - Maintenance Work Only**

| Reason Code        | Reason Code Explanation                                     | Frequency | Type of Change Order |
|--------------------|---|-----------|----------------------|
| 3                  | Fuel & Asphalt Adjustment                                   | 158       | Engineering          |
| 1                  | Asphalt Lot Pay Adjustment                                  | 134       | Engineering          |
| 6                  | Contract Item Overrun                                       | 114       | Engineering          |
| 4                  | Contract Omission   | 93        | Engineering          |
| 8                  | Owner Induced Enhancement                                   | 73        | Engineering          |
| 20                 | Contract Item Underrun                                      | 63        | Administrative       |
| 16                 | Cost comparison to competitive bid in area for similar work | 23        | Administrative       |
| 17                 | Item special in nature                                      | 21        | Administrative       |
| 24                 | Specification/Special Note Change                           | 18        | Administrative       |
| 12                 | Accounting Adjustment                                       | 17        | Administrative       |
| Pearson Chi-Square |   | 426.284   |                      |
| Significance       |   | 0.000     |                      |

Note: The highlighted reason codes are found to be prevalent on all the lists.

Table 4 shows the highest average change order dollar amounts by reason code for new construction and maintenance work combined. The ANOVA analysis shows that the average change order dollar amount by reason code for new construction and maintenance combined has a statistically significant difference. The highest average change order dollar amounts by reason code are Contract Incentive (\$246,861.130), Contract Item Overrun (\$104,857.53) and Claim Settlement (\$102,508.19). It is important to note that while Contract Incentive has a much higher average change order dollar amount than any other reason code it does not show up in any of the frequency lists. This is also true for Claim Settlement. While it is important to know which change orders have high average dollar amounts, it is also important to consider the frequency when the respective change orders occur.

**Table 4: Largest Average Change Order Dollar Amount per Code - New Construction & Maintenance Work Combined**

| Reason Code | Reason Code Explanation                        | Average CO Amount (\$) | Type of Change Order |
|-------------|--|------------------------|----------------------|
| 10          | Contract Incentive                             | \$246,861.13           | Administrative       |
| 6           | Contract Item Overrun                          | \$104,857.53           | Engineering          |
| 21          | Claim settlement                               | \$102,508.19           | Administrative       |
| 7           | Geotechnical Issue                             | \$90,777.41            | Engineering          |
| 15          | Itemized cost breakdown supplied by contractor | \$88,357.88            | Administrative       |
| 8           | Owner Induced Enhancement                      | \$88,297.13            | Engineering          |
| 3           | Fuel & Asphalt Adjustment                      | \$82,336.07            | Engineering          |
| 18          | Cost plus worksheets                           | \$76,847.60            | Administrative       |
| 4           | Contract Omission                              | \$57,410.90            | Engineering          |
| 17          | Item special in nature                         | \$55,360.59            | Administrative       |
| 20          | Contract Item Underrun                         | (\$193,171.41)         | Administrative       |
|             | F-value  | 12.588                 |                      |
|             | P-value  | 0.000                  |                      |

Note: 11 codes are shown because Contract Item Underrun is a negative value. CO = change order. The highlighted reason codes are found to be prevalent on all the lists.

Table 5 shows the highest average change order dollar amounts by reason code for new construction only. The ANOVA analysis shows that the average change order

dollar amount by reason code for new construction only has a statistically significant difference. The highest average change order dollar amounts by reason code are Contract Incentive (\$494,271.16), Fuel & Asphalt Adjustment (\$195,264.36), and Contract Item Overrun (\$160,934.37). Again, it is important to understand that Contract Incentive has a high average change order dollar amount, but it does not frequently occur, thus minimizing its overall impact.

**Table 5: Largest Average Change Order Dollar Amount per Code - New Construction Only**

| Reason Code | Reason Code Explanation                        | Average CO Amount (\$) | Type of Change Order |
|-------------|--|------------------------|----------------------|
| 10          | Contract Incentive                             | \$494,271.16           | Administrative       |
| 3           | Fuel & Asphalt Adjustment                      | \$195,264.36           | Engineering          |
| 6           | Contract Item Overrun                          | \$160,934.37           | Engineering          |
| 8           | Owner Induced Enhancement                      | \$104,964.93           | Engineering          |
| 15          | Itemized cost breakdown supplied by contractor | \$102,911.76           | Administrative       |
| 7           | Geotechnical Issue                             | \$96,857.14            | Administrative       |
| 21          | Claim settlement                               | \$92,431.33            | Administrative       |
| 18          | Cost plus worksheets                           | \$87,280.32            | Administrative       |
| 4           | Contract Omission                              | \$73,788.63            | Engineering          |
| 12          | Accounting Adjustment                          | \$66,152.73            | Administrative       |
| 20          | Contract Item Underrun                         | (\$236,826.74)         | Administrative       |
|             | F-value  | 9.638                  |                      |
|             | P-value  | 0.000                  |                      |

Note: 11 codes are shown because Contract Item Underrun is a negative value. CO = change order. The highlighted reason codes are found to be prevalent on all the lists.

Table 6 shows the highest average change order dollar amounts by reason code for maintenance work only. The ANOVA analysis shows that the average change order dollar amounts by reason code for maintenance work only has a statistically significant difference. The highest average change order dollar amounts by reason code are Claim Settlement (\$193,200.00), Contract Incentive (\$98,415.12), and Owner Induced Enhancement (\$64,496.29). Again, Claim Settlement and Contract Incentive have high average change order dollar amounts, but neither one occurs frequently.

**Table 6: Largest Average Change Order Dollar Amount per Code - Maintenance Work Only**

| Reason Code | Reason Code Explanation                        | Average CO Amount (\$) | Type of Change Order |
|-------------|--|------------------------|----------------------|
| 21          | Claim settlement                               | \$193,200.00           | Administrative       |
| 10          | Contract Incentive                             | \$98,415.12            | Administrative       |
| 8           | Owner Induced Enhancement                      | \$62,496.29            | Engineering          |
| 6           | Contract Item Overrun                          | \$49,272.60            | Engineering          |
| 2           | Ride Quality Adjustment                        | \$46,537.24            | Administrative       |
| 3           | Fuel & Asphalt Adjustment                      | \$39,451.92            | Engineering          |
| 15          | Itemized cost breakdown supplied by contractor | \$38,080.84            | Administrative       |
| 7           | Geotechnical Issue                             | \$35,191.31            | Engineering          |
| 17          | Item special in nature                         | \$33,480.91            | Administrative       |
| 4           | Contract Omission                              | \$30,995.20            | Engineering          |
| 20          | Contract Item Underrun                         | (\$122,491.35)         | Administrative       |
|             | F-value  | 3.547                  |                      |
|             | P-value  | 0.000                  |                      |

Note: 11 codes are shown because Contract Item Underrun is a negative value. CO = change order. The highlighted reason codes are found to be prevalent on all the lists

Table 7 shows the highest average percent change by reason code for new construction and maintenance work combined. The ANOVA analysis shows that the average change by reason code for new construction and maintenance work has a statistically significant difference. The highest average percent change by reason code are Contract Incentive (9.26%), Owner Induced Enhancement (7.80%), and Fuel & Asphalt Adjustment (7.05%). It is important to see that Contract Incentive creates a high average percent change, but it is more important to understand that codes that occur more frequently such as Owner Induced Enhancement and Fuel & Asphalt Adjustment also have high average percent changes.

**Table 7: Largest Average Percent Change from Original Contract Amount per Code - New Construction & Maintenance Work Combined**

| Reason Code | Reason Code Explanation                                     | Average Percent Change | Type of Change Order |
|-------------|---|------------------------|----------------------|
| 10          | Contract Incentive  | 9.26%                  | Administrative       |
| 8           | Owner Induced Enhancement                                   | 7.80%                  | Engineering          |
| 3           | Fuel & Asphalt Adjustment                                   | 7.05%                  | Engineering          |
| 6           | Contract Item Overrun                                       | 6.73%                  | Engineering          |
| 16          | Cost comparison to competitive bid in area for similar work | 6.36%                  | Administrative       |
| 4           | Contract Omission   | 4.53%                  | Engineering          |
| 17          | Item special in nature                                      | 4.31%                  | Administrative       |
| 15          | Itemized cost breakdown supplied by contractor              | 3.86%                  | Administrative       |
| 18          | Cost plus worksheets  | 3.21%                  | Administrative       |
| 5           | Utility Issue   | 3.16%                  | Engineering          |
| 20          | Contract Item Underrun                                      | -6.48%                 | Administrative       |
|             | F-value   | 20.434                 |                      |
|             | P-value   | 0.000                  |                      |

Note: 11 codes are shown because Contract Item Underrun is a negative value. CO = change order. The highlighted reason codes are found to be prevalent on all the lists

Table 8 shows the highest average percent change by reason code for new construction only. The ANOVA analysis shows that the average percent change by reason code for new construction only has a statistically significant difference. The highest average percent change by reason code are Contract Item Overrun (5.39%), Owner Induced Enhancement (4.99%), and Contract Omission (4.02%). This result is interesting and should be noted because these three codes show up on all lists and are the top three for average percent change on new construction only.

**Table 8: Largest Average Percent Change From Original Contract Amount per Code - New Construction Only**

| Reason Code | Reason Code Explanation                                     | Average Percent Change | Type of Change Order |
|-------------|---|------------------------|----------------------|
| 6           | Contract Item Overrun                                       | 5.39%                  | Engineering          |
| 8           | Owner Induced Enhancement                                   | 4.99%                  | Engineering          |
| 4           | Contract Omission   | 4.02%                  | Engineering          |
| 7           | Geotechnical Issue  | 3.93%                  | Engineering          |
| 15          | Itemized cost breakdown supplied by contractor              | 3.80%                  | Administrative       |
| 18          | Cost plus worksheets  | 3.19%                  | Administrative       |
| 14          | Cost is less than or equal to 110% of avg. unit bid price   | 3.03%                  | Administrative       |
| 16          | Cost comparison to competitive bid in area for similar work | 2.68%                  | Administrative       |
| 10          | Contract Incentive  | 2.56%                  | Administrative       |
| 21          | Claim settlement  | 2.34%                  | Administrative       |
| 20          | Contract Item Underrun                                      | -4.19%                 | Administrative       |
| F-value     |   | 10.379                 |                      |
| P-value     |   | 0.000                  |                      |

Note: 11 codes are shown because Contract Item Underrun is a negative value. CO = change order. The highlighted reason codes are found to be prevalent on all the lists

Table 9 shows the highest average percent change by reason code for maintenance work only. The ANOVA analysis shows that the average percent change by reason code for maintenance work only has a statistically significant difference. The highest average percent change by reason code are Contract Incentive (13.28%), Owner Induced Enhancement (12.16%), and Cost comparison to competitive bid in area for similar work (10.84%). Again, Contract Incentive and Cost comparison to competitive bid in area for similar work do not occur frequently. However, Owner Induced Enhancement does occur frequently and the high average percent change is noted.

**Table 9: Largest Average Percent Change from Original Contract Amount per Code - Maintenance Work Only**

| Reason Code | Reason Code Explanation                                     | Average Percent Change | Type of Change Order |
|-------------|---|------------------------|----------------------|
| 10          | Contract Incentive  | 13.28%                 | Administrative       |
| 8           | Owner Induced Enhancement                                   | 12.16%                 | Engineering          |
| 16          | Cost comparison to competitive bid in area for similar work | 10.84%                 | Administrative       |
| 17          | Item special in nature                                      | 9.22%                  | Administrative       |
| 3           | Fuel & Asphalt Adjustment                                   | 8.84%                  | Engineering          |
| 6           | Contract Item Overrun                                       | 8.05%                  | Engineering          |
| 5           | Utility Issue   | 7.86%                  | Engineering          |
| 4           | Contract Omission   | 5.35%                  | Engineering          |
| 15          | Itemized cost breakdown supplied by contractor              | 4.07%                  | Administrative       |
| 18          | Cost plus worksheets  | 3.35%                  | Administrative       |
| 20          | Contract Item Underrun                                      | -10.18%                | Administrative       |
|             | F-value   | 11.545                 |                      |
|             | P-value   | 0.000                  |                      |

Note: 11 codes are shown because Contract Item Underrun is a negative value. CO = change order. The highlighted reason codes are found to be prevalent on all the lists

From these lists, three reason codes consistently appear on all lists:

- Contract Omission,
- Contract Item Overrun, and
- Owner Induced Enhancement.

These reason codes are often associated with engineering design issues which directly affect the construction process. If not addressed and handled properly, engineering issues can lead to rework and a loss of productivity. These three specific codes are having a broad impact on the Cabinet’s portfolio of projects.

In addition to the above lists, the analyses examined which codes occur on the same project so that causes of change orders can be expected and accounted for. For example if there is an Asphalt Lot Pay Adjustment, there is a good chance the same project will have change orders resulting from Fuel & Asphalt Adjustment. By understanding the correlation of two reason codes, both causes can be planned for and minimized. Table 10 shows the top reason code combinations on projects.

Table 10: Top 10 Combinations of Reason Codes on Projects

| Code Combo | Reason Code Explanation   | Pearson's Correlation | P-value | Sample Size | Type of Change Order         |
|------------|---|-----------------------|---------|-------------|------------------------------|
| 26 & 27    | Incorrect project wage rates, reimburse contractor the difference & Item shall include all labor, equipment, materials, & overhead for item | 0.814                 | 0.00    | 6           | Administrative               |
| 1 & 3      | Asphalt Lot Pay Adjustment & Fuel & Asphalt Adjustment  | 0.443                 | 0.00    | 127         | Engineering                  |
| 15 & 18    | Itemized cost breakdown supplied by contractor & Cost plus worksheets   | 0.299                 | 0.00    | 11          | Administrative               |
| 5 & 17     | Utility Issue & Item special in nature  | 0.289                 | 0.00    | 23          | Engineering & Administrative |
| 15 & 16    | Itemized cost breakdown supplied by contractor & Cost comparison to competitive bid in area for similar work                                | 0.281                 | 0.00    | 17          | Administrative               |
| 7 & 17     | Geotechnical Issue & Item special in nature   | 0.281                 | 0.00    | 25          | Engineering & Administrative |
| 5 & 7      | Utility Issue & Geotechnical Issue  | 0.275                 | 0.00    | 23          | Engineering                  |
| 16 & 17    | Cost comparison to competitive bid in area for similar work & Item special in nature  | 0.273                 | 0.00    | 20          | Administrative               |
| 4 & 20     | Contract Omission & Contract Item Underrun  | 0.273                 | 0.00    | 102         | Engineering & Administrative |
| 14 & 15    | Cost is less than or equal to 110% of avg. unit bid price & Itemized cost breakdown supplied by contractor                                  | 0.272                 | 0.00    | 16          | Administrative               |

Note: Contract Omission & Contract Item Underrun is ignored because Contract Item Underrun is considered an administrative reason in this study.

The above lists include both engineering issues and administrative issues. The administrative reasons tend to be supplemental in nature such as renewals and cost comparisons, which are separate from issues that arise in the field. The Pearson Correlation Coefficient is used to determine the likelihood of two reason codes occurring on the same project.

The code combinations that show up frequently in pairs are not surprising. Asphalt Lot Pay Adjustment and Fuel & Asphalt Adjustment both involve asphalt work so it is expected that there is a stronger chance of occurring on the same project when compared with other causes. They have a Pearson Correlation Coefficient of 0.443 and a P-value of 0.00 so the correlation between the two codes is statistically significant. Utility Issue and Geotechnical Issue occurring on the same project also have a statistically significant correlation with a coefficient of 0.275 and a P-value of 0.000.

The eight engineering reason codes and their descriptive statistics are listed below:

**Table 11: Descriptive Statistics for Reason Codes**

| <b>Code</b> | <b>Reason</b>              | <b>Frequency</b> | <b>Avg. CO Amt. (\$)</b> | <b>Avg. Percent Change</b> |
|-------------|----------------------------|------------------|--------------------------|----------------------------|
| 1           | Asphalt Lot Pay Adjustment | 188              | \$7,699.93               | 0.79%                      |
| 3           | Fuel & Asphalt Adjustment  | 218              | \$82,336.07              | 7.05%                      |
| 4           | Contract Omission          | 243              | \$57,410.90              | 4.53%                      |
| 5           | Utility Issue              | 60               | \$35,428.11              | 3.16%                      |
| 6           | Contract Item Overrun      | 227              | \$104,857.53             | 6.73%                      |
| 7           | Geotechnical Issue         | 71               | \$90,777.41              | 3.02%                      |
| 8           | Owner Induced Enhancement  | 186              | \$88,297.13              | 7.80%                      |
| 9           | Environmental Issue        | 20               | \$19,737.72              | 0.47%                      |
| F-Value     |                            |                  | 4.025                    | 13.024                     |
| P-Value     |                            |                  | 0.000                    | 0.000                      |

Note: CO = change order.

The descriptive statistics for the reason codes in Table 11 show that Contract Omission has the highest frequency, occurring on 243 projects, yet Contract Omission only has the fifth highest average change order dollar amount and the fourth highest average percent change. The highest average change order dollar amount is Contract Item Overrun, with an average of \$104,857.53. Contract Item Overrun also has the second highest frequency, occurring on 227 projects and the second highest average percent change with an average of 6.73%. The highest average percent change is Owner Induced Enhancement, with an average contract change of 7.80%. Owner Induced Enhancement has the fifth highest frequency, occurring on 186 projects and the third highest average

change order dollar amount. Asphalt Lot Pay Adjustment occurs on 188 projects, but has the lowest average change order dollar amount and the second lowest average percent change. Environmental Issue has the lowest frequency and average percent change, occurring on only 20 projects and having a 0.47% change in contract budget. The P-value for the average change order dollar amount is 0.000, which signifies a statistically significant difference between the reason codes average change order dollar amount. The P-value for the average percent change is 0.000, which signifies a statistically significant difference between the reason codes average percent change.

It is important to understand that there is a statistically significant difference between the average change order dollar amounts of each reason code and the average percent change of each reason code. However, not a single reason code stood out as the number one concern for the Cabinet according to the descriptive statistics. When examined by frequency, the primary concern was Contract Omission, but it was followed close by Contract Item Overrun, and Fuel & Asphalt Adjustment. When looking at average change order dollar amount, Contract Item Overrun has the highest average dollar amount, but Geotechnical Issue, Owner Induced Enhancement, and Fuel & Asphalt Adjustment also have high average change order dollar amounts. When considering the average percent change, Owner Induced Enhancement has the highest average, but Fuel & Asphalt Adjustment and Contract Item Overrun also have high average percent changes.

The descriptive statistics show an important statistical breakdown of the frequency and magnitude of the reason codes, but more analyses are done to incorporate the descriptive statistics along with project characteristics. The next part of the analyses looks at the road type of the projects.

### **3.3 Road Types**

The following analyses examine the causes of change orders on different road types. With this awareness, the Cabinet can allocate their resources more efficiently and anticipate specific change orders on individual road types, especially during constructability reviews. The road type for each project was given in the original data set provided by the Cabinet. However, the road type was not identified for all projects in the original data set. Some of the road types were determined by reading the brief

description given in the original data set, while some of the road types were not able to be determined. There are 481 of the 610 projects that have a determined road type and there are 129 of the 610 projects with undetermined road types. The road types used in the following analyses and their corresponding descriptive statistics are listed in Table 12.

**Table 12: Road Types**

| Description | Initials | Frequency | Avg. CO Amount (\$) | Avg. Percent Change |
|-------------|----------|-----------|---------------------|---------------------|
| State       | KY       | 305       | \$70,082.6075       | 8.51%               |
| US          | US       | 112       | \$73,253.7493       | 8.32%               |
| Interstate  | I        | 30        | \$370,743.0109      | 3.96%               |
| Parkway     | PW       | 19        | \$63,628.9520       | 5.25%               |
| County Road | CR       | 13        | \$45,577.5815       | 6.56%               |
| City Street | CS       | 2         | \$9,983.4700        | 8.16%               |
| F-value     |          |           | 2.647               | 2.455               |
| P-value     |          |           | 0.035               | 0.048               |

Note: County Street only had 2 projects so the sample size was too small to use. CO = change order.

In Table 12, the descriptive statistics for the different road types show that Kentucky roadways have the most frequent number of projects (305) experiencing change orders followed by US roadways (112). The highest average change order dollar amount is \$370,743.01, and it occurs on Interstates. US roadways and Kentucky roadways have the next highest average change order dollar amounts (\$73,253.75 and \$70,082.61 respectively). The highest average percent change occurs on Kentucky roadways (8.51%). US roadways have the second highest percent change with a change of 8.32%. City Streets also have high average percent change, but only have a sample size of 2. Another important finding is that there is a statistically significant difference between the road types for average change order dollar amount (P-value = 0.035) and average percent change (P-value = 0.048). It is also important to consider that while Interstates have a high average change order dollar amount; their percent change is the smallest, reflecting their relatively higher contract values compared to other road types. When examining the statistics, it is important to realize that the percent change accounts for the change orders effect on the original contract amount regardless of size or complexity of construction.

The next analysis uses the ANOVA analysis by comparing the means of the different reason codes and determines which reason codes have a statistically significant difference on the various road types. Once the statistically significant reason codes are known and the results are studied, resources are used to minimize the causes of change orders. Furthermore, breaking the projects down by road type allows resources to be efficiently allocated to limit the negative effects of change orders and creates the greatest chance of project success.

In Table 13, the average percent change by road type is compared between the most frequent reason codes. For new construction and maintenance work combined, the only code that shows a statistically significant difference from the other codes is Fuel & Asphalt Adjustment. Its F-value is 5.348 and its P-value is 0.000. For Fuel & Asphalt Adjustment, Kentucky roadways have the largest average percent change (8.44%). In Table 15, N represents the frequency of projects. The light gray represents a reason code that has a statistically significant difference from the other reason codes. The dark gray represents the road type that has the highest average percent change for the reason code that has a statistically significant difference.

**Table 13: ANOVA Analysis - New Construction & Maintenance Work Combined**

| Average Percent Change from Original Contract Amount by Road Type – New Construction & Maintenance Work Combined |        |   |           |      |   |           |       |    |           |       |     |           |       |    |           |       |    |           |            |    |           |         |       |
|--|--------|---|-----------|------|---|-----------|-------|----|-----------|-------|-----|-----------|-------|----|-----------|-------|----|-----------|------------|----|-----------|---------|-------|
| Road Type  | CR     |   |           | CS   |   |           | I     |    |           | KY    |     |           | PW    |    |           | US    |    |           | Not Listed |    |           | F Value | Sig.  |
|  | Mean   | N | Std. Dev. | Mean | N | Std. Dev. | Mean  | N  | Std. Dev. | Mean  | N   | Std. Dev. | Mean  | N  | Std. Dev. | Mean  | N  | Std. Dev. | Mean       | N  | Std. Dev. |         |       |
| Contract Incentive   |        |   |           |      |   |           | 2.34  | 2  | 1.29      | 0     | 1   | .         |       |    |           |       |    |           | 11.03      | 13 | 8.67      | 1.599   | 0.239 |
| Owner Induced Enhancement  | 2.58   | 2 | 3.64      |      |   |           | 2.26  | 21 | 3.63      | 7.73  | 72  | 12.24     | 0.84  | 10 | 1.38      | 9.8   | 35 | 14.89     | 10.67      | 46 | 19.95     | 1.688   | 0.14  |
| Fuel & Asphalt Adjustments   | 0.07   | 2 | 0.09      |      |   |           | 4.54  | 11 | 3.32      | 8.44  | 120 | 5.63      | 1.98  | 10 | 3.98      | 6.34  | 44 | 5.52      | 5.66       | 31 | 4.15      | 5.348   | 0.00  |
| Contract Item Overrun  | 11.86  | 7 | 21.85     | 11.8 | 1 | .         | 4.39  | 11 | 6.13      | 6.77  | 105 | 11.87     | 6.21  | 10 | 8.2       | 3.74  | 35 | 4.02      | 8.28       | 58 | 12.14     | 0.97    | 0.446 |
| Cost comparison to competitive bid in area for similar work  |        |   |           |      |   |           | 0.37  | 4  | 0.33      | 4.14  | 30  | 7.36      | 19.51 | 1  | .         | 2.54  | 4  | 2.76      | 14.08      | 12 | 29.35     | 1.286   | 0.289 |
| Contract Omission  | 2.43   | 7 | 2.03      | 4.51 | 1 | .         | 1.67  | 19 | 1.98      | 5.54  | 109 | 8.67      | 2.61  | 11 | 4.07      | 5.85  | 46 | 11.74     | 2.92       | 50 | 4.46      | 1.389   | 0.22  |
| Item special in nature   | 0.27   | 1 | .         |      |   |           | 1.5   | 11 | 2.06      | 2.97  | 25  | 5.14      | 0.47  | 1  | .         | 7.32  | 10 | 14.97     | 6.53       | 19 | 14.47     | 0.653   | 0.66  |
| Itemized cost breakdown supplied by contractor   | 3.1    | 1 | .         |      |   |           | 0.67  | 9  | 0.76      | 5.73  | 21  | 10.28     |       |    |           | 1.09  | 7  | 2.03      | 4.72       | 11 | 6.26      | 0.987   | 0.425 |
| Cost plus worksheets   | 3.01   | 1 | .         |      |   |           | 0.55  | 4  | 0.84      | 6.24  | 9   | 12.6      |       |    |           | 2.5   | 3  | 1.3       | 0.34       | 5  | 0.22      | 0.512   | 0.728 |
| Utility Issue  | 6.9    | 3 | 5.41      |      |   |           | 0.06  | 2  | 0.04      | 1.77  | 28  | 3.62      | 0.57  | 1  | .         | 1.49  | 13 | 2.39      | 7.67       | 13 | 14.69     | 1.488   | 0.209 |
| Contract Item Underrun   | -18.18 | 3 | 23.69     |      |   |           | -3.76 | 17 | 5.28      | -5.57 | 66  | 8.61      | -4.51 | 9  | 3.89      | -4.42 | 24 | 5.44      | -9.48      | 46 | 27.47     | 0.884   | 0.494 |

Table 14 shows the ANOVA analysis for new construction only. The ANOVA analysis shows one reason code having an average percent change with a statistically significant difference from the other codes, “Cost comparison to competitive bid in area for similar work”. This is an administrative issue, so it can be ignored. However, there are three codes that do not currently have a statistically significant difference at the 95% confidence interval, but they are close to the 0.05 significance level. The codes are Owner Induced Enhancement, Contract Omission, and Geotechnical Issue. The highest average percent change for Owner Induced Enhancement occurs on US roadways (7.64%). For Contract Omission, the highest average percent change occurs on Kentucky roadways (5.92%). The highest average percent change for Geotechnical Issue occurs on US roadways (8.89%). In Table 16, N represents the frequency of projects. The light gray represents a reason code that has a statistically significant difference from the other reason codes or that is close to the 0.05 significance level. The dark gray represents the road type that has the highest average percent change for the reason codes that have a statistically significant difference or that are close to the 0.05 significance level.

**Table 14: ANOVA Analysis - New Construction Only**

| Average Percent Change from Original Contract Amount by Road Type – New Construction Only |       |   |           |      |   |           |       |    |           |      |    |           |       |    |           |       |    |           |            |    |           |         |       |
|---|-------|---|-----------|------|---|-----------|-------|----|-----------|------|----|-----------|-------|----|-----------|-------|----|-----------|------------|----|-----------|---------|-------|
| Road Type   | CR    |   |           | CS   |   |           | I     |    |           | KY   |    |           | PW    |    |           | US    |    |           | Not Listed |    |           | F Value | Sig.  |
|   | Mean  | N | Std. Dev. | Mean | N | Std. Dev. | Mean  | N  | Std. Dev. | Mean | N  | Std. Dev. | Mean  | N  | Std. Dev. | Mean  | N  | Std. Dev. | Mean       | N  | Std. Dev. |         |       |
| <b>Contract Item Overrun</b>  | 3.66  | 6 | 2.76      |      |   |           | 4.29  | 8  | 7.14      | 5.68 | 54 | 11.27     | 6.21  | 10 | 8.2       | 3.33  | 14 | 3.51      | 6.55       | 21 | 13.72     | 0.232   | 0.948 |
| <b>Owner Induced Enhancement</b>  | 2.58  | 2 | 3.64      |      |   |           | 2.38  | 20 | 3.67      | 7.58 | 42 | 12.88     | 0.84  | 10 | 1.38      | 7.64  | 15 | 8.49      | 2.9        | 24 | 4.62      | 2.022   | 0.081 |
| <b>Contract Omission</b>  | 2.43  | 7 | 2.03      | 4.51 | 1 | .         | 1.45  | 16 | 1.58      | 5.92 | 74 | 9.3       | 2.61  | 11 | 4.07      | 1.85  | 14 | 2.05      | 2.42       | 27 | 2.81      | 1.922   | 0.081 |
| <b>Geotechnical Issue</b>   | 10.34 | 1 | .         |      |   |           | 0.12  | 4  | 0.67      | 2.92 | 32 | 4.95      | 3.78  | 3  | 5.66      | 8.89  | 8  | 8.23      | 4.08       | 16 | 6.04      | 2.069   | 0.082 |
| <b>Itemized cost breakdown supplied by contractor</b>                                     | 3.1   | 1 | .         |      |   |           | 0.66  | 8  | 0.81      | 6.21 | 18 | 11.07     |       |    |           | 0.26  | 3  | 0.09      | 2.92       | 8  | 2.7       | 0.879   | 0.487 |
| <b>Cost plus worksheets</b>   | 3.01  | 1 | .         |      |   |           | 0.55  | 4  | 0.84      | 7.13 | 7  | 14.35     |       |    |           | 1.87  | 2  | 0.99      | 0.34       | 5  | 0.22      | 0.51    | 0.729 |
| <b>Cost is less than or equal to 110% of avg. unit bid price</b>                          | 0.96  | 1 | .         | 4.51 | 1 | .         | 0.37  | 6  | 0.47      | 4.47 | 22 | 9.38      | 1.13  | 2  | 0.56      | 1.15  | 1  | .         | 1.66       | 7  | 2.06      | 0.347   | 0.906 |
| <b>Cost comparison to competitive bid in area for similar work</b>                        |       |   |           |      |   |           | 0.37  | 4  | 0.33      | 2.32 | 18 | 3.19      | 19.51 | 1  | .         | 0.07  | 1  | .         | 3.06       | 4  | 3.42      | 8.685   | 0.00  |
| <b>Contract Incentive</b>   |       |   |           |      |   |           | 2.34  | 2  | 1.29      | 0    | 1  | .         |       |    |           |       |    |           | 3.56       | 3  | 3.3       | 0.617   | 0.596 |
| <b>Claim Settlement</b>   |       |   |           |      |   |           | 0.03  | 1  | .         | 2.73 | 3  | 3.07      |       |    |           | 5.17  | 2  | 7.05      | 0.85       | 3  | 0.79      | 0.68    | 0.601 |
| <b>Contract Item Underrun</b>   | -4.54 | 2 | 2.56      |      |   |           | -2.63 | 14 | 3.09      | -5.5 | 46 | 8.83      | -4.51 | 9  | 3.89      | -1.83 | 6  | 2.11      | -3.1       | 25 | 8.31      | 0.627   | 0.68  |

Table 15 shows the ANOVA analysis for maintenance work only. The ANOVA analysis shows the reason codes having average percent changes with a statistically significant difference from the other reason codes. The codes of statistically significant difference are Fuel & Asphalt Adjustment, Contract Item Overrun, and Utility Issue. The highest average percent change for Fuel & Asphalt Adjustment occurs on Kentucky roadways (9.82%). For Contract Item Overrun, the highest average percent change also occurs on Kentucky roadways (7.93%). In this analysis, Utility Issue is ignored because its high average percent change occurs on projects that do not have a specified road type. It is noted that Utility Issue has a high average percent change of 19.14%, but it cannot be correlated with a specific road type. Also, the sample size is only 5 projects and the standard deviation is 19.48, indicating a large amount of variability in the data. In Table 15, N represents the frequency of projects. The light gray represents a reason code that has a statistically significant difference from the other reason codes. The dark gray represents the road type that has the highest average percent change for the reason codes that have a statistically significant difference.

**Table 15: ANOVA Analysis - Maintenance Work Only**

| Average Percent Change from Original Contract by Road Type – Maintenance Work Only |        |   |           |      |   |           |       |   |           |       |    |           |       |    |           |            |    |           |         |       |
|--|--------|---|-----------|------|---|-----------|-------|---|-----------|-------|----|-----------|-------|----|-----------|------------|----|-----------|---------|-------|
| Road Type  | CR     |   |           | CS   |   |           | I     |   |           | KY    |    |           | US    |    |           | Not Listed |    |           | F Value | Sig.  |
|  | Mean   | N | Std. Dev. | Mean | N | Std. Dev. | Mean  | N | Std. Dev. | Mean  | N  | Std. Dev. | Mean  | N  | Std. Dev. | Mean       | N  | Std. Dev. |         |       |
| <b>Contract Incentive</b>  |        |   |           |      |   |           |       |   |           |       |    |           |       |    |           | 13.28      | 10 | 8.59      | N/A     | N/A   |
| <b>Owner Induced Enhancement</b>   |        |   |           |      |   |           | -0.25 | 1 | .         | 7.94  | 30 | 11.48     | 11.42 | 20 | 18.36     | 19.15      | 22 | 26.17     | 1.66    | 0.184 |
| <b>Cost comparison to competitive bid in area for similar work</b>                 |        |   |           |      |   |           |       |   |           | 6.88  | 12 | 10.65     | 3.37  | 3  | 2.71      | 19.59      | 8  | 35.27     | 0.971   | 0.396 |
| <b>Item Special in Nature</b>  |        |   |           |      |   |           |       |   |           | 4.4   | 8  | 6.67      | 10.82 | 4  | 21.64     | 12.8       | 9  | 19.6      | 0.585   | 0.567 |
| <b>Fuel &amp; Asphalt Adjustments</b>  |        |   |           |      |   |           | 6.76  | 2 | 5.11      | 9.82  | 97 | 5.31      | 7.64  | 35 | 5.4       | 6.8        | 24 | 3.87      | 3.175   | 0.026 |
| <b>Contract Item Overrun</b>   | 61.09  | 1 | .         | 11.8 | 1 | .         | 4.65  | 3 | 3.01      | 7.93  | 51 | 12.47     | 4.01  | 21 | 4.39      | 9.26       | 37 | 11.22     | 5.539   | 0.000 |
| <b>Utility Issue</b>   |        |   |           |      |   |           |       |   |           | 1.8   | 6  | 6.36      | 1.19  | 3  | 1.53      | 19.14      | 5  | 19.48     | 3.156   | 0.083 |
| <b>Contract Omission</b>   |        |   |           |      |   |           | 2.82  | 3 | 3.75      | 4.73  | 35 | 7.22      | 7.61  | 32 | 13.7      | 3.5        | 23 | 5.86      | 0.973   | 0.409 |
| <b>Itemized cost breakdown supplied by contractor</b>                              |        |   |           |      |   |           | 0.77  | 1 | .         | 2.84  | 3  | 0.59      | 1.72  | 4  | 2.66      | 9.54       | 3  | 11.08     | 1.11    | 0.407 |
| <b>Cost plus worksheets</b>  |        |   |           |      |   |           |       |   |           | 3.14  | 2  | 2.98      | 3.77  | 1  | .         |            |    |           | 0.03    | 0.891 |
| <b>Contract Item Underrun</b>  | -45.46 | 1 | .         |      |   |           | -9.04 | 3 | 10.48     | -5.73 | 20 | 8.3       | -5.28 | 18 | 5.97      | -17.09     | 21 | 38.77     | 1.386   | 0.25  |

In addition to the ANOVA analysis, the Pearson Chi-Square analysis is used to compare frequency counts of the top ten most frequent codes. The frequencies are also broken down into road type. Table 16 shows the Pearson Chi-Square analysis for new construction and maintenance work combined. The codes that show a statistically significant difference from the other codes are Contract Omission and Owner Induced Enhancement. On interstates, Contract Omission occurs on 63.33% of the projects (19 out of 30 projects) and Owner Induced Enhancement occurs on 70.00% of the projects (21 out of 30 projects). The frequencies for Contract Item Underrun and “Item special in nature” also show a statistically significant difference but are ignored in this study since they are classified as administrative issues. In Table 16, N represents the frequency of projects. The light gray represents a reason code with a statistically significant difference from the other reason codes and also highlights road types having a high percentage of occurrences.

**Table 16: Chi-Square Analysis – New Construction and Maintenance Work Combined**

| Chi-Square – New Construction and Maintenance Work Combined |    |                   |               |                       |               |                            |               |                             |               |                           |               |                        |               |                    |               |                        |               |               |               |   |               |
|---|----|-------------------|---------------|-----------------------|---------------|----------------------------|---------------|-----------------------------|---------------|---------------------------|---------------|------------------------|---------------|--------------------|---------------|------------------------|---------------|---------------|---------------|---|---------------|
|   |    | Contract Omission |               | Contract Item Overrun |               | Fuel & Asphalt Adjustments |               | Asphalt Lot Pay Adjustments |               | Owner Induced Enhancement |               | Contract Item Underrun |               | Geotechnical Issue |               | Item special in nature |               | Utility Issue |               | Cost comparison to competitive bid in area for similar work |               |
|   |    | Code 4            |               | Code 6                |               | Code 3                     |               | Code 1                      |               | Code 8                    |               | Code 20                |               | Code 7             |               | Code 17                |               | Code 5        |               | Code 16   |               |
|   |    | N                 | % of Projects | N                     | % of Projects | N                          | % of Projects | N                           | % of Projects | N                         | % of Projects | N                      | % of Projects | N                  | % of Projects | N                      | % of Projects | N             | % of Projects | N   | % of Projects |
| Road Type   | CR | 7 of 13           | 53.8<br>5%    | 7 of 13               | 53.8<br>5%    | 2 of 13                    | 15.3<br>8%    | 2 of 13                     | 15.3<br>8%    | 2 of 13                   | 15.3<br>8%    | 3 of 13                | 23.0<br>8%    | 1 of 13            | 7.69<br>%     | 1 of 13                | 7.69<br>%     | 3 of 13       | 23.0<br>8%    | 0 of 13   | 0.00<br>%     |
|   | I  | 19 of 30          | 63.3<br>3%    | 11 of 30              | 36.6<br>7%    | 11 of 30                   | 36.6<br>7%    | 6 of 30                     | 20.0<br>0%    | 21 of 30                  | 70.0<br>0%    | 17 of 30               | 56.6<br>7%    | 4 of 30            | 13.3<br>3%    | 11 of 30               | 36.6<br>7%    | 2 of 30       | 6.67<br>%     | 4 of 30   | 13.3<br>3%    |
|   | KY | 109 of 305        | 35.7<br>4%    | 105 of 305            | 34.4<br>3%    | 120 of 305                 | 39.3<br>4%    | 115 of 305                  | 37.7<br>0%    | 72 of 305                 | 23.6<br>1%    | 66 of 305              | 21.6<br>4%    | 37 of 305          | 12.1<br>3%    | 25 of 305              | 8.20<br>%     | 28 of 305     | 9.18<br>%     | 30 of 305   | 9.84<br>%     |
|   | PW | 11 of 19          | 57.8<br>9%    | 10 of 19              | 52.6<br>3%    | 10 of 19                   | 52.6<br>3%    | 6 of 19                     | 31.5<br>8%    | 10 of 19                  | 52.6<br>3%    | 9 of 19                | 47.3<br>7%    | 3 of 19            | 15.7<br>9%    | 1 of 19                | 5.26<br>%     | 1 of 19       | 5.26<br>%     | 1 of 19   | 5.26<br>%     |
|   | US | 46 of 112         | 41.0<br>7%    | 35 of 112             | 31.2<br>5%    | 44 of 112                  | 39.2<br>9%    | 35 of 112                   | 31.2<br>5%    | 35 of 112                 | 31.2<br>5%    | 24 of 112              | 21.4<br>3%    | 10 of 112          | 8.93<br>%     | 10 of 112              | 8.93<br>%     | 13 of 112     | 11.6<br>1%    | 4 of 112  | 3.57<br>%     |
| Pearson Chi-Square  |    | 12.731            |               | 5.393                 |               | 4.617                      |               | 6.885                       |               | 35.226                    |               | 23.833                 |               | 1.477              |               | 25.452                 |               | 3.910         |               | 6.743   |               |
| Sig.  |    | .013              |               | .249                  |               | .329                       |               | .142                        |               | .000                      |               | .000                   |               | .831               |               | .000                   |               | .418          |               | .150  |               |

Table 17 shows the Chi-Square analysis for new construction only. The codes that show a statistically significant difference from the other codes are Owner Induced Enhancement and Fuel & Asphalt Adjustment. On Interstates, Owner Induced Enhancement occurs on 86.96% (20 out of 23 projects) of the projects. On Parkways, Fuel & Asphalt Adjustment occurs on 52.63% (10 out of 19 projects) of the projects. While the Pearson Chi-Square analysis does not show any other codes having a statistically significant difference, there are a couple of codes and roadways to note. Contract Omission occurs on 69.57% (16 out of 23) of Interstate projects and on 62.18% (74 out of 119 projects) of Kentucky roadways. Owner Induced Enhancement also occurs on Parkways on 52.63% (10 out of 19 projects) of the projects and on US roadways on 53.57% (15 out of 28 projects) of the projects. Utility Issue is just above the statistically significant difference level, with a P-value of 0.053. In Table 17, N represents the frequency of projects. The light gray represents a reason code that has a statistically significant difference from the other reason codes and also highlights road types having a high percentage of occurrences.

**Table 17: Chi-Square Analysis – New Construction Only**

| Chi-Square – New Construction Only |    |                   |                |                       |                |                           |                |                        |                |                    |                |                            |                |                             |                |               |                |                        |                |   |                |
|------------------------------------|----|-------------------|----------------|-----------------------|----------------|---------------------------|----------------|------------------------|----------------|--------------------|----------------|----------------------------|----------------|-----------------------------|----------------|---------------|----------------|------------------------|----------------|---|----------------|
|                                    |    | Contract Omission |                | Contract Item Overrun |                | Owner Induced Enhancement |                | Contract Item Underrun |                | Geotechnical Issue |                | Fuel & Asphalt Adjustments |                | Asphalt Lot Pay Adjustments |                | Utility Issue |                | Item special in nature |                | Cost is less than or equal to 110% of avg. unit bid price |                |
|                                    |    | Code 4            |                | Code 6                |                | Code 8                    |                | Code 20                |                | Code 7             |                | Code 3                     |                | Code 1                      |                | Code 5        |                | Code 17                |                | Code 14   |                |
|                                    |    | N                 | % of Proje cts | N                     | % of Proje cts | N                         | % of Proje cts | N                      | % of Proje cts | N                  | % of Proje cts | N                          | % of Proje cts | N                           | % of Proje cts | N             | % of Proje cts | N                      | % of Proje cts | N   | % of Proje cts |
| Road Type                          | CR | 7 of 12           | 58.3 3%        | 6 of 12               | 50.0 0%        | 2 of 12                   | 16.6 7%        | 2 of 12                | 16.6 7%        | 1 of 12            | 8.33 %         | 2 of 12                    | 16.6 7%        | 2 of 12                     | 16.6 7%        | 3 of 12       | 25.0 0%        | 1 of 12                | 8.33 %         | 1 of 6  | 8.33 %         |
|                                    | I  | 16 of 23          | 69.5 7%        | 8 of 23               | 34.7 8%        | 20 of 23                  | 86.9 6%        | 14 of 23               | 60.8 7%        | 4 of 23            | 17.3 9%        | 9 of 23                    | 39.1 3%        | 5 of 23                     | 21.7 4%        | 2 of 23       | 8.70 %         | 11 of 23               | 47.8 3%        | 6 of 23   | 26.0 9%        |
|                                    | KY | 74 of 119         | 62.1 8%        | 54 of 119             | 45.3 8%        | 42 of 119                 | 35.2 9%        | 46 of 119              | 38.6 6%        | 32 of 119          | 26.8 9%        | 23 of 119                  | 19.3 3%        | 28 of 119                   | 23.5 3%        | 22 of 119     | 18.4 9%        | 17 of 119              | 14.2 9%        | 22 of 119   | 18.4 9%        |
|                                    | PW | 11 of 19          | 57.8 9%        | 10 of 19              | 52.6 3%        | 10 of 19                  | 52.6 3%        | 9 of 19                | 47.3 7%        | 3 of 19            | 15.7 9%        | 10 of 19                   | 52.6 3%        | 6 of 19                     | 31.5 8%        | 1 of 19       | 5.26 %         | 1 of 19                | 5.26 %         | 2 of 19   | 10.5 3%        |
|                                    | US | 14 of 28          | 50.0 0%        | 14 of 28              | 50.0 0%        | 15 of 28                  | 53.5 7%        | 6 of 28                | 21.4 3%        | 8 of 28            | 28.5 7%        | 9 of 28                    | 32.1 4%        | 6 of 28                     | 21.4 3%        | 10 of 28      | 35.7 1%        | 6 of 28                | 21.4 3%        | 1 of 28   | 3.57 %         |
| Pearson Chi-Square                 |    | 2.302             |                | 1.775                 |                | 26.098                    |                | 11.374                 |                | 3.745              |                | 12.780                     |                | 1.110                       |                | 9.335         |                | 18.115                 |                | 6.481   |                |
| Sig.                               |    | .680              |                | .777                  |                | .000                      |                | .023                   |                | .442               |                | .012                       |                | .893                        |                | .053          |                | .001                   |                | .116  |                |

Table 18 shows the Chi-Square analysis for maintenance work only. The code that shows a statistically significant difference from the other codes is Contract Omission. On Interstates, Contract Omission occurs on 42.86% (3 out of 7 projects) of the projects. While not showing a statistically significant difference at the 95% confidence interval, Fuel & Asphalt Adjustment and Asphalt Lot Pay Adjustment occurs on Kentucky roadways on 52.15% (97 out of 186 projects) of the projects and on 46.77% (87 out of 186 projects) of the projects respectively. In Table 18, N represents the frequency of projects. The light gray represents a reason code that has a statistically significant difference from the other reason codes and also highlights road types having a high percentage of occurrences.

**Table 18: Chi-Square Analysis – Maintenance Work Only**

| Chi-Square – Maintenance Work Only |     |                            |               |                             |               |                       |               |                   |               |                           |               |                        |               |   |               |                        |               |                                    |               |                       |               |
|------------------------------------|-----|----------------------------|---------------|-----------------------------|---------------|-----------------------|---------------|-------------------|---------------|---------------------------|---------------|------------------------|---------------|---|---------------|------------------------|---------------|------------------------------------|---------------|-----------------------|---------------|
|                                    |     | Fuel & Asphalt Adjustments |               | Asphalt Lot Pay Adjustments |               | Contract Item Overrun |               | Contract Omission |               | Owner Induced Enhancement |               | Contract Item Underrun |               | Cost comparison to competitive bid in area for similar work |               | Item special in nature |               | Specification/ Special Note Change |               | Accounting Adjustment |               |
|                                    |     | Code 3                     |               | Code 1                      |               | Code 6                |               | Code 4            |               | Code 8                    |               | Code 20                |               | Code 16   |               | Code 17                |               | Code 24                            |               | Code 12               |               |
|                                    |     | N                          | % of Projects | N                           | % of Projects | N                     | % of Projects | N                 | % of Projects | N                         | % of Projects | N                      | % of Projects | N   | % of Projects | N                      | % of Projects | N                                  | % of Projects | N                     | % of Projects |
| Road Type                          | C R | 0 of 1                     | 0.00 %        | 0 of 1                      | 0.00 %        | 1 of 1                | 100.00 %      | 0 of 1            | 0.00 %        | 0 of 1                    | 0.00 %        | 1 of 1                 | 100.00 %      | 0 of 1  | 0.00 %        | 0 of 1                 | 0.00 %        | 0 of 1                             | 0.00 %        | 0 of 1                | 0.00 %        |
|                                    | I   | 2 of 7                     | 28.57 %       | 1 of 7                      | 14.29 %       | 3 of 7                | 42.86 %       | 3 of 7            | 42.86 %       | 1 of 7                    | 14.29 %       | 3 of 7                 | 42.86 %       | 0 of 7  | 28.57 %       | 0 of 7                 | 0.00 %        | 1 of 7                             | 14.29 %       | 2 of 7                | 28.57 %       |
|                                    | K Y | 97 of 186                  | 52.15 %       | 87 of 186                   | 46.77 %       | 51 of 186             | 27.42 %       | 35 of 186         | 18.82 %       | 30 of 186                 | 16.13 %       | 20 of 186              | 10.75 %       | 12 of 186   | 1.08 %        | 8 of 186               | 4.30 %        | 7 of 186                           | 3.76 %        | 2 of 186              | 1.08 %        |
|                                    | U S | 35 of 84                   | 41.67 %       | 29 of 84                    | 34.52 %       | 21 of 84              | 25.00 %       | 32 of 84          | 38.10 %       | 20 of 84                  | 23.81 %       | 18 of 84               | 21.43 %       | 3 of 84   | 7.14 %        | 4 of 84                | 4.76 %        | 5 of 84                            | 5.95 %        | 6 of 84               | 7.14 %        |
| Pearson Chi-Square                 |     | 4.609                      |               | 6.594                       |               | 3.738                 |               | 12.932            |               | 2.586                     |               | 15.189                 |               | 1.410   |               | .401                   |               | 2.154                              |               | 19.084                |               |
| Sig.                               |     | .203                       |               | .086                        |               | .291                  |               | .005              |               | .460                      |               | .002                   |               | .703  |               | .940                   |               | .541                               |               | .000                  |               |

### **3.4 New Construction vs. Maintenance Work**

The next set of analyses examined the relative magnitude of change orders on maintenance projects. By knowing the causes of change orders on the two types of work (construction and maintenance), the Cabinet can take preventative measures to minimize change orders whether it is new construction or maintenance work. Also, it is possible that different levels of planning go into new construction and maintenance work. The Cabinet will see if the attention to detail and level of planning needs to be increased for new construction or maintenance work. The projects are broken into new construction and maintenance work based on the type of construction listed in the original data sets obtained from the Cabinet. Out of the 610 projects, there are 246 new construction projects and 364 maintenance projects. The type of construction and whether it is considered new construction or maintenance work is listed in Table 19.

**Table 19: New Construction vs. Maintenance Work - Frequencies**

| <b>New Construction</b>              | <b>Frequency</b> | <b>Maintenance Work</b>            | <b>Frequency</b> |
|--------------------------------------|------------------|------------------------------------|------------------|
| Asphalt Surfacing                    | 100              | Asphalt Resurfacing                | 282              |
| Bridge Work                          | 5                | Bridge Maintenance                 | 12               |
| Design Build                         | 1                | Culvert Replacement                | 7                |
| Grade & Drain                        | 90               | Flood/Slide Repair                 | 24               |
| Guardrail                            | 40               | Intersection Markings –<br>Install | 1                |
| Intelligent<br>Transportation System | 2                | Jointed Plain Concrete<br>Repair   | 17               |
| Jointed Plain Concrete               | 2                | Operations<br>(Maintenance)        | 4                |
| Lighting                             | 1                | Parking Lot Sealing                | 1                |
| Retaining Wall                       | 1                | Pavement Markers &<br>Reflectors   | 1                |
| Signs-Lighting-Signals               | 1                | Pipe Replacement                   | 4                |
| Sound Barrier Wall                   | 1                | Signs                              | 1                |
| Traffic/Signing &<br>Lighting        | 1                | Waterbourne Paint<br>Striping      | 10               |
| Weigh Station                        | 1                |                                    |                  |
| <b>Total</b>                         | <b>246</b>       | <b>Total</b>                       | <b>364</b>       |

Table 20 and 21 present the descriptive statistics for new construction only and maintenance work only and uses the ANOVA analysis to show that there is statistically significant differences between the reason codes. Table 22 presents the F-value and P-value for the average change order dollar amount and the average percent change between new construction and maintenance work. Both the average change order dollar amount (P-value = 0.000) and average percent change from original contract amount (P-value = 0.000) have a statistically significant difference between new construction and maintenance work.

Table 20 shows the descriptive statistics for new construction only. The most frequent reason code is Contract Omission (150) followed by Contract Item Overrun (113) and Owner Induced Enhancement (113). The highest average change order dollar amount is Fuel & Asphalt Adjustment (\$195,264.36) followed by Contract Item Overrun (\$160,934.37) and Owner Induced Enhancement (\$104,964.93). The highest average percent change is Contract Item Overrun (5.39%) followed by Owner Induced Enhancement (4.99%) and Contract Omission (4.02%). Asphalt Lot Pay Adjustment, Utility Issue, and Environmental Issue have the lowest values of the descriptive statistics.

Table 20 also shows that there is a statistically significant difference between the reason codes for average change order amount on new construction. Table 20 also shows that there is a statistically significant difference between the reason codes for average percent change on new construction. To minimize the effect of change orders on new construction the focus needs to be on Contract Omission, Contract Item Overrun, and Owner Induced Enhancement.

**Table 20: Descriptive Statistics – New Construction Only**

| Code                   | Reason                     | Frequency | Avg. CO Amt. (\$) | Average Percent Change |
|------------------------|----------------------------|-----------|-------------------|------------------------|
| 1                      | Asphalt Lot Pay Adjustment | 54        | \$17,570.75       | 0.47%                  |
| 3                      | Fuel & Asphalt Adjustment  | 60        | \$195,264.36      | 2.33%                  |
| 4                      | Contract Omission          | 150       | \$73,788.63       | 4.02%                  |
| 5                      | Utility Issue              | 46        | \$40,458.13       | 1.74%                  |
| 6                      | Contract Item Overrun      | 113       | \$160,934.37      | 5.39%                  |
| 7                      | Geotechnical Issue         | 64        | \$96,857.14       | 3.93%                  |
| 8                      | Owner Induced Enhancement  | 113       | \$104,964.93      | 4.99%                  |
| 9                      | Environmental Issue        | 15        | \$24,691.36       | 0.54%                  |
| <b>Overall Average</b> |                            |           | \$101,154.30      | 3.71%                  |
| <b>F-value</b>         |                            |           | 3.018             | 4.219                  |
| <b>P-value</b>         |                            |           | 0.004             | 0.000                  |

Note: CO = change order

Table 21 shows the descriptive statistics for maintenance work only. The most frequent reason code is Fuel & Asphalt Adjustment (158) followed by Asphalt Lot Pay Adjustment (134) and Contract Item Overrun (114). The highest average change order dollar amount is Owner Induced Enhancement (\$62,496.29) followed by Contract Item Overrun (\$49,272.60) and Fuel & Asphalt Adjustment (\$39,451.92). The highest average percent change is Owner Induced Enhancement (12.16%) followed by Fuel & Asphalt Adjustment (8.84%) and Contract Item Overrun (8.05%). Environmental Issue has a small frequency and small averages. One interesting code is Asphalt Lot Pay Adjustment. While it has a high frequency, it has the smallest average change order dollar amount (\$3,722.14) and the second smallest average percent change (0.92%). Another

observation is that Geotechnical Issue has a negative average percent change (-5.35%). This is due to two projects with large negative percent changes (-33.62% and -20.48%). The project code ids are 52309 and 62049. When the two projects are excluded, the average percent change is 3.33%. The data for the two projects might have been input incorrectly, leading to the large negative percent change. Table 21 also shows that there is a statistically significant difference between the reason codes for average change order amount on maintenance work. Table 21 also shows that there is a statistically significant difference between the reason codes for average percent change on maintenance work. To minimize the effect of change orders on maintenance work the focus needs to be on Contract Omission, Contract Item Overrun, and Owner Induced Enhancement. Fuel & Asphalt Adjustment is another code with a large effect, but it is outside of the Cabinet's control due to market prices.

**Table 21: Descriptive Statistics – Maintenance Work Only**

| Code                   | Reason                     | Frequency | Average CO Amt.(\$) | Average Percent Change |
|------------------------|----------------------------|-----------|---------------------|------------------------|
| 1                      | Asphalt Lot Pay Adjustment | 134       | \$3,722.14          | 0.92%                  |
| 3                      | Fuel & Asphalt Adjustment  | 158       | \$39,451.92         | 8.84%                  |
| 4                      | Contract Omission          | 93        | \$30,995.20         | 5.35%                  |
| 5                      | Utility Issue              | 14        | \$18,900.92         | 7.86%                  |
| 6                      | Contract Item Overrun      | 114       | \$49,272.60         | 8.05%                  |
| 7                      | Geotechnical Issue         | 7         | \$35,191.31         | -5.35%                 |
| 8                      | Owner Induced Enhancement  | 73        | \$62,496.29         | 12.16%                 |
| <b>Overall Average</b> |                            |           | \$33,995.59         | 6.52%                  |
| <b>F-value</b>         |                            |           | 3.995               | 12.695                 |
| <b>P-value</b>         |                            |           | 0.000               | 0.000                  |

Note: CO = change order

Table 22 shows that there is a statistically significant difference between the average change order dollar amount on new construction and maintenance work. Table 22 also shows that there is a statistically significant difference between the average percent change from original contract amount on new construction and maintenance work.

**Table 22: Significance between New Construction & Maintenance**

| Significance Between New Construction & Maintenance Work for Average Change Order Dollar Amount and Average Percent Change from Original Contract Amount |                                       |         |                   |                        |
|--|---------------------------------------|---------|-------------------|------------------------|
|  |                                       |         | Avg. CO Amt. (\$) | Average Percent Change |
| Group  | New Construction vs. Maintenance Work | F-value | 30.110            | 28.546                 |
|  |                                       | P-value | 0.000             | 0.000                  |

Note: CO = change order

### 3.5 Type of Construction

Knowing the causes of change orders with relation to the grouping of construction type allows the Cabinet to understand not only which types of construction projects occur

more frequently, but also the causes of change orders on the specific types of construction. The Cabinet can focus on the reasons for change orders that are linked to the specific types of construction to minimize the effects of change orders.

There are obviously many types of construction, but for analysis purposes, the type of construction is grouped into three categories: earthwork, road surface, and structures. Earthwork consists of the following:

- Grade and drain; and
- Flood/Slide repair

Road surface consists of the following:

- Asphalt resurfacing;
- Asphalt surfacing;
- Intersection markings – install;
- Jointed plain concrete;
- Jointed plain concrete repair;
- Operations (maintenance);
- Parking lot sealing;
- Pavement markers & reflectors; and
- Waterborne paint striping

Structures consist of the following:

- Bridge maintenance;
- Bridge work;
- Culvert replacement;
- Design build;
- Guardrail;
- Lighting;
- Pipe replacement;
- Retaining wall;
- Signs;
- Signs-lighting-signals;
- Sound barrier wall;

- Traffic/signing & lighting; and
- Weigh station

Out of the 610 construction projects, 114 (18.69% of projects) are classified as earthwork, 417 (68.36% of projects) are classified as road surface, and 79 (12.95% of projects) are classified as structures.

Table 23 through 25 presents the descriptive statistics for earthwork, road surface, and structures construction and uses the ANOVA analysis to show that there is a statistically significant difference between the reason codes. Table 28 presents the F-value and P-value for the average change order dollar amount and the average percent change between earthwork, road surface, and structures construction. The average change order dollar amount (P-value = 0.317) does not show a statistically significant difference between the types of construction. However, the average percent change (P-value = 0.000) shows a statistically significant difference between the types of construction. From the ANOVA analysis, the average percent change shows a statistically significant difference.

Table 23 shows the descriptive statistics for earthwork. The most frequent reason code is Contract Omission (69) followed by Contract Item Overrun (52) and Owner Induced Enhancement (41). The highest average change order dollar amount is Fuel & Asphalt Adjustment (\$163,984.27) followed by Contract Item Overrun (\$107,312.65) and Geotechnical Issue (\$92,241.81). The highest average percent change is Contract Item Overrun (6.37%) followed by Utility Issue (4.22%) and Contract Omission (3.08%). Asphalt Lot Pay Adjustment and Environmental Issue have the lowest values of the descriptive statistics. Table 23 also shows that there is not a statistically significant difference between the reason codes for average change order amount or average percent change for earthwork. To minimize the effect of change orders on earthwork construction the focus needs to be on Contract Omission, Contract Item Overrun, and Geotechnical Issue. Again, Fuel & Asphalt Adjustment is out of the Cabinet's control.

**Table 23: Earthwork - Descriptive Statistics**

| <b>Code</b>     | <b>Reason</b>              | <b>Frequency</b> | <b>Avg. CO Amt. (\$)</b> | <b>Average Percent Change</b> |
|-----------------|----------------------------|------------------|--------------------------|-------------------------------|
| 1               | Asphalt Lot Pay Adjustment | 18               | \$25,942.54              | 0.53%                         |
| 3               | Fuel & Asphalt Adjustment  | 27               | \$163,984.27             | 1.89%                         |
| 4               | Contract Omission          | 69               | \$70,166.07              | 3.08%                         |
| 5               | Utility Issue              | 32               | \$38,078.40              | 4.22%                         |
| 6               | Contract Item Overrun      | 52               | \$107,312.65             | 6.37%                         |
| 7               | Geotechnical Issue         | 40               | \$92,241.81              | 2.66%                         |
| 8               | Owner Induced Enhancement  | 41               | \$37,614.30              | 2.48%                         |
| 9               | Environmental Issue        | 10               | \$32,841.07              | 0.76%                         |
| Overall Average |                            |                  | \$76,453.41              | 3.31%                         |
| F-value         |                            |                  | 1.977                    | 1.835                         |
| P-value         |                            |                  | 0.58                     | 0.080                         |

Note: CO = change order

Table 24 shows the descriptive statistics for road surface work. The most frequent reason code is Fuel & Asphalt Adjustment (189) followed by Asphalt Lot Pay Adjustment (166) and Contract Item Overrun (143). The highest average change order dollar amount is Contract Item Overrun (\$117,941.95) followed by Owner Induced Enhancement (\$107,919.76) and Geotechnical Issue (\$85,858.43). The highest average percent change is Owner Induced Enhancement (9.07%) followed by Fuel & Asphalt Adjustment (7.84%) and Contract Item Overrun (5.78%). Asphalt Lot Pay Adjustment has a high frequency, which was expected since asphalt is a major part of road surface work. However, it has the smallest average change order dollar amount (\$5,891.14) and the second smallest average percent change (0.83%). Environmental Issue has the lowest frequency (7) and average percent change (0.09%) and the second smallest average change order dollar amount (\$6,404.95). Table 26 also shows that there is a statistically significant difference between the reason codes for average change order amount on road surface work. Table 24 also shows that there is a statistically significant difference between the reason codes for average percent change on road surface work. To minimize the effect of change orders on road surface construction the focus needs to be on Contract

Item Overrun, Owner Induced Enhancement, and Contract Omission. Again, Fuel & Asphalt Adjustment is out of the Cabinet’s control.

**Table 24: Road Surface - Descriptive Statistics**

| <b>Code</b>     | <b>Reason</b>              | <b>Frequency</b> | <b>Avg. CO Amt. (\$)</b> | <b>Average Percent Change</b> |
|-----------------|----------------------------|------------------|--------------------------|-------------------------------|
| 1               | Asphalt Lot Pay Adjustment | 166              | \$5,891.14               | 0.83%                         |
| 3               | Fuel & Asphalt Adjustment  | 189              | \$70,521.52              | 7.84%                         |
| 4               | Contract Omission          | 134              | \$65,657.01              | 4.38%                         |
| 5               | Utility Issue              | 22               | \$20,590.24              | 1.75%                         |
| 6               | Contract Item Overrun      | 143              | \$117,941.95             | 5.78%                         |
| 7               | Geotechnical Issue         | 26               | \$85,858.43              | 3.12%                         |
| 8               | Owner Induced Enhancement  | 120              | \$107,919.76             | 9.07%                         |
| 9               | Environmental Issue        | 7                | \$6,404.95               | 0.09%                         |
| Overall Average |                            |                  | \$68,960.03              | 5.25%                         |
| F-value         |                            |                  | 3.279                    | 14.411                        |
| P-value         |                            |                  | 0.002                    | 0.000                         |

Note: CO = change order

Table 25 shows the descriptive statistics for structures work. The most frequent reason code is Contract Omission (40) followed by Contract Item Overrun (32) and Owner Induced Enhancement (25). The highest average change order dollar amount is Geotechnical Issue (\$104,640.88) followed by Fuel & Asphalt Adjustment (\$96,560.48) and Owner Induced Enhancement (\$77,228.32). The highest average percent change is Contract Item Overrun (11.56%) followed by Owner Induced Enhancement (10.45%) and Contract Omission (7.54%). Asphalt Lot Pay Adjustment and Environmental Issue have the smallest descriptive statistics. Fuel & Asphalt Adjustment does have a high average change order dollar amount, but there are only two projects and the average percent change is low (2.17%). Table 25 also shows that there is not a statistically significant difference between the reason codes for average change order amount or average percent change on structures work. To minimize the effect of change orders on structures

construction the focus needs to be on Contract Item Overrun, Owner Induced Enhancement, and Contract Omission.

**Table 25: Structures - Descriptive Statistics**

| <b>Code</b>     | <b>Reason</b>              | <b>Frequency</b> | <b>Avg. CO Amt. (\$)</b> | <b>Average Percent Change</b> |
|-----------------|----------------------------|------------------|--------------------------|-------------------------------|
| 1               | Asphalt Lot Pay Adjustment | 4                | \$672.75                 | 0.26%                         |
| 3               | Fuel & Asphalt Adjustment  | 2                | \$96,560.48              | 2.17%                         |
| 4               | Contract Omission          | 40               | \$7,783.77               | 7.54%                         |
| 5               | Utility Issue              | 6                | \$75,698.74              | 2.72%                         |
| 6               | Contract Item Overrun      | 32               | \$42,396.97              | 11.56%                        |
| 7               | Geotechnical Issue         | 5                | \$104,640.88             | 5.33%                         |
| 8               | Owner Induced Enhancement  | 25               | \$77,228.32              | 10.45%                        |
| 9               | Environmental Issue        | 3                | \$7,169.67               | 0.39%                         |
| Overall Average |                            |                  | \$40,969.91              | 8.40%                         |
| F-value         |                            |                  | 1.722                    | .976                          |
| P-value         |                            |                  | 0.111                    | 0.452                         |

Note: CO = change order

Table 26 shows that there is a statistically significant difference between the average change order dollar amount for earthwork, road surface work, and structures work. Table 22 also shows that there is a statistically significant difference between the average percent change from original contract amount for earthwork, road surface work, and structures work.

**Table 26: Significance between Types of Construction – Earthwork, Road Surface, & Structure**

| <b>Significance Between Earthwork, Road Surface, &amp; Structure for Average Change Order Dollar Amount and Average Percent Change from Original Contract Amount</b> |   |         |                          |                               |
|--|---|---------|--------------------------|-------------------------------|
|  |   |         | <b>Avg. CO Amt. (\$)</b> | <b>Average Percent Change</b> |
| <b>Group</b>   | Earthwork<br>Road Surface<br>Structures | F-value | 1.149                    | 13.201                        |
|  |   | P-value | 0.317                    | 0.000                         |

Note: CO = change order

The codes that stood out for the different types of construction are Contract Omission, Contract Item Overrun, and Owner Induced Enhancement. Focusing efforts on minimizing these three codes will provide the greatest improvement in change order management and project success.

### **3.6 Districts**

In Kentucky, there are twelve district offices (Figure 3). The following analyses examined the variability in size and frequency of change orders among the Cabinet's twelve districts.

In addition to knowing the location of where different reason codes occur, the reason code breakdown by district can possibly shed light on how different districts avoid or anticipate change orders. While this paper focuses on the causes of change orders on Kentucky transportation projects, having a breakdown of reason codes by district can lead to future research on how different districts address change orders and their effectiveness.

It is possible to break down the reason codes by district because the latitudes and longitudes for each project were given in the original Excel files. However, only 346 of the projects in the original Excel files had latitudes and longitudes listed. To figure out the unlisted latitudes and longitudes, the descriptions and county that were listed for each project was used. Most of the descriptions have a location and road name, so it was possible to designate the district where the project occurred. If the description did not give a location, then the listed county was used to designate the district.

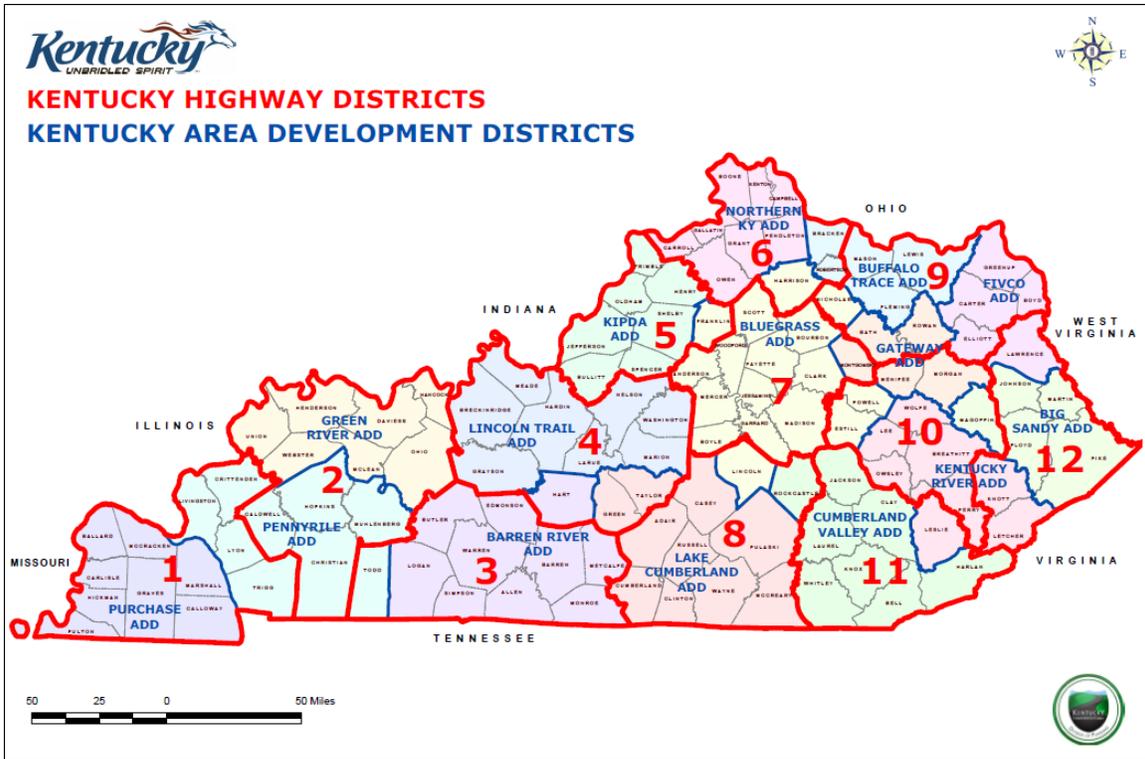


Figure 3: Kentucky Highway District Map

Breaking down the causes of the change orders by district is important for the analysis, but a visual tool for determining geographical trends is also desirable. GIS mapping is used to create a visual of the project location and twelve districts. GIS Maps are created that show the average percent change by district, the average change order dollar amount by district, and the reason code distribution by district.

After creating the GIS maps, the maps were examined in hopes of determining change order trends. Based on Kentucky being prone to areas of karst, it was thought that change orders due to geotechnical issues would be more frequent and costly in those regions. It was also thought that change orders might be more frequent in Eastern Kentucky due to its relatively hilly terrains compared to Western Kentucky. To test these hypotheses, a karst map of Kentucky was overlaid on a Kentucky map in GIS (Figures 9, 11, 13, and 14).

After examining the GIS maps, no major trends developed. The only minor trend is associated with districts 3, 4, 5, and 6. In these districts, projects in the karst-prone regions experienced an average higher percent change than non-karst regions. Table 27 shows the statistics for the karst-prone regions. The gray highlighted data represents the minor trend that developed for the higher average percent changes in districts 3, 4, 5, and 6. The GIS maps are shown in Figures 4 through 9.

**Table 27: Descriptive Statistics for Change Orders by Karst Prone Regions and Districts**

| District | None-Karst |                   |               | Karst-Moderate |                   |               | Karst-Major |                   |               | Karst (Major+ Moderate) |                   |               |
|----------|------------|-------------------|---------------|----------------|-------------------|---------------|-------------|-------------------|---------------|-------------------------|-------------------|---------------|
|          | N          | Avg. CO Amt. (\$) | Avg. % Change | N              | Avg. CO Amt. (\$) | Avg. % Change | N           | Avg. CO Amt. (\$) | Avg. % Change | N                       | Avg. CO Amt. (\$) | Avg. % Change |
| 1        | 36         | \$91,472.92       | 7.33%         | 1              | \$25,155.02       | 9.00%         | 3           | \$19,795.95       | 8.33%         | 4                       | \$21,135.72       | 8.50%         |
| 2        | 42         | \$27,246.29       | 5.60%         | 1              | -\$167.11         | 0.00%         | 3           | \$131,524.59      | 2.67%         | 4                       | \$140,912.66      | 2.00%         |
| 3        | 5          | \$26,671.09       | 8.00%         | 5              | \$8,982.23        | 12.20%        | 19          | -\$17,287.86      | 8.00%         | 24                      | -\$20,714.33      | 9.04%         |
| 4        | 16         | \$87,721.36       | 9.13%         | 20             | \$86,636.97       | 16.00%        | 14          | \$207,530.00      | 21.73%        | 34                      | \$126,911.14      | 18.44%        |
| 5        | 9          | \$17,145.51       | 2.78%         | 31             | \$226,875.42      | 15.55%        | 12          | \$223,106.27      | 11.13%        | 43                      | \$208,331.33      | 15.09%        |
| 6        | 50         | \$114,355.19      | 7.24%         | 29             | \$224,584.09      | 12.28%        | 5           | \$21,621.45       | 8.00%         | 34                      | \$199,944.47      | 12.09%        |
| 7        | 17         | \$60,922.85       | 10.65%        | 15             | \$102,389.31      | 6.53%         | 45          | \$106,606.28      | 7.89%         | 60                      | \$102,623.29      | 8.45%         |
| 8        | 24         | \$147,620.22      | 19.25%        | 7              | \$16,270.25       | 5.71%         | 13          | \$52,824.04       | 9.46%         | 20                      | \$38,598.83       | 8.75%         |
| 9        | 23         | \$323,805.31      | 21.52%        | 7              | \$63,443.64       | 9.43%         | 0           | NA                | 10.00%        | 7                       | \$144,792.12      | 9.43%         |
| 10       | 47         | \$91,632.41       | 13.85%        | 1              | \$7,100.00        | 1.00%         | 1           | \$33,060.97       | 14.00%        | 2                       | \$20,080.49       | 7.50%         |
| 11       | 42         | \$142,162.96      | 11.95%        | 0              | NA                | NA            | 1           | \$1,557.46        | 0.00%         | 1                       | \$1,557.46        | 0.00%         |
| 12       | 65         | \$32,383.99       | 7.06%         | 0              | NA                | NA            | 1           | \$157,367.21      | 15.00%        | 1                       | \$157,367.21      | 15.00%        |

Note: CO = change order

# Project Locations by District with Karst Map Overlaid

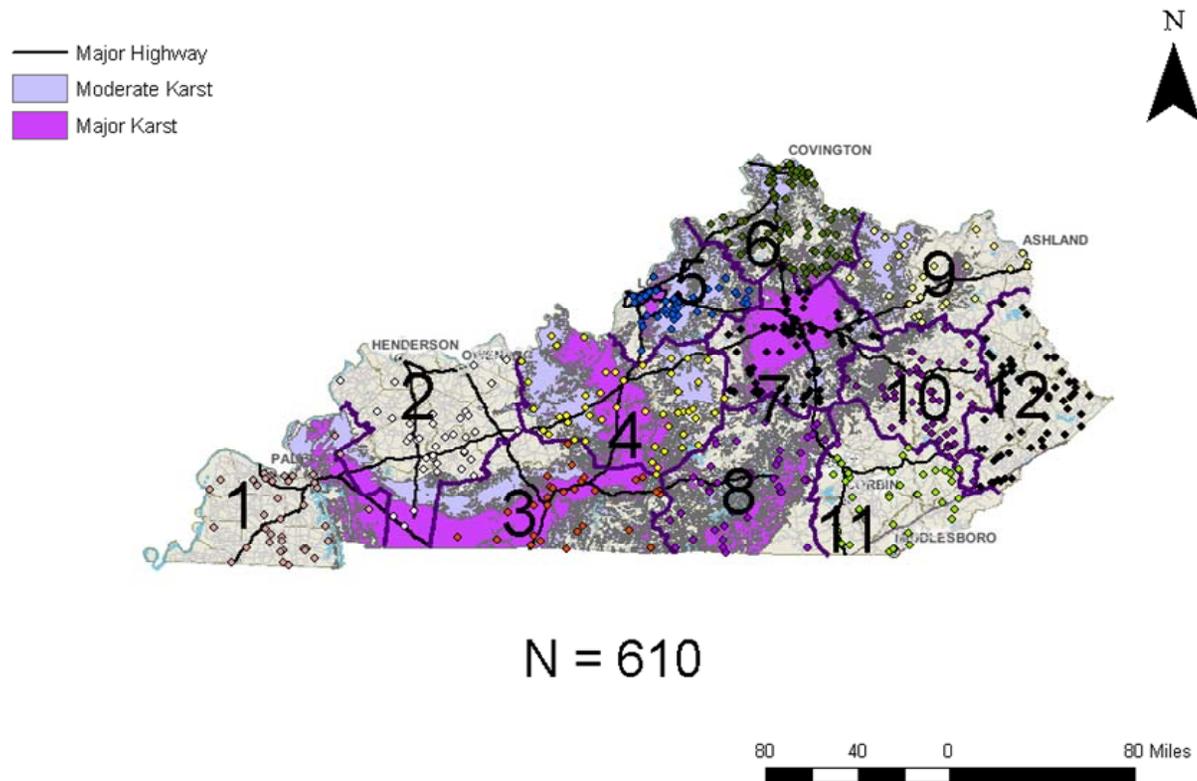
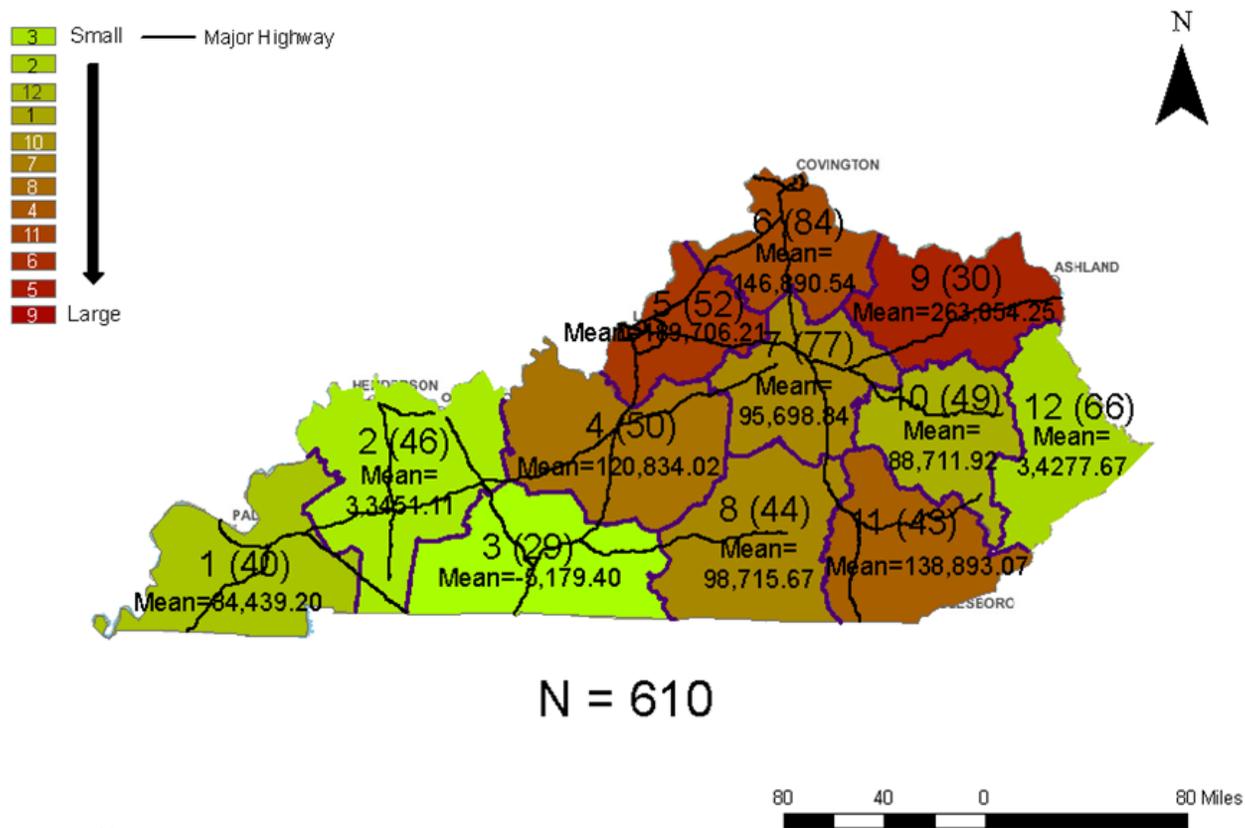


Figure 4: Project Locations by District with Karst Map Overlaid

# Average Change Order Dollar Amount by District



Note: 11 (43) denotes 43 projects in District 11

Figure 5: Average Change Order Dollar Amount by District

# Average Change Order Dollar Amount by District with Karst Map Overlaid

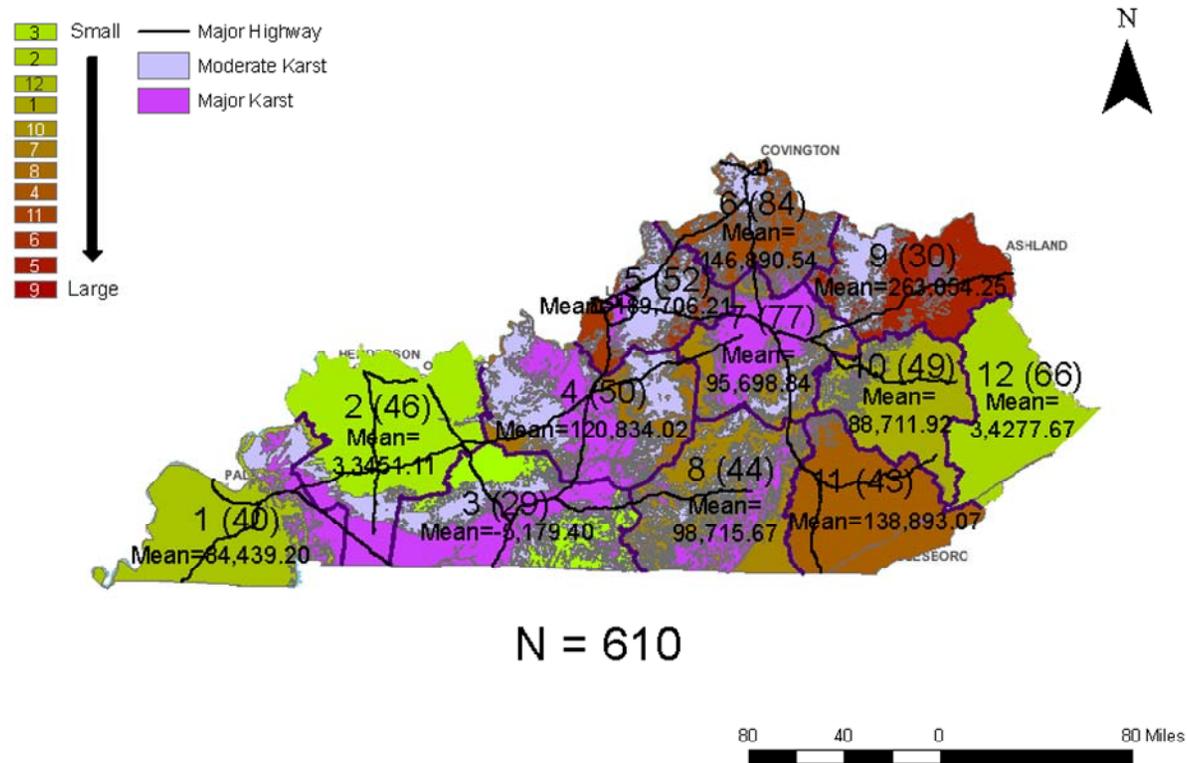


Figure 6: Average Change Order Dollar Amount by District with Karst Map Overlaid

# Average Percent Change from Original Contract Amount by District

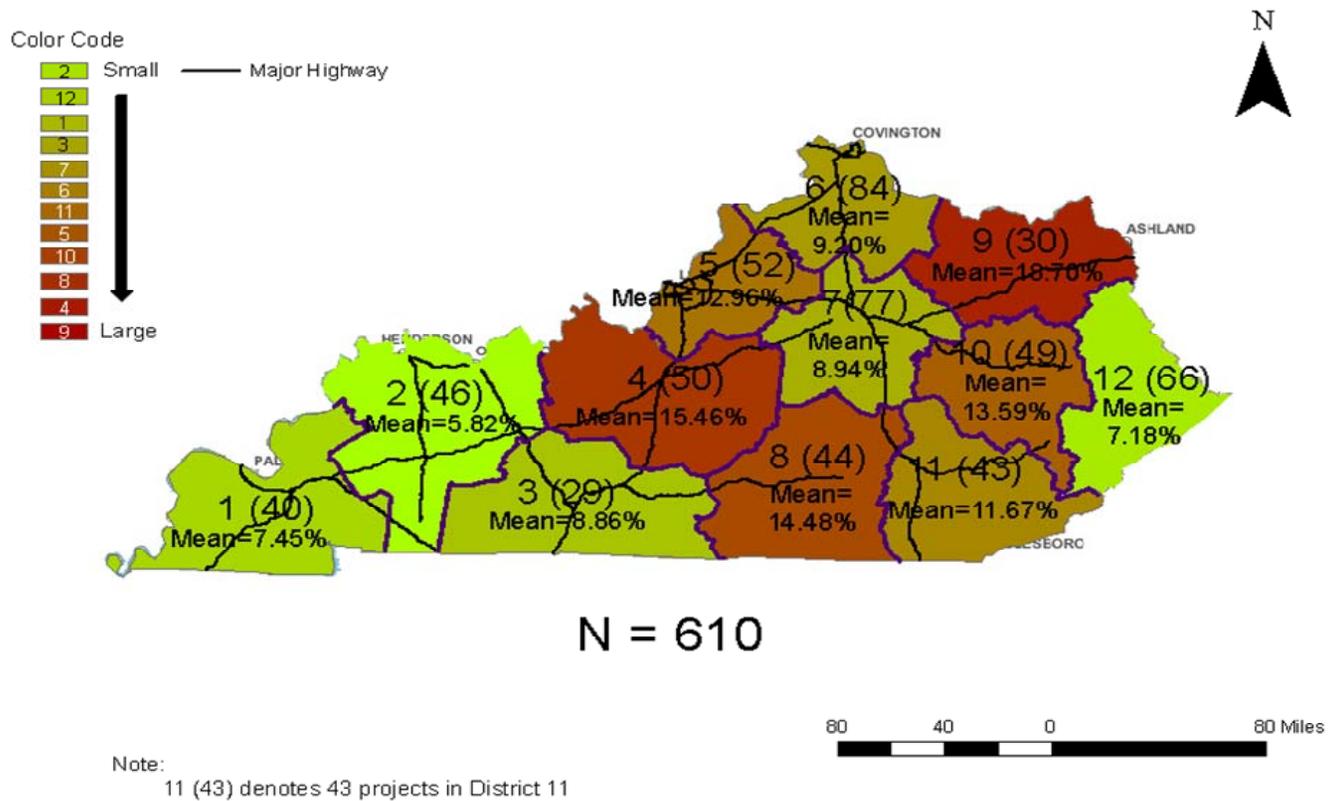
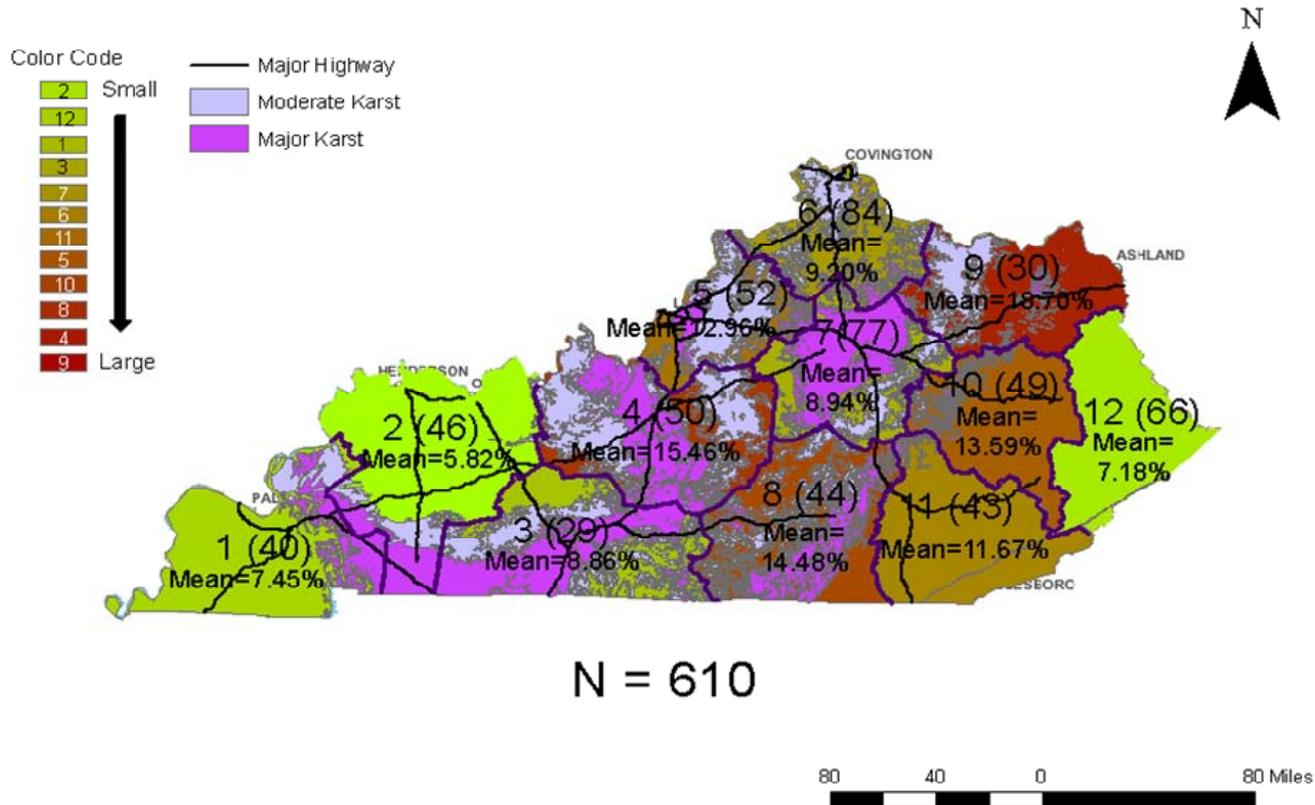


Figure 7: Average Percent Change from Original Contract Amount by District

# Average Percent Change from Original Amount by District with Karst Map Overlaid



Note:  
 11 (43) denotes 43 projects in District 11

Figure 8: Average Percent Change from Original Contract Amount by District with Karst Map Overlaid

# Project Locations Identified with Percent Change from Original Contract Amount with Karst Map Overlaid

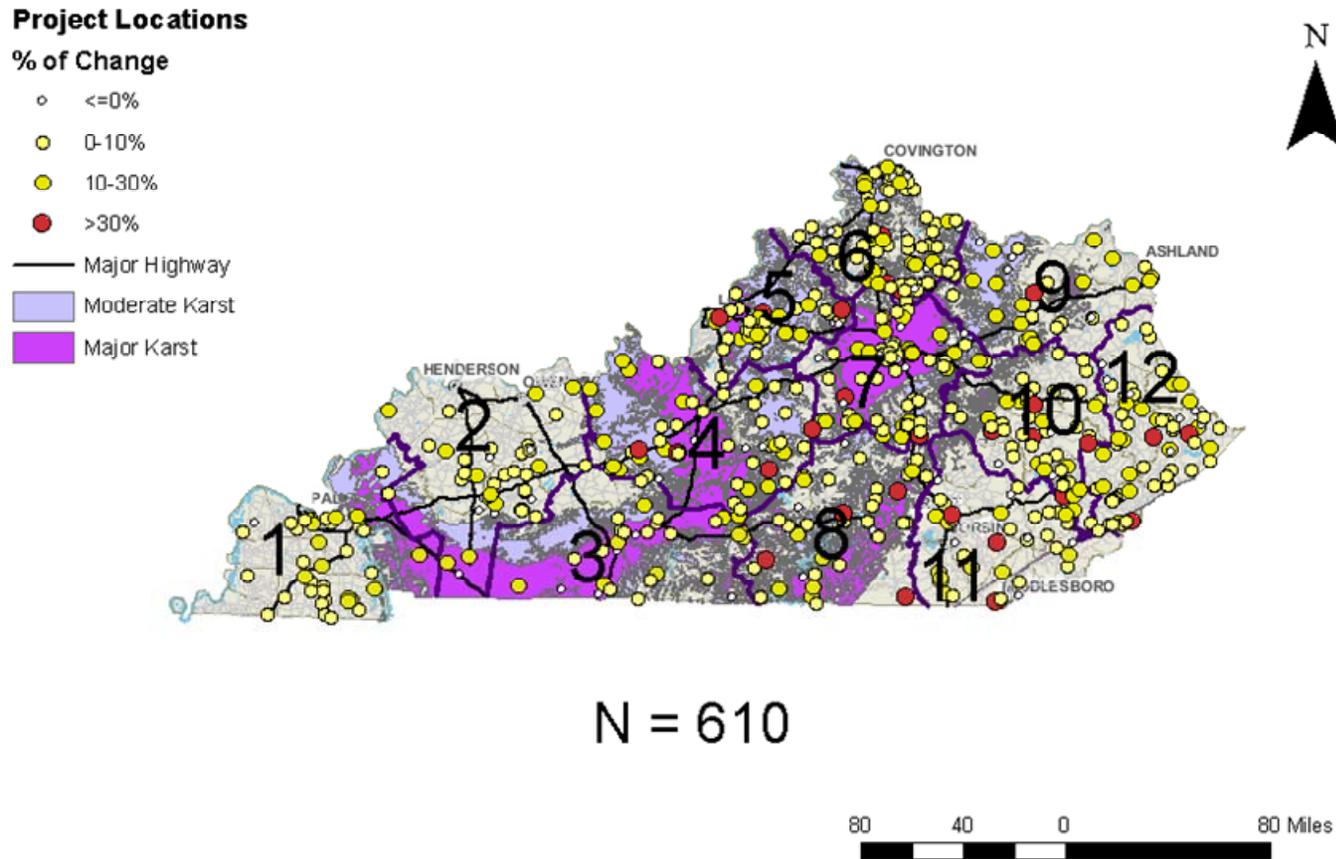


Figure 9: Project Locations Identified with Percent Change from Original Contract Amount and Karst Map Overlaid

### 3.6.1 District 9 – Area of Concern

One area of interest is district 9, which is located in Eastern Kentucky. District 9 had a higher average percent change than the other districts. This higher average percent change raised questions, because it was not in a karst-prone region. While it was located in the mountains of Eastern Kentucky, surrounding mountainous districts did not have similar high average percent changes. More analysis and research was performed specifically on district 9 through examining the reason codes that occurred in the district. It was determined that district 9 had a high average change order dollar amount and a high average percent change due to Fuel & Asphalt Adjustment, which is due to market conditions and is out of the Cabinet's control. There was still some concern for why Fuel & Asphalt Adjustment did not show up as costly in other districts. To investigate this, the dates of the projects are compared with the market prices of diesel and asphalt during the same time period.

The Kentucky Oil Price Information Service (OPIS) and Kentucky Average Price Index (KAPI) indices are used to determine the market prices. The Kentucky OPIS is used to determine the average price of diesel fuel in the Kentucky region. The Kentucky OPIS Index is the average reseller price from diesel fuel, excluding taxes, discounts, and superfund line in the Kentucky region. The KAPI is used to determine the average price of asphalt in the Kentucky region. The KAPI is calculated monthly and it uses the weighted average price (per ton at the terminal) from active suppliers of liquid asphalt.

The projects impacted by Fuel & Asphalt Adjustment are graphed against the diesel and asphalt price indices (Figure 10 and 11). It was determined that the work in district 9 was being performed at the same time that the market prices for asphalt and diesel prices spiked upwards. In this instance, the Cabinet is at the mercy of market prices.

Table 28 looks at the major change order causes for district 9. Fuel & Asphalt Adjustment has the highest average change order dollar amount, the highest average percent change, and the highest frequency. The high average change order dollar amount and high average percent change for Fuel & Asphalt Adjustment along with the time of construction and corresponding high diesel and asphalt prices help explain why district 9 shows up as an area of concern.

**Table 28: Major Change Order Causes for District 9**

| Reason Code               | Total CO Amount (\$) | Avg. CO Amount (\$) | Avg. Percent Change | N  |
|---------------------------|----------------------|---------------------|---------------------|----|
| Fuel & Asphalt Adjustment | \$3,368,129          | \$187,119           | 7.68%               | 18 |
| Owner Induced Enhancement | \$1,253,361          | \$89,526            | 6.49%               | 14 |
| Contract Item Overrun     | \$400,592            | \$44,510            | 7.32%               | 9  |
| Contract Omission         | \$841,019            | \$76,456            | 3.15%               | 11 |

N denotes the frequency of applicable projects for corresponding reason code. CO = change order.

Table 29 shows the Fuel & Asphalt Adjustment breakdown by district. District 9 does not have the highest frequency, but it has the highest average change order dollar amount out of all the districts. Its average change order dollar amount is \$187,118, or \$24,697 higher than the next district. The high average change order dollar amount compared to other districts helps explain why district 9 shows up as an area of concern.

**Table 29: Reason Code Fuel & Asphalt Adjustment Comparison (District 9 vs. Other District)**

| District | Reason Code 3 – Fuel & Asphalt Adjustment |    |
|----------|---|----|
|          | Average Change Order Amount (\$)          | N  |
| 9        | \$187,118                                 | 18 |
| 6        | \$162,421                                 | 21 |
| 3        | \$122,307                                 | 14 |
| 1        | \$104,253                                 | 17 |
| 2        | \$99,756                                  | 22 |
| 8        | \$87,914                                  | 11 |
| 11       | \$53,412                                  | 14 |
| 4        | \$47,950                                  | 29 |
| 5        | \$47,687                                  | 11 |
| 7        | \$47,243                                  | 21 |
| 12       | \$24,063                                  | 24 |
| 10       | \$18,219                                  | 16 |

N denotes the frequency of applicable projects for corresponding reason code. The gray highlights district 9.

Table 30 shows the data used to create the graphs that track the percentage of projects impacted by Fuel & Asphalt Adjustment vs. the Diesel Price Index and Fuel & Asphalt Adjustment vs. the Asphalt Price Index. The graphs are shown in Figure 10 and 11. The graphs show that the spikes and dips of projects affected by Fuel & Asphalt Adjustment coincide with the price of diesel and asphalt during the same time period. There is a slight lag in the graphs at times, but for the most part the graphs support the idea that when the price of diesel and asphalt are high, the affect of Fuel & Asphalt Adjustment is greater. It is nearly impossible to forecast the price of diesel and asphalt so the contract needs to address the issue of rising or falling prices and how the owner and contractor will handle the situation. One possibility is the use of long-term contracts with diesel and asphalt suppliers that locks in a price for the purchase of future diesel and asphalt. The advantage is that the price of fuel and asphalt is known for the future and change orders due to Fuel & Asphalt Adjustment are minimized.

**Table 30: Frequency of Reason Code 3 – Fuel & Asphalt Adjustment vs. Asphalt and Diesel Price Index (2005-2008)**

| Date Awarded                  | Frequency | N   | Percentage of Projects Impacted | Diesel Price Index | Asphalt Price Index |
|-------------------------------|-----------|-----|---------------------------------|--------------------|---------------------|
| 1 <sup>st</sup> Quarter, 2005 | 6         | 38  | 15.8%                           |                    |                     |
| 2 <sup>nd</sup> Quarter, 2005 | 16        | 74  | 21.6%                           | 1.69               | 183.62              |
| 3 <sup>rd</sup> Quarter, 2005 | 24        | 65  | 36.9%                           | 2.00               | 204.34              |
| 4 <sup>th</sup> Quarter, 2005 | 47        | 76  | 61.8%                           | 2.10               | 215.42              |
| 1 <sup>st</sup> Quarter, 2006 | 17        | 30  | 56.7%                           | 1.88               | 227.36              |
| 2 <sup>nd</sup> Quarter, 2006 | 92        | 121 | 76.0%                           | 2.22               | 310.97              |
| 3 <sup>rd</sup> Quarter, 2006 | 5         | 31  | 16.1%                           | 2.20               | 382.87              |
| 4 <sup>th</sup> Quarter, 2006 | 1         | 32  | 3.1%                            | 1.92               | 333.54              |
| 1 <sup>st</sup> Quarter, 2007 | 2         | 24  | 8.3%                            | 1.91               | 311.44              |
| 2 <sup>nd</sup> Quarter, 2007 | 0         | 57  | 0.0%                            | 2.16               | 294.48              |
| 3 <sup>rd</sup> Quarter, 2007 | 2         | 39  | 5.1%                            | 2.29               | 281.00              |
| 4 <sup>th</sup> Quarter, 2007 | 5         | 18  | 27.8%                           | 2.65               | 276.04              |
| 1 <sup>st</sup> Quarter, 2008 | 1         | 4   | 25.0%                           | 2.92               | 318.37              |
| 2 <sup>nd</sup> Quarter, 2008 | 0         | 1   | 0.0%                            | 3.77               | 409.15              |

Note: N denotes the number of projects awarded during the corresponding quarter of the year.

Figures 10 and 11 are the graphs showing the percentage of projects impacted by Fuel & Asphalt Adjustment vs. the diesel price and asphalt price indices. The data in Table 30 is used to create the graphs.

# Percentage of Projects Impacted by Fuel & Asphalt Adjustment Vs. Diesel Price Index (2005-2008)

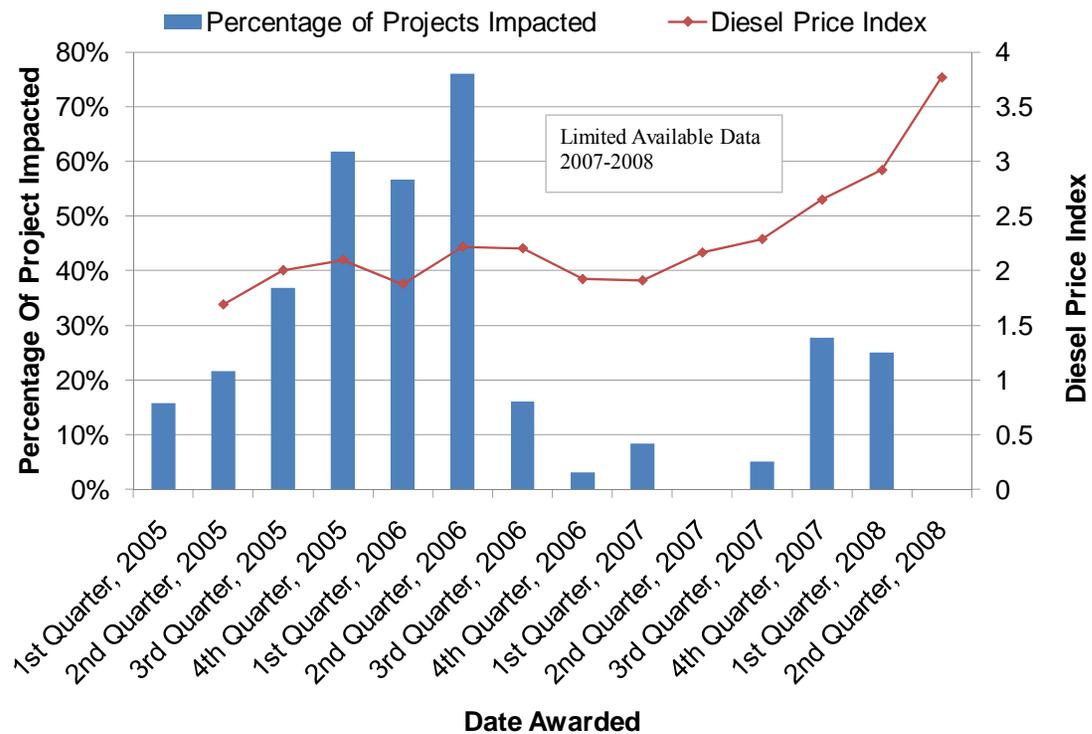


Figure 10: Percentage of Projects Impacted by Fuel & Asphalt Adjustment vs. Diesel Price Index (2005-2008)

# Percentage of Projects Impacted by Fuel & Asphalt Adjustment Vs. Asphalt Price Index (2005-2008)

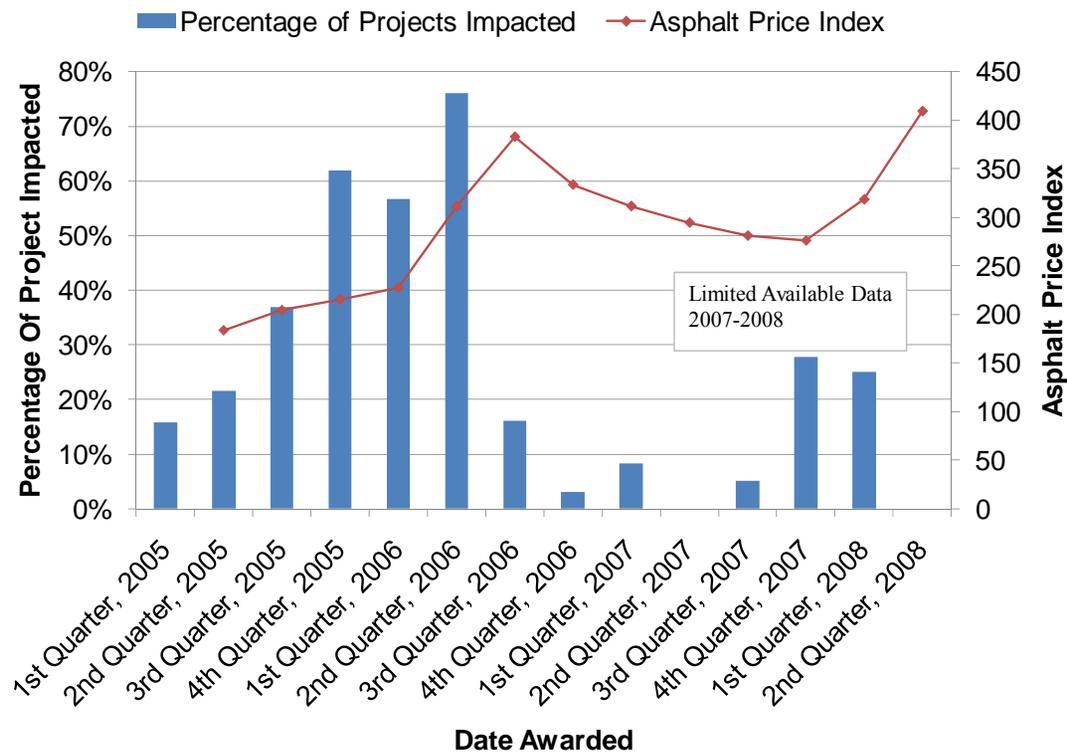


Figure 11: Percentage of Projects Impacted by Fuel & Asphalt Adjustment vs. Asphalt Price Index 92005-2008)

### **3.7 Work Type Analysis Charts**

Change order data that had been sorted into reason codes was further categorized and line items within each of the reason codes were classified into 14 broad work categories shown below. Not all of the reason codes contain items that fit into all of the 14 categories. The 14 categories are shown below.

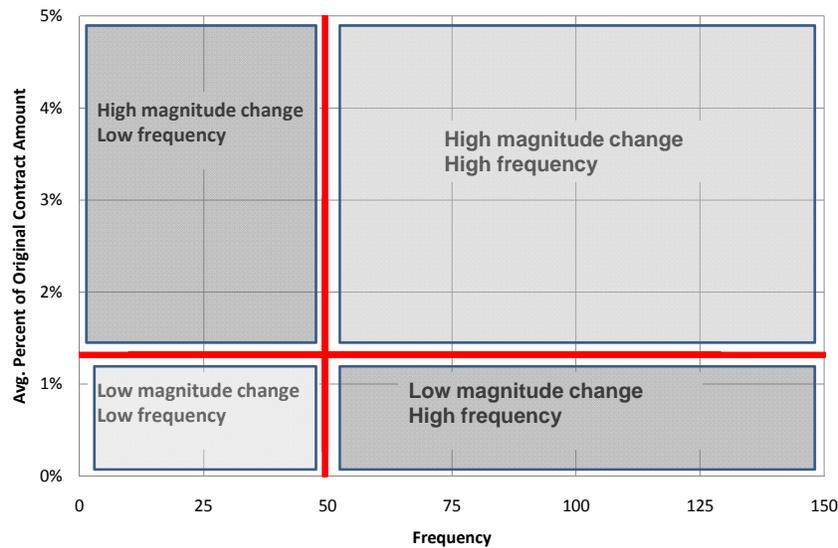
1. Aggregate
2. Asphalt Bases
3. Guardrail and Barrier
4. PCC Pavement
5. Earthwork
6. Curb, Gutter and Sidewalk
7. Pavement striping and Marking
8. Erosion Control and Landscaping
9. Signs and Signaling
10. Steel Reinforcement
11. Utility Piping
12. Railroads
13. Fences
14. Demolition

Once the line items were sorted into one of the 14 categories, information on the frequency of the items within each category, the average percent of the original contract amount and the mean amount of each category was computed. An example of one of the tables is shown below in Table 31 for Code 04 – Contract Omissions. For example, Table 31 shows that for the Earthwork category there were 37 change order items that were classified as earthwork items within the Contract Omissions code. Of these 37 items, the average percent of the original contract amount was 3.00% and the mean amount for these 37 items was \$37,660.90.

**Table 31: Work Item Analysis Chart for Code 04 – Contract Omissions**

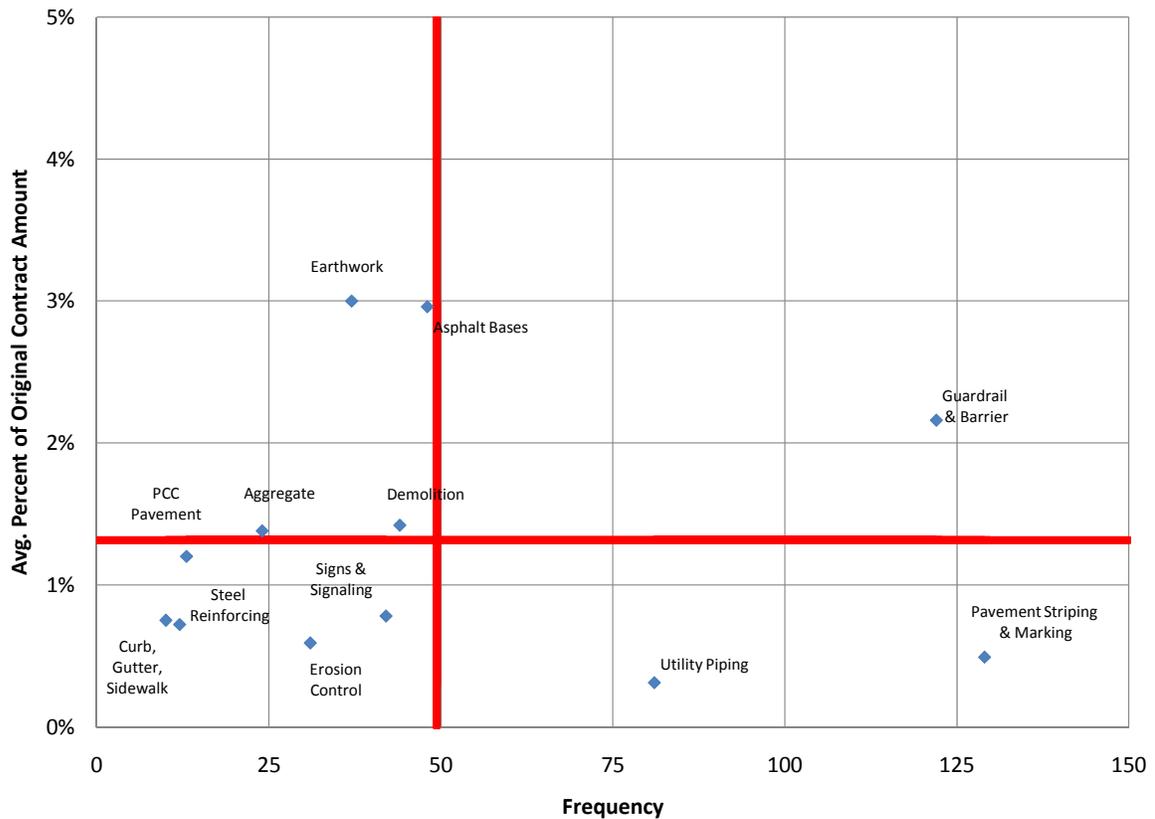
| Classification of Bid Items     | Bid Classification Statistics |  |             |
|---------------------------------|-------------------------------|--|-------------|
|                                 | Frequency                     | Avg. Percent of Original Contract Amount | Mean        |
| Earthwork                       | 37                            | 3.00%                                    | \$37,660.90 |
| Asphalt Bases                   | 48                            | 2.96%                                    | \$39,203.20 |
| Guardrail And Barrier           | 122                           | 2.16%                                    | \$6,996.90  |
| Demolition                      | 44                            | 1.42%                                    | \$10,456.94 |
| Aggregate                       | 24                            | 1.38%                                    | \$31,714.63 |
| PCC Pavement                    | 13                            | 1.20%                                    | \$23,875.09 |
| Signs & Signaling               | 42                            | 0.78%                                    | \$6,465.33  |
| Steel Reinforcement             | 10                            | 0.75%                                    | \$6,555.24  |
| Curb, Gutter And Sidewalk       | 12                            | 0.72%                                    | \$21,045.26 |
| Erosion Control And Landscaping | 31                            | 0.59%                                    | \$16,088.86 |
| Pavement Striping & Marking     | 129                           | 0.49%                                    | \$2,744.22  |
| Utility Piping                  | 81                            | 0.31%                                    | \$5,018.67  |

Part of this study was to develop charts showing individually grouped bid items that fall into one of four risk categories based on a graphing of items by Average Percent of Original Contract Amount and their Frequency of occurrence. A sample chart is shown below. The chart conveys the magnitude and nature of risks associated with each change orders in each work category. For example, a category that falls into the upper, right quadrant of the chart indicates a change that occurs relatively frequently and that typically results in a relatively large increase in the cost of the project.



**Figure 12: Generic Risk Chart For Work Item Analysis**

From a risk management perspective, categories that fall in the upper right quadrant should receive risk mitigation attention first because they happen more frequently and result in large cost increases. Categories falling within the upper left and lower right quadrant should receive risk mediation attention next because they either occur frequently with low cost increase or infrequently with high cost increases when they do occur. Finally, those categories in the lower left quadrant should receive risk mitigation attention last because they occur infrequently and have minimal cost impacts when they do occur. The separation lines for the four quadrants were determined by calculating the mean frequency and the mean average percent of original contract amount. Once the means were determined, the points for each category's frequency was charted versus its' average percent of original contract amount. An example of the Contract Omissions chart is shown in Figure 13.



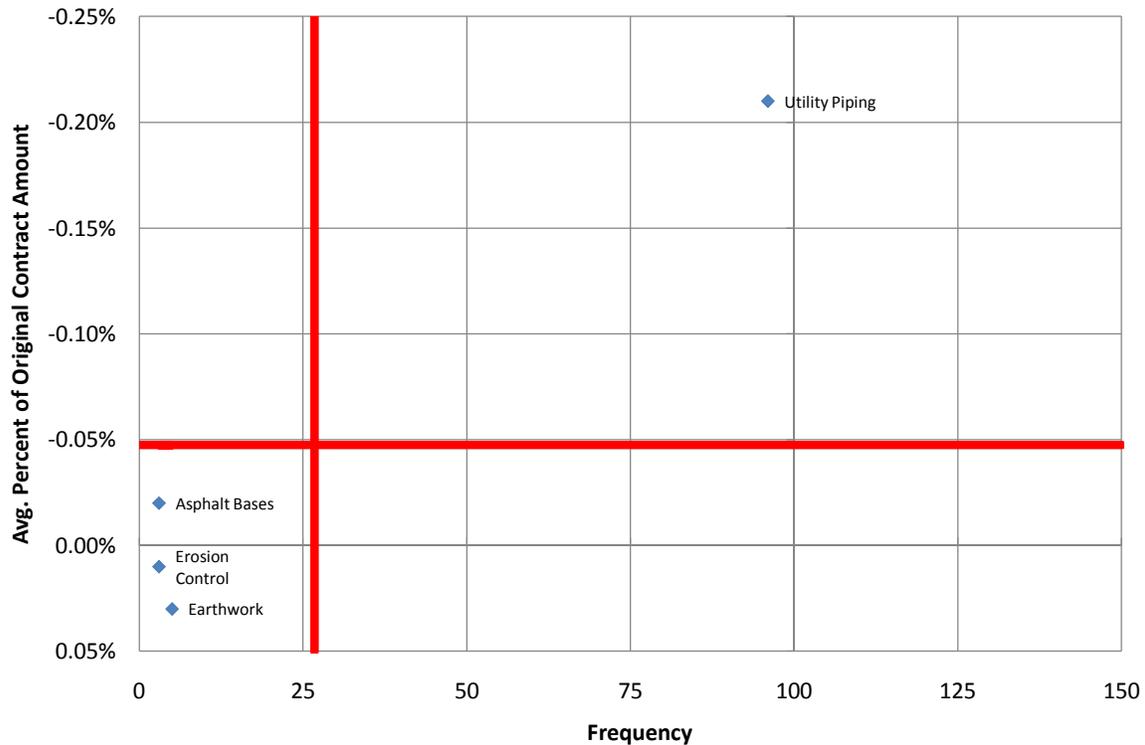
**Figure 13: Work Item Analysis Matrix for Contract Omissions**

In this example, Guardrail & Barrier items are clearly in the high risk quadrant. Asphalt Bases are close to this region but fall slightly into the medium risk region. Guardrail & Barrier frequency items appear to vary greatly from the mean. They show less deviation from the average percent of original contract amount mean but almost twice the percentage of the mean.

The remaining codes show some similarity in chart location of the different categories but do vary in some of the different codes. The table and matrix for Code 05 – Utility Issues is shown below in Table 32 and Figure 14. Note that the y-axis for this graph contains negative percent contract change indicating that the change order resulted in a decrease in contract amount.

**Table 32: Work Item Analysis Chart for Code 05 – Utility Issues**

| Classification of Bid Items     | Bid Classification Statistics |  |            |
|---------------------------------|-------------------------------|--|------------|
|                                 | Frequency                     | Avg. Percent of Original Contract Amount | Mean       |
| Earthwork                       | 5                             | 0.03%                                    | \$1,586.20 |
| Erosion Control and Landscaping | 3                             | 0.01%                                    | \$661.67   |
| Asphalt Bases                   | 3                             | -0.02%                                   | \$1,398.33 |
| Utility Piping                  | 96                            | -0.21%                                   | \$6,773.24 |



**Figure 14: Work Item Analysis Matrix for Utility Issues**

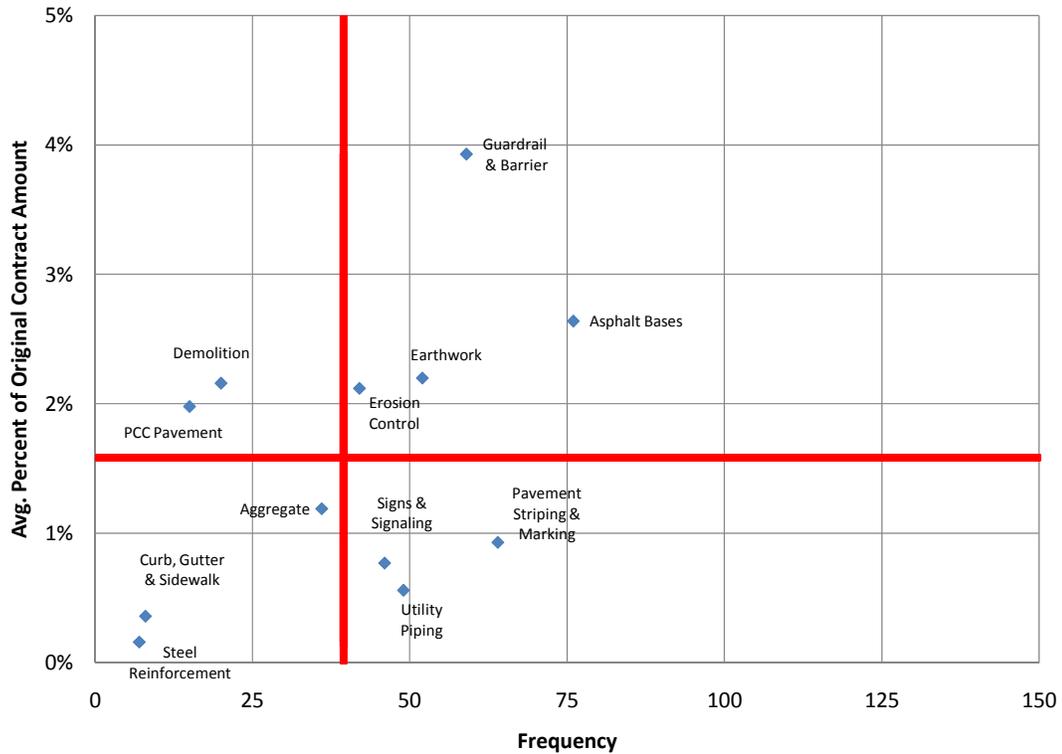
Utility Issues only contained four categories. Utility piping appears to be one category that could use further investigation on its' high magnitude change and high

frequency. However, it is important to note that the magnitude of the contract change is small and results in a reduction in contract amount.

Code 06 – Contract Item Overrun, reflects a number of categories and has a fairly even distribution (Table 33 and Figure 15).

**Table 33: Work Item Analysis Chart for Code 06 - Contract Item Overrun**

| Classification of Bid Items     | Bid Classification Statistics |  |             |
|---------------------------------|-------------------------------|--|-------------|
|                                 | Frequency                     | Avg. Percent of Original Contract Amount | Mean        |
| Guardrail and Barrier           | 59                            | 3.93%                                    | \$6,749.05  |
| Asphalt Bases                   | 76                            | 2.64%                                    | \$32,675.25 |
| Earthwork                       | 52                            | 2.20%                                    | \$37,147.06 |
| Demolition                      | 20                            | 2.16%                                    | \$64,779.74 |
| Erosion Control and Landscaping | 42                            | 2.12%                                    | \$20,670.33 |
| PCC Pavement                    | 15                            | 1.98%                                    | \$73,968.56 |
| Aggregate                       | 36                            | 1.19%                                    | \$31,806.28 |
| Pavement Striping and Marking   | 64                            | 0.93%                                    | \$8,145.47  |
| Signs and Signaling             | 46                            | 0.77%                                    | \$4,297.33  |
| Utility Piping                  | 49                            | 0.56%                                    | \$6,177.53  |
| Curb, Gutter and Sidewalk       | 8                             | 0.36%                                    | \$14,716.50 |
| Steel Reinforcement             | 7                             | 0.16%                                    | \$2,236.53  |



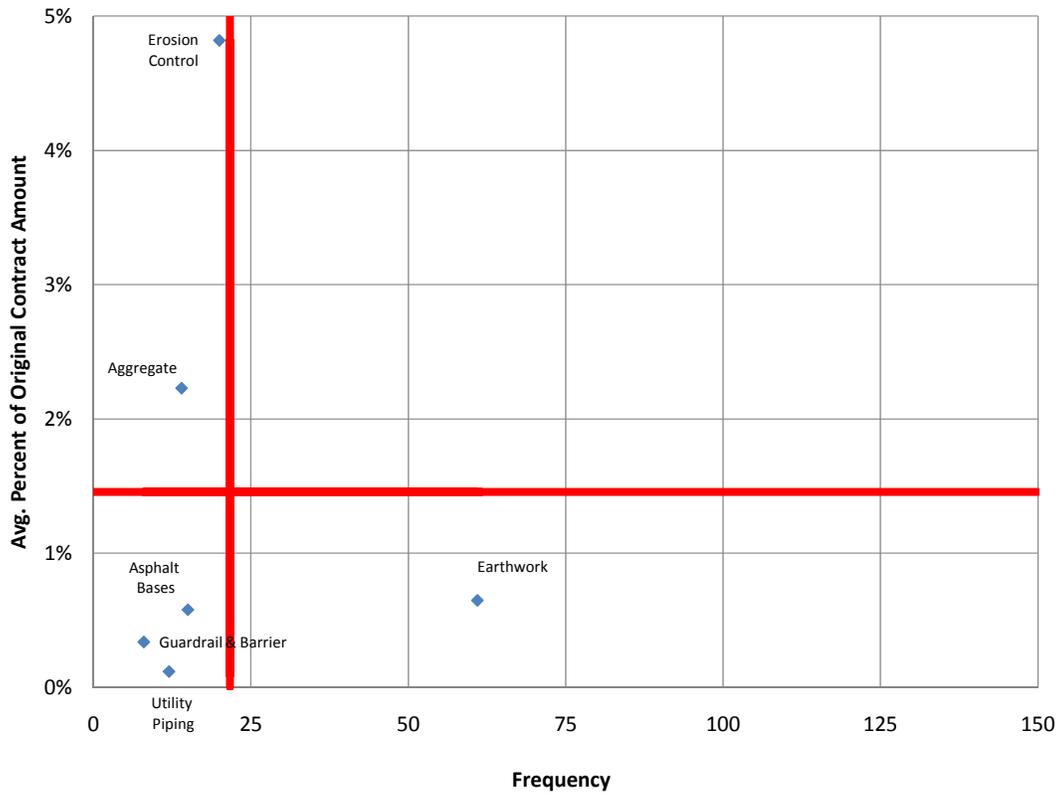
**Figure 15: Work Item Analysis Matrix for Contract Item Overrun**

Contract Item Overruns has four areas of immediate concern. Guardrail & Barrier, Asphalt Bases, Earthwork, and Erosion Control all fall within the high risk/ high frequency quadrant. Guardrail & Barrier and Asphalt Bases appear to be the highest concern items due their large derivation from the mean frequency and/or mean average percent of original contract amount.

Table 34 and Figure 16 display the risk analysis results for Code 07 – Geotechnical Issues.

**Table 34: Work Item Analysis Chart for Code 07 - Geotechnical Issues**

| Classification of Bid Items     | Bid Classification Statistics |  |             |
|---------------------------------|-------------------------------|--|-------------|
|                                 | Frequency                     | Avg. Percent of Original Contract Amount | Mean        |
| Erosion Control and Landscaping | 20                            | 4.82%                                    | \$23,134.44 |
| Aggregate                       | 14                            | 2.23%                                    | \$30,618.35 |
| Earthwork                       | 61                            | 0.65%                                    | \$15,043.65 |
| Asphalt Bases                   | 15                            | 0.58%                                    | \$4,315.53  |
| Guardrail and Barrier           | 8                             | 0.34%                                    | \$11,875.00 |
| Utility Piping                  | 12                            | 0.12%                                    | \$3,400.54  |

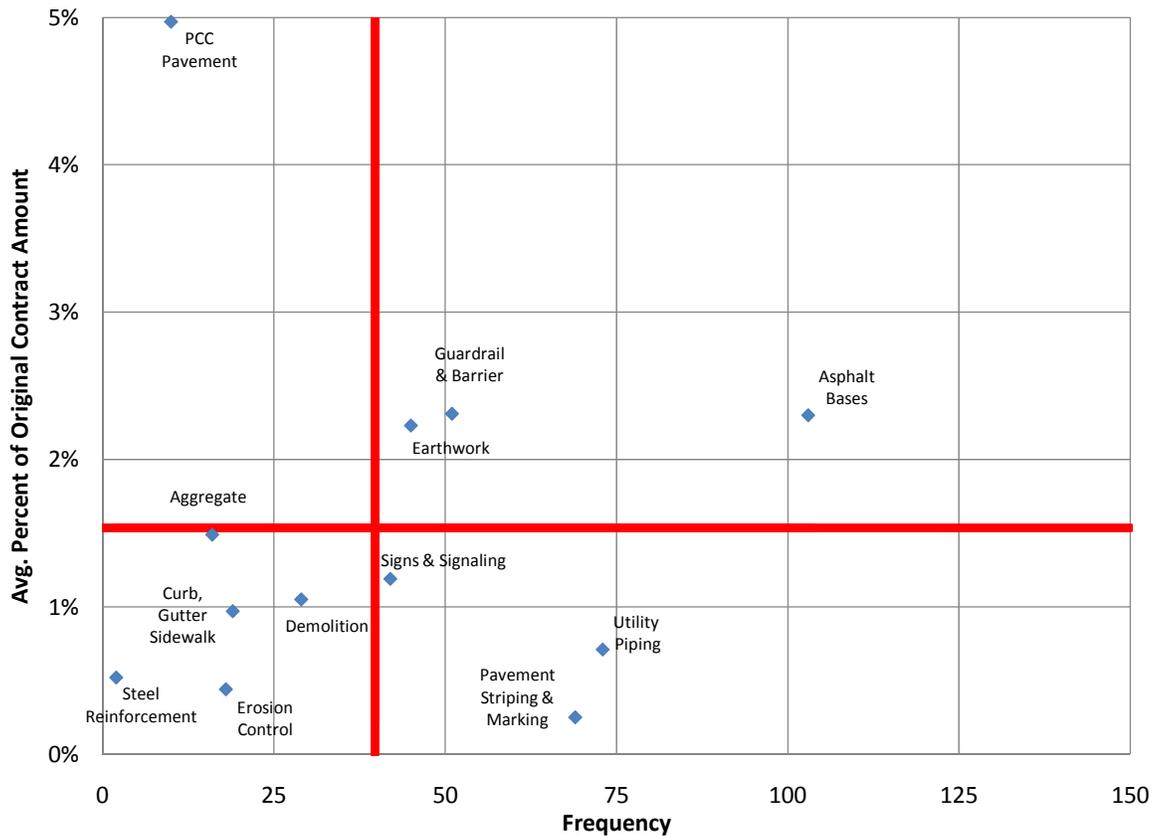


**Figure 16: Work Item Analysis Matrix for Geotechnical Issues**

There are no categories within Geotechnical Issues that warrant immediate concern although Earthwork issues occur at the twice the mean relevant to the data given. Erosion control items also have a large deviation from the mean average percent of original contract amount and need to be studied.

**Table 35: Work Item Analysis Chart for Code 08 - Owner Induced Enhancement**

|                                 | Bid Classification Statistics |  |              |
|---------------------------------|-------------------------------|--|--------------|
|                                 | Frequency                     | Avg. Percent of Original Contract Amount | Mean         |
| PCC Pavement                    | 10                            | 4.97%                                    | \$230,590.70 |
| Guardrail and Barrier           | 51                            | 2.31%                                    | \$6,323.10   |
| Asphalt Bases                   | 103                           | 2.30%                                    | \$27,611.87  |
| Earthwork                       | 45                            | 2.23%                                    | \$5,150.69   |
| Aggregate                       | 16                            | 1.49%                                    | \$22,119.05  |
| Signs and Signaling             | 42                            | 1.19%                                    | \$6,843.60   |
| Demolition                      | 29                            | 1.05%                                    | \$17,389.52  |
| Curb, Gutter and Sidewalk       | 19                            | 0.97%                                    | \$10,229.19  |
| Utility Piping                  | 73                            | 0.71%                                    | \$7,407.31   |
| Steel Reinforcement             | 2                             | 0.52%                                    | \$8,172.50   |
| Erosion Control and Landscaping | 18                            | 0.44%                                    | \$2,775.14   |
| Pavement Striping and Marking   | 69                            | 0.25%                                    | \$2,275.70   |



**Figure 17: Work Item Analysis Matrix for Owner Induced Enhancement**

Owner Induced Enhancement has three categories that fall within the high risk area. Guardrail & Barrier, Asphalt Bases and Earthwork appear in the upper right hand quadrant and would be items to investigate. Asphalt Bases again is shown to have occurred at least twice as often as the mean amount for this code.

The Contract Item Underrun chart and matrix are similar to the other tables except that all of the mean dollar amounts are negative and the y-axis runs in an increasing negative fashion.

**Table 36: Work Item Analysis Chart for Code 20 - Contract Item Underrun**

| Classification of Bid Items     | Bid Classification Statistics |  |               |
|---------------------------------|-------------------------------|--|---------------|
|                                 | Frequency                     | Avg. Percent of Original Contract Amount | Mean          |
| Curb, Gutter and Sidewalk       | 6                             | -0.32%                                   | (\$19,157.92) |
| Utility Piping                  | 71                            | -0.34%                                   | (\$11,031.96) |
| Demolition                      | 13                            | -0.37%                                   | (\$20,012.71) |
| Signs and Signaling             | 32                            | -0.51%                                   | (\$4,881.69)  |
| Erosion Control and Landscaping | 42                            | -0.59%                                   | (\$35,728.66) |
| Steel Reinforcement             | 4                             | -0.75%                                   | (\$9,916.39)  |
| Pavement Striping and Marking   | 46                            | -0.76%                                   | (\$21,574.85) |
| Aggregate                       | 20                            | -0.91%                                   | (\$71,902.85) |
| PCC Pavement                    | 5                             | -0.95%                                   | (\$93,201.75) |
| Asphalt Bases                   | 52                            | -2.54%                                   | (\$70,824.51) |
| Guardrail and Barrier           | 54                            | -2.85%                                   | (\$13,280.03) |
| Earthwork                       | 30                            | -4.45%                                   | (\$72,827.53) |

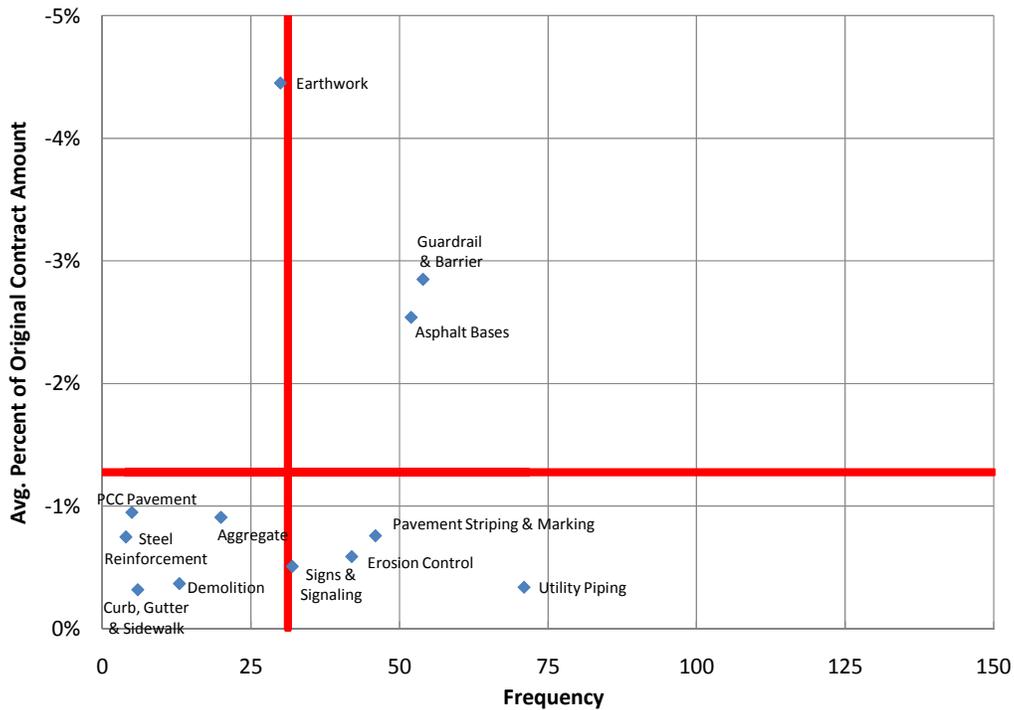


Figure 18: Work Item Analysis Matrix for Contract Item Underrun

Guardrail & Barrier and Asphalt Bases are also shown in the high risk/high frequency quadrant for Contract Item Underrun items. Both of these categories are shown to be twice the amount of the mean of both the average percent of the original contract amount and the frequency of occurrences.

Figures 13 through 18 shows that Guardrail & Barrier items and Asphalt Base items consistently display the highest change order risks in terms of both cost and frequency compared to the other 10 work categories.

### 3.8 High Risk Change Order Items

An analysis was performed to compare different methods for pricing change orders. From analyzing the work item analysis charts, it was observed that there were two categories that were consistently located in or near the high frequency/high average percent of original contract amount; Guardrail & Barrier items and Asphalt Bases items.

Because of the consistently higher risk associated with these two categories they were selected for additional analysis. All of the change order items that were classified as Guardrails & Barriers and Asphalt Bases were separated and sorted alphabetically by item name for ease of locating each item's corresponding information in the average unit bid price list. It was decided to use data from only four codes: Code 04 – *Contract Omissions*, Code 06 – *Contract Item Overrun*, Code 08 – *Owner Induced Enhancement*, and Code 20 – *Contract Item Underrun*. These codes were selected because they represented the observed highest risk for Guardrails & Barriers and Asphalt Bases. The change order items included in these four codes encompassed the majority of the items for all of the categories.

Two methods were to be used for developing an estimate for comparison to the final approved change order price. The first method was to access the Average Unit Bid Price (AUBP) database from the Cabinet's website. This website has access to price lists dating back to 1994. The methodology was to use pricing from the previous year's list compared to the final approved date on the change order. For example, in Figure 19 below, the circled approval date is shown as 20050921, reflecting an approval date of September 21, 2005. Therefore, any items chosen from this change order for sampling will use the 2004 AUBP database. The logic for using the previous year's listing is that the engineer would only have access to the previous year's database.

**Commonwealth of Kentucky**  
**Transportation Cabinet**

|                           |  |                       |  |
|---------------------------|--|-----------------------|--|
| <b>Contract ID</b>        | 052175                                 | <b>District</b>       | MANCHESTER (11311)                         |
| <b>Change Order No.</b>   | 001 APPR 20050921                      | <b>County</b>         | LESLIE                                     |
| <b>Contractor</b>         | MOUNTAIN ENTERPRISES INCORPORATED      | <b>Project Number</b> | NH 80-4(10)                                |
| <b>Contractor Address</b> | PO BOX 13070 ,LEXINGTON, KY 40583-3070 | <b>Road Name</b>      | HAL ROGERS (FORMERLY DANIEL BOONE) PARKWAY |

| Prj_Nbr       | Catg | LIN  | Item Code | Item Description            | Quantity    | Unit | Unit Price | Net Change    |
|---------------|------|------|-----------|-----------------------------|-------------|------|------------|---------------|
| MP066900605W1 | 0001 | 0030 | 07650     | SMA SURFACE(EXP)            | 800.000     | TON  | 83.100     | \$66,480.00   |
| MP066900605W1 | 0001 | 0040 | 00309     | CL2 ASPH SURF 0.50D PG64-22 | 435.000     | TON  | 48.890     | \$21,267.15   |
| MP066900605W1 | 0001 | 0140 | 02381     | REMOVE GUARDRAIL            | 51,200.000  | LF   | 1.250      | \$64,000.00   |
| MP066900605W1 | 0001 | 0230 | 00276     | CL3 ASPH BIND 0.50D PG76-22 | 3,100.000   | TON  | 55.910     | \$173,321.00  |
| MP066900605W1 | 0001 | 0240 | 00207     | CL3 ASPH BASE 1.50D PG76-22 | -4,900.000  | TON  | 50.920     | \$-249,508.00 |
| MP066900605W1 | 0001 | 0290 | 00338     | ASPHALT PLACEMENT WITH MTV  | -19,275.000 | TON  | 1.850      | \$-35,658.75  |
| MP066900605W1 | 0001 | 8000 | 00216     | CL3 ASPH BASE 1.00D PG76-22 | 4,900.000   | TON  | 50.920     | \$249,508.00  |

**Change Order Amount: \$289,409.40**

Figure 19: Change Order Date Example

The item description for each line item could usually be found in the prior year's AUBP list under the exact description listed so there was no need to make any assumptions about the line item's purpose. Each item was priced using the AUBP and compared to the actual approved price (Net Change) from the change order.

The percentage difference of change between the approved price and the price calculated using AUBP was calculated for each item using the following formula:

$$(\text{AUBP} - \text{Actual Approved Price}) / \text{Actual Approved Price}$$

**Equation 1: Formula for Percentage Difference of Change between Approved Change Order Price and Price Calculated Using Average Unit Bid Price**

Instead of having groups of items with only one, two, or three items, it was decided to consolidate the change order line items into broader groups. The purpose was to offer a more statistically significant sample to graphically display rather than have the reader view a chart that may lead them to make assumptions based on only one or two data points. These groups were sorted by year and an average of all line items percent difference was calculated for each year. All of the data analyzed was from change orders approved between 2005 and 2008.

The second method for comparison was to derive an estimate using the 2009 Means Heavy Construction Cost Data Manual in order to examine whether sources would create comparable estimates to using the AUBP. Once an estimate was calculated, the necessary adjustments for time and location would be performed. The location factor for Lexington, Kentucky of 0.917 was used to adjust the cost. Yearly factors used to adjust the cost are listed below:

2005 – 0.815  
 2006 – 0.817  
 2007 – 0.911  
 2008 – 0.970

There were a number of issues that impeded accurate estimating using the Means manual. Many of the change order line items were specific types of material and encompassed a number of materials to construct. The options for pricing the items in Means were limited and establishing a match was difficult. The engineer would have to make a number of assumptions when trying to put together an estimate.

For example, most of the estimating for any Guardrail & Barrier items had to be taken from Section 34 71 13.26 – Vehicle Guide Rails of the Means manual. The different line items were few in number and there were limited options when trying to price change order line items such as a guardrail connection to a bridge end. In this example all components of a guardrail connection to a bridge end were unknown to the estimator. We were able to find standard drawings on the KTC website at <http://www.kytc.state.ky.us/design/standard/pdf2008/StdTableofContents.htm> for [Drawing RBC-001-09](#) titled “Guardrail Connector to Bridge End Type A and A-1.” Since Means provided no detailed items found on the standard drawing such as rub rails, offset blocks, or metal plates, the pricing for the item “Guardrail Connector to Bridge End Type A” was detailed as follows:

|  |                |
|--|----------------|
| 25’ of corrugated steel guardrail with<br>steel posts spaced 6’-3” OC @ \$27.50/LF | \$ 688         |
| 1 concrete drop box  | <u>\$1,250</u> |
| Total Means Estimate for Guardrail Connector<br>to Bridge End Type A               | \$1,938        |

This estimation could vary depending upon the engineer's assessment of what is needed for this item. However, even with a clear picture of the scope of the bid item, the engineer would likely still have difficulty in translating this scope to specific Means line items.

Comparing the Means estimate to the price referenced from the AUBP list of \$2,014.10, the Means price per item is in line with this listing. The question remains about how accurate the Means price is considering the lack of detail in pricing the different parts of the line item. Items such as delineators are fairly common and can readily be found in the Means manual. The price listed in Means for a barrier and curb delineator that is reflectorized is listed as \$7.75. This price was used for white and yellow delineators in comparison to the change order line item listed. The AUBP list prices ranged from \$5.94 to \$8.12. Once the Means price is adjusted for location and time, these prices fall in line with the AUBP prices.

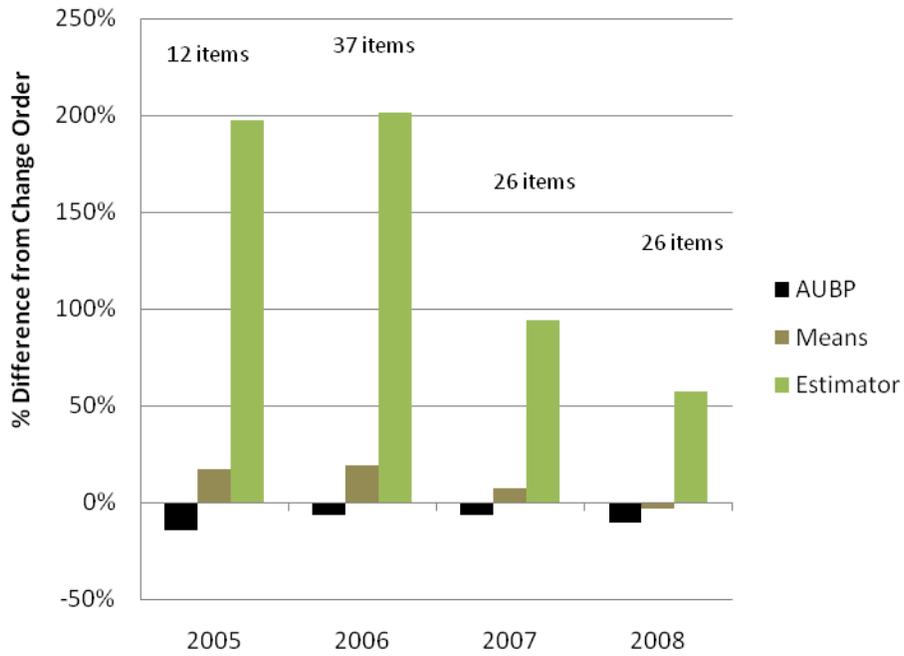
Other items could not be priced using the Means manual. Items such as the Crash Cushions, Extra Length for Guardrail Posts, Relocation of Crash Cushions, and Removal of Guardrail End Treatment were not listed in Means.

The third method for price estimation was to use the Cabinet's Estimator software that is used primarily by their design professionals. The software references databases from previous years that allowed for pricing change order items more accurately. Problems with local installation of the software limited estimating a price to using an excel sheet with database pricing for a limited number of change order line items. This information was provided by Bob Lewis, the Assistant State Highway Engineer for Kentucky. The price estimates developed using Estimator data are reflected in charts that have a third data component labeled as such. The process was similar to using Average Unit Bid Price in that a change order line item was found in the spreadsheet and its corresponding unit price was used to establish an estimated price.

### 3.8.1 Results

The grouping of common line items for Guardrail & Barrier items produced 14 different charts while grouping common items for Asphalt Base items produced 5 different charts. An example chart from each code is shown below in Figures 20 and 21.

**Average % Difference between approved change order cost and estimated cost using Average Unit Bid Price (AUBP), Means, and Estimator for Asphalt Bases, Surfaces & Binders**



**Figure 20: Asphalt Base Chart Example**

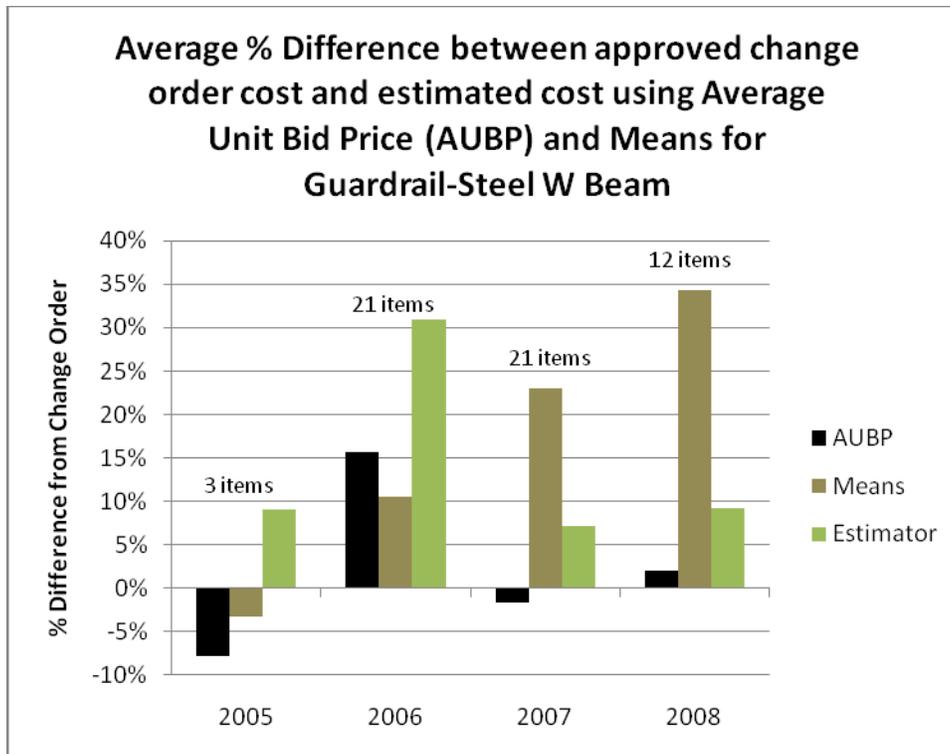


Figure 21: Guardrail & Barrier Chart Example

Each chart reflects the calculated average percent difference between the approved change order cost and the estimated cost using the Average Unit Bid Price list, the Means manual and the Estimator database. By grouping common items together, we were able to include a larger sample to graphically display. Grouping did not always produce a larger sample as is shown in Figure 10 where the year 2005 is only based on three items. Other charts shown in Appendix A had no items for some years, usually 2005.

Comparison of the average unit bid price to the approved price usually produced no more than a 50% difference, either positive or negative. The exceptions for the Guardrail and Barrier items were the Concrete Barrier Wall for 2006 at -66.8% and 2007 at -54.6% (Figure L.2), the Removing Guardrail End Treatment items for 2007 at -56% (Figure L.13) and the Guardrail End Treatment items for 2006 at -62.9% (Figure L.8). Some line items were not included in the averages due to improper pricing listed on the change order. These items included prices that were inaccurate and may have been used as a supplemental item in producing the change order.

Comparison of average unit bid price to the approved price for Asphalt Base items also produced results that reflected average differences of less than 50%, positive or negative, from the approved price. There was one exception, that being the Mobilization for Milling and Texturing where there was a 105.8% change difference for 2006 and a 172.1% change difference for 2007 (Figure L.19). This may be due to the fact that Mobilization is categorized as a lump sum item and comparisons to an average unit bid price may vary greatly if the price happens to be for a smaller project requiring less mobilization or for a larger project that requires a more mobilization.

The groups of each code can be divided into three different categories of level of variance between the average unit bid price and the actual price:

**Low Variance** – Average percent difference for all years generally ranges from 0% to 10%

**Medium Variance** – Average percent difference for all years generally ranges from 11% to 30%

**High Variance** – Average percent difference for all years generally exceeds 30%  
The Guardrail & Barrier and Asphalt Base groups are categorized as shown in Tables 37 & 38.

**Table 37: Guardrail & Barrier Variance Breakdown**

| <b>Low Variance (+/- 0%-10%)</b> | <b>Medium Variance (+/- 11%-30%)</b> | <b>High Variance (&gt; +/- 30%)</b> |
|----------------------------------|--------------------------------------|-------------------------------------|
| Guardrail Terminal Sections      | Remove Guardrail End Treatment       | Extra Length Guardrail Post         |
| Guardrail –Steel W Beam          | Remove and Reset Guardrail           | Temporary Guardrail                 |
|                                  | Relocate Crash Cushion               | Crash Cushion                       |
|                                  | Guardrail End Treatment              | Concrete Barrier Wall               |
|                                  | Guardrail Connector to Bridge End    |                                     |
|                                  | Flexible Delineator Post             |                                     |
|                                  | Delineator for Guardrail & Barrier   |                                     |
|                                  | Barricades                           |                                     |

**Table 38: Asphalt Bases Variance Breakdown**

| <b>Low Variance (+/- 0%-10%)</b>    | <b>Medium Variance (+/- 11%-30%)</b> | <b>High Variance (&gt; +/- 30%)</b> |
|-------------------------------------|--------------------------------------|-------------------------------------|
| Asphalt Bases, Surfaces and Binders | Asphalt Mix for Pavement Wedging     | Mobilization                        |
|                                     | Asphalt Pavement Milling & Texturing |                                     |
|                                     | Leveling & Wedging                   |                                     |

Most of the categories fall within the medium variance range. Positive variances reflect the average unit bid price was greater than the actual approved price. Negative variances reflect the average unit bid prices were lower than the actual approved price. For 2005 there were no positive variances for either Guardrails & Barriers or for Asphalt Bases. Of 14 categories in Guardrails & Barriers, only 4 showed positive variances and of 5 Asphalt Bases categories, only 1 had a positive variance for 2006 data. In 2007, there were 2 instances of a positive variance for Guardrails & Barriers and only 1 for Asphalt Bases. 2008 data was almost completely opposite in results from the previous three years. In that year, there were 9 instances of positive variances for the Guardrails and Barriers and 2 instances for Asphalt Bases. See figures in Appendix L.

Generally there was a trend that showed if the average unit bid price list had been used to price change order items, it could have produced a lower estimated price and thereby might have saved some money if negotiations with the contractor could have worked favorably towards the engineer. Certain items within each category showed that some are more in line with what the AUBP list reflects (i.e. Low Variance categories) and may not be the focus of intense scrutiny. But those items in the Medium and High Variance categories may need to be looked at further to reduce cost when negotiating a change order price with the contractor. Items that reflected a positive variance should be studied to see why they tend to go against the trend of AUBP being less than the approved price.

Estimating change order costs using the Means manual was found to be unreliable. From review of the charts there are some categories that have what seem to be similar estimates when compared with the estimate produced using AUBP. Other

Means estimates vary greatly from those produced using AUBP, sometimes by greater than or less than 100%. Reflecting on how the estimate was made, the lack of comparable pricing units between what KTC uses and what is used for Means produced what could only be termed a “soft” estimate from Means. The level of trust of the estimate would be far below that of using the AUBP. An engineer with more knowledge of the change order item and a better familiarity with the Means manual might be able to produce a more accurate and comparable bid.

The Means manual does not seem to support large highway construction projects and therefore the line items they list can usually need to be adapted to produce a highway item estimate. In a number of instances there were no comparable items to make an estimate with. Even though calculation of estimates using Means produced less than desirable results, it was important to attempt to produce the estimate to show at what level of accuracy an engineer could use Means as another source of pricing information. From this study it appears the use of Means would cost the engineer valuable time in research and would mostly produce inaccurate results.

Use of the Estimator software to produce a price estimate for Asphalt Bases items provided prices that were much higher on average in comparison to using AUBP and Means where pricing was available for the different bid items. The average price differences for most of the different categories ranged from 50% to almost 200% on the positive side. As stated earlier, the large difference in price could be due to inaccurate pricing database. Price estimates for Guardrail & Barrier items produced mixed results as some years had comparable variances while other years were significantly higher than AUBP or Means. Cabinet personnel stated the pricing was not as reliable as the AUBP and was only used to make initial price estimates by designers.

While Estimator allows the engineer to accurately pick the exact line items to be priced, similar to using AUBP, the prices can be misleading to the field engineer and should not be relied on until a more updated pricing database can be established.

## 4.0 Change Order Reference Cards

With the analyses of the causes of change orders and project characteristics complete, the next step developed a tool that summarizes the analyses. Change order reference cards were developed with the intention of aiding the Cabinet in quickly determining the causes and project characteristics of greatest concern with regards to change orders on current and future construction projects. The parameters for the reference cards are based on the analyses, and include the following eight reference cards:

- Risk of Impact by reason code and road type;
- Risk of Impact by reason code and district;
- Risk of Impact by reason code and new/maintenance projects;
- Risk of Impact by reason code and construction type;
- Risk of percent change by reason code and road type;
- Risk of percent change by reason code and district;
- Risk of percent change by reason code and new/maintenance projects; and
- Risk of percent change by reason code and construction type

It is important to define what impact represents in this research. For this research impact is defined as the percent change multiplied by the frequency of the specific reason code. Frequency along with percent change needs to be considered because the Cabinet has to allocate resources for both. While the percent change is directly linked to a dollar value, frequency creates issues with resources such as time and manpower required. For example, if a reason code or project characteristic has a small percent change, yet it occurs frequently then the Cabinet has to constantly use their resources to address the issue. Examining the impact identifies the areas of greatest concern with regard to change orders to provide the Cabinet the opportunity to most efficiently allocate their resources for minimizing change orders on future projects.

Control charts were used to develop the reference cards. For the reference cards there are three categories used for ranking. If the data fell above the upper control limit then it is considered extreme risk. If the data fell below the upper control limit, but above

the average then it is considered risk. Finally, if the data fell below the average then it is considered low risk. In Figure 22, the pink represents areas of extreme risk, the yellow represents areas of risk, and the green represents areas of low risk.

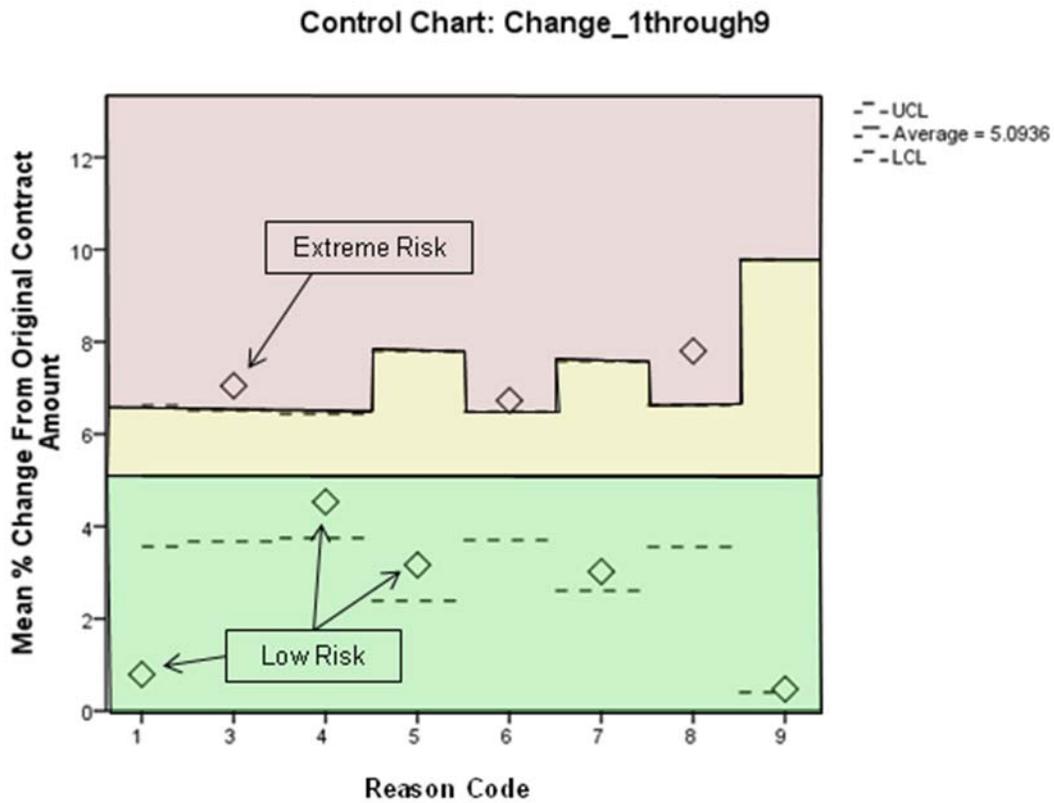


Figure 22: Extreme Risk, Risk, and Low Risk categories on a control chart

In this research, the upper and lower control limits are found by  $\mu \pm 3\sigma$ .  $\mu$  ( $\mu$ ) represents the average value and  $\sigma$  ( $\sigma$ ) represents the standard deviation. It is important to note that the upper control limit and lower control limit are not the same for each group (such as reason code 1, 2, 3, etc. in Figure 17 above) in the control charts. The differing limits are due to the variation in the sample size of each group. In many control charts, the sample size is consistent so the upper control limit and lower control limit are straight lines. However, in this study each group's sample size differs. Because the standard deviation ( $\sigma$ ) is derived from the sample size being considered, the upper and lower control limits vary.

For each reference card, there is an “overall” control chart and a “sub” control chart. The overall control chart is an overall average of the reason codes focused on in the research. For the overall control chart, the  $\bar{x}$  chart is used and the standard deviation chart is not, since the overall variability between reason codes is not a concern. The sub control charts are the individual averages of each reason code. For the sub control charts, both the  $\bar{x}$  and standard deviation charts are used because the mean and variability within each reason code is a concern.

Once the control charts were developed in SPSS Inc. the data points were assigned ratings of extreme, risk, or low. For the overall control chart, one rating is assigned to each reason code, since only the  $\bar{x}$  chart is used. However, the sub control chart has a rating for both the  $\bar{x}$  and standard deviation charts (See Figure 18). To gain one rating for the sub control chart, a process similar to taking the average of the two ratings is used. For instance, an extreme and low rating equals a risk rating or an extreme and risk equals an extreme risk rating (when next to each other such as low and risk or risk and extreme always use worst case scenario). Table 39 shows the algorithm for determining the change order reference card rating.

**Table 39: Algorithm for Change Order Reference Card Rating**

| Overall Control Chart | Sub Control Chart | Rating  |
|-----------------------|-------------------|---------|
| Extreme               | Extreme           | Extreme |
| Extreme               | Risk              | Extreme |
| Risk                  | Extreme           | Extreme |
| Extreme               | Low               | Risk    |
| Risk                  | Risk              | Risk    |
| Risk                  | Low               | Risk    |
| Low                   | Extreme           | Risk    |
| Low                   | Risk              | Risk    |
| Low                   | Low               | Low     |

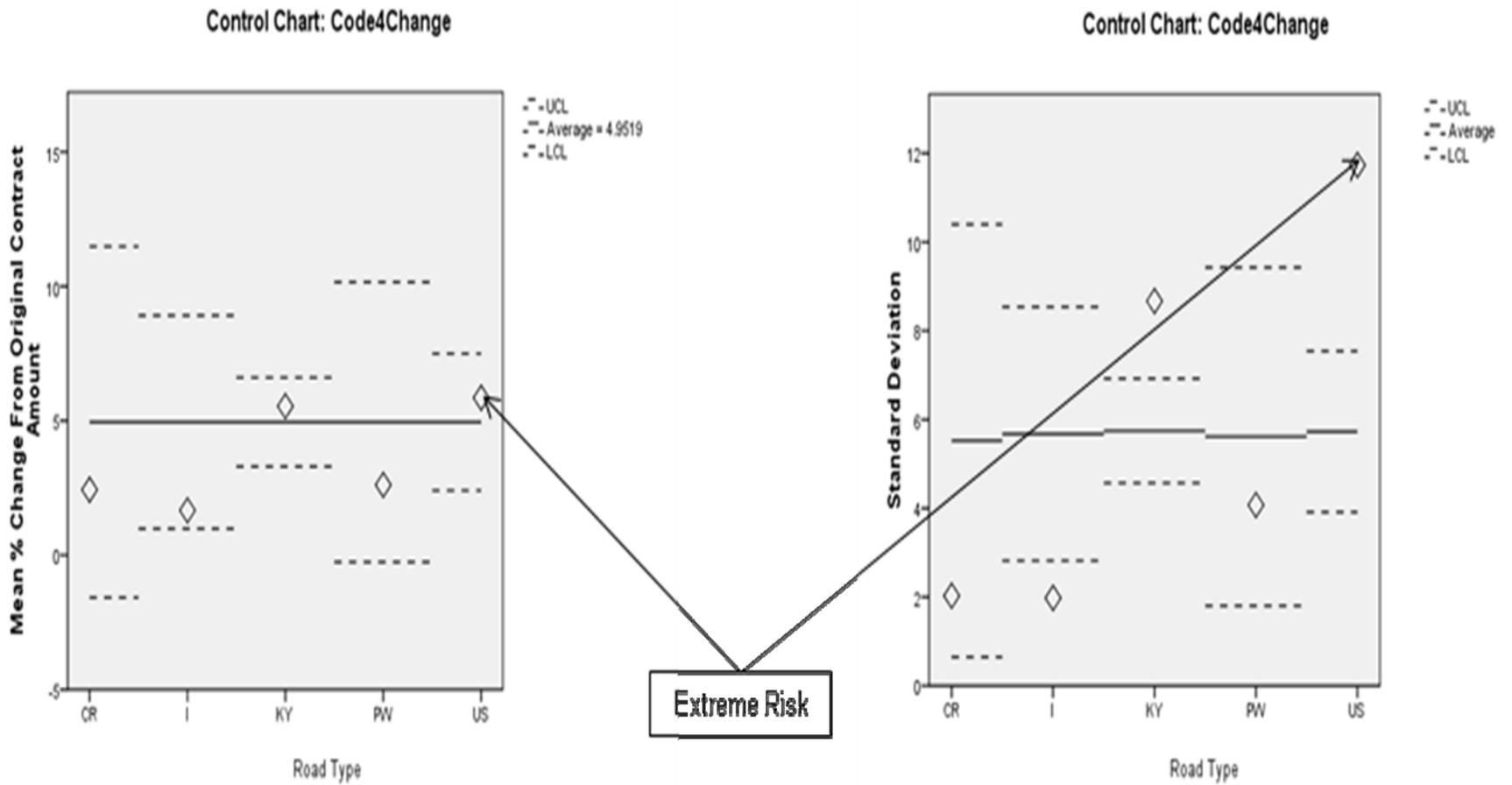


Figure 23: Example of assigning risk from the control charts

After assigning ratings to the overall and sub control charts (For example, see Tables 40 and 41), the ratings are combined using the same algorithm shown in Table 39 to create the final rating that is on the change order reference card. It is important to note that the change order reference card is also referred to as a Quick Guide in this report.

**Table 40: Example of Assigned Overall Control Chart Rating**

| Overall Rating |     |         |     |     |         |     |         |     |
|----------------|-----|---------|-----|-----|---------|-----|---------|-----|
| Code           | 1   | 3       | 4   | 5   | 6       | 7   | 8       | 9   |
| Rating         | Low | Extreme | Low | Low | Extreme | Low | Extreme | Low |

**Table 41: Example of Assigned Sub Control Chart Rating**

| Sub Rating |      |      |         |         |      |         |      |         |         |
|------------|------|------|---------|---------|------|---------|------|---------|---------|
|            | Code | 1    | 3       | 4       | 5    | 6       | 7    | 8       | 9       |
| Road Type  | CR   | Low  | Low     | Low     | Risk | Extreme | ---  | Low     | ---     |
|            | I    | Low  | Low     | Low     | Low  | Low     | Low  | Low     | Low     |
|            | KY   | Risk | Extreme | Extreme | Risk | Risk    | Risk | Extreme | Extreme |
|            | PW   | Risk | Risk    | Low     | ---  | Risk    | Risk | Low     | ---     |
|            | US   | Risk | Extreme | Extreme | Low  | Low     | Risk | Extreme | Low     |

The final change order reference cards are discussed below:

Figure 24 examines the impact by reason code and road type. The road types with the greatest risk are Kentucky and US roadways. The reason codes with the highest impact on Kentucky roadways are Fuel & Asphalt Adjustment, Contract Omission, and Contract Item Overrun. On US roadways the reason codes with the highest impact are Fuel & Asphalt Adjustment, Contract Omission, and Owner Induced Enhancement. Other areas of extreme risk are Contract Item Overrun on County Roads and Parkways and Fuel & Asphalt Adjustment on Parkways. Interstates show no reason codes of extreme risk.

Quick Guide: Risk of **IMPACT** by Reason Code and Road Type

| Reason Code | Description                | Road Type |   |    |     |    |
|-------------|----------------------------|-----------|---|----|-----|----|
|             |                            | CR        | I | KY | PW  | US |
| 1           | Asphalt Lot Pay Adjustment | ○         | ○ | ●  | ○   | ●  |
| 3           | Fuel & Asphalt Adjustment  | ●         | ● | ●  | ●   | ●  |
| 4           | Contract Omission          | ●         | ● | ●  | ●   | ●  |
| 5           | Utility Issue              | ●         | ○ | ○  | --- | ○  |
| 6           | Contract Item Overrun      | ●         | ● | ●  | ●   | ●  |
| 7           | Geotechnical Issues        | ---       | ○ | ●  | ●   | ●  |
| 8           | Owner Induced Enhancement  | ●         | ● | ●  | ●   | ●  |
| 9           | Environmental Issues       | ---       | ○ | ●  | --- | ○  |

- Low Risk of impact
- Risk of impact
- Extreme Risk of impact
- Data Insufficient

Figure 24: Quick Guide: Risk of Impact by Reason Code and Road Type

Figure 25 shows the second change order reference card. It looks at the impact by reason code and district. No districts stood out as having the highest risk when compared with the other districts. Instead, there are a few change order causes that are extreme risk. The reason codes that have extreme risk are Contract Omission, Contract Item Overrun, and Owner Induced Enhancement. Fuel & Asphalt Adjustment also has a higher number of districts with extreme risk, but it is out of the Cabinet’s control. There are a couple of districts that have less risk than the other districts. District 3 has no reason codes with extreme risk and districts 2 and 12 only have one reason code with extreme risk. Also, Asphalt Lot Pay Adjustment, Utility Issue, Geotechnical Issue, and Environmental Issue have no extreme risk in any of the districts.

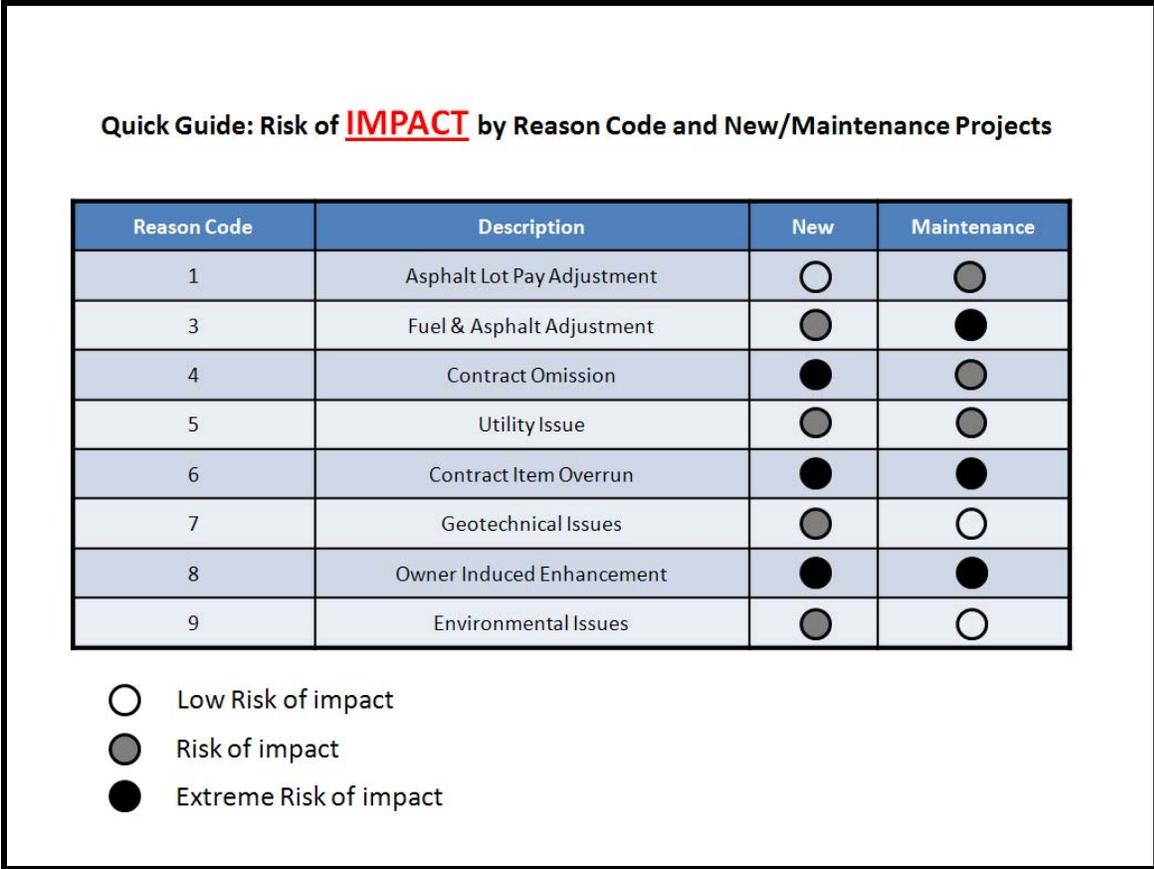
Quick Guide: Risk of **IMPACT** by Reason Code and District

| Reason Code | Description                | District |     |   |     |   |   |   |   |     |    |     |     |
|-------------|----------------------------|----------|-----|---|-----|---|---|---|---|-----|----|-----|-----|
|             |                            | 1        | 2   | 3 | 4   | 5 | 6 | 7 | 8 | 9   | 10 | 11  | 12  |
| 1           | Asphalt Lot Pay Adjustment | ○        | ●   | ○ | ●   | ○ | ○ | ○ | ○ | ○   | ●  | ●   | ●   |
| 3           | Fuel Adjustment            | ●        | ●   | ● | ●   | ● | ● | ● | ● | ●   | ●  | ●   | ●   |
| 4           | Contract Omission          | ●        | ●   | ● | ●   | ● | ● | ● | ● | ●   | ●  | ●   | ●   |
| 5           | Utility Issue              | ●        | ○   | ○ | ○   | ○ | ● | ○ | ○ | --- | ●  | ○   | ●   |
| 6           | Contract Item Overrun      | ●        | ●   | ● | ●   | ● | ● | ● | ● | ●   | ●  | ●   | ●   |
| 7           | Geotechnical Issues        | ●        | ○   | ○ | ○   | ○ | ○ | ○ | ○ | ○   | ○  | --- | ○   |
| 8           | Owner Induced Enhancement  | ●        | ●   | ● | ●   | ● | ● | ● | ● | ●   | ●  | ●   | ●   |
| 9           | Environmental Issues       | ---      | --- | ● | --- | ○ | ○ | ● | ● | --- | ●  | ○   | --- |

○ Low Risk of impact      --- Data Insufficient  
 ● Risk of impact  
 ● Extreme Risk of impact

Figure 25: Quick Guide: Risk of Impact by Reason Code and District

Figure 36 shows the third change order reference card. It looks at the impact by reason code and new construction vs. maintenance work. Maintenance work has Fuel & Asphalt Adjustment, Contract Item Overrun, and Owner Induced Enhancement as extreme risk. The card also shows that maintenance work has low risk for Geotechnical Issue and Environmental Issue. New construction has Contract Omission, Contract Item Overrun, and Owner Induced Enhancement as extreme risk. The card also shows that new construction has low risk for Asphalt Lot Pay Adjustment. This change order reference card shows that there are reason codes with extreme risk for both maintenance work and new construction. To minimize the risk, maintenance work and new construction needs more planning and better management of change orders.



Figure

26: Quick Guide: Risk of Impact by Reason Code and New/Maintenance Projects

Figure 27 shows the fourth change order reference card. It looks at the impact by reason code and construction type (earthwork, road surface, and structures). Earthwork is the type of construction with the least amount of extreme risk, but it has no reason codes with low risk. Contract Item Overrun is the only reason code for earthwork that has extreme risk. Road surface shows extreme risk for Fuel & Asphalt Adjustment and Owner Induced Enhancement, while Utility Issue, Geotechnical Issue, and Environmental Issue have low risk. Structures show extreme risk for Contract Omission and Contract Item Overrun, while Asphalt Lot Pay Adjustment, Utility Issue, Geotechnical Issue, and Environmental Issue have low risk. This change order reference card shows that there is more extreme risk on road surface and structures work. Road surface and structures work needs more planning and better management of change orders.

Quick Guide: Risk of **IMPACT** by Reason Code and Construction Type

| Reason Code | Description                | Earthwork | Road Surface | Structures |
|-------------|----------------------------|-----------|--------------|------------|
| 1           | Asphalt Lot Pay Adjustment | ●         | ●            | ○          |
| 3           | Fuel & Asphalt Adjustment  | ●         | ●            | ●          |
| 4           | Contract Omission          | ●         | ●            | ●          |
| 5           | Utility Issue              | ●         | ○            | ○          |
| 6           | Contract Item Overrun      | ●         | ●            | ●          |
| 7           | Geotechnical Issues        | ●         | ○            | ○          |
| 8           | Owner Induced Enhancement  | ●         | ●            | ●          |
| 9           | Environmental Issues       | ●         | ○            | ○          |

- Low Risk of impact
- Risk of impact
- Extreme Risk of impact

Earthwork: Grade & Drain, Flood/Slide Repair  
 Road Surface: Asphalt Surfacing, Asphalt Resurfacing, Jointed Plain Concrete  
 Structure: Bridge Work, Culvert Replacement, Guardrail, Pipe Replacement

27: Quick Guide: Risk of Impact by Reason Code and Construction Type

Figure

Figure 28 shows the fifth change order reference card. It looks at the percent change by reason code and road type. The road types that have the highest risk are Kentucky and US roadways. Kentucky roadways have extreme risk for Fuel & Asphalt Adjustment, Contract Item Overrun, and Owner Induced Enhancement. On US roadways Fuel & Asphalt Adjustment and Owner Induced Enhancement have extreme risk. Parkways also have extreme risk on Fuel & Asphalt Adjustment and Contract Item Overrun, but have no change orders due to Utility Issue or Environmental Issue. As is the case with impact by road type, Interstates have the lowest risk with no reason codes having extreme risk.

**Quick Guide: Risk of PERCENT CHANGE by Reason Code and Road Type**

| Reason Code | Description                | Road Type |   |    |     |    |
|-------------|----------------------------|-----------|---|----|-----|----|
|             |                            | CR        | I | KY | PW  | US |
| 1           | Asphalt Lot Pay Adjustment | ○         | ○ | ●  | ○   | ●  |
| 3           | Fuel & Asphalt Adjustment  | ●         | ● | ●  | ●   | ●  |
| 4           | Contract Omission          | ○         | ○ | ●  | ○   | ●  |
| 5           | Utility Issue              | ●         | ○ | ●  | --- | ○  |
| 6           | Contract Item Overrun      | ●         | ● | ●  | ●   | ●  |
| 7           | Geotechnical Issues        | ---       | ○ | ●  | ●   | ●  |
| 8           | Owner Induced Enhancement  | ●         | ● | ●  | ●   | ●  |
| 9           | Environmental Issues       | ---       | ○ | ●  | --- | ○  |

- Low Risk of % change from original contract amount     --- Data Insufficient
- Risk of % change from original contract amount
- Extreme Risk of % change from original contract amount

**Figure 28: Quick Guide: Risk of Percent Change by Reason Code and Road Type**

Figure 29 shows the sixth change order reference card. It looks at the percent change by reason code and district. As is the case with impact by district, no districts stood out as having the highest risk when compared with the other districts. Instead, there are a few reason codes with extreme risk. The reason codes that have more extreme risk are Contract Item Overrun and Owner Induced Enhancement. Fuel & Asphalt Adjustment also has extreme risk in several districts, but is out of the Cabinet’s control. There are a couple of districts that have less risk than the other districts. District 1 has no reason codes with extreme risk and district 2 and 5 only have extreme risk for Fuel & Asphalt Adjustment. Also, Asphalt Lot Pay Adjustment, Contract Omission, Utility Issue, Geotechnical Issue, and Environmental Issue have no extreme risk in any of the districts.

Quick Guide: Risk of **PERCENT CHANGE** by Reason Code and District

| Reason Code | Description                | District |     |   |     |   |   |   |   |     |    |     |     |
|-------------|----------------------------|----------|-----|---|-----|---|---|---|---|-----|----|-----|-----|
|             |                            | 1        | 2   | 3 | 4   | 5 | 6 | 7 | 8 | 9   | 10 | 11  | 12  |
| 1           | Asphalt Lot Pay Adjustment | ○        | ○   | ● | ●   | ● | ○ | ● | ○ | ○   | ●  | ●   | ●   |
| 3           | Fuel & Asphalt Adjustment  | ●        | ●   | ● | ●   | ● | ● | ● | ● | ●   | ●  | ●   | ●   |
| 4           | Contract Omission          | ●        | ○   | ● | ●   | ● | ● | ○ | ● | ○   | ●  | ○   | ○   |
| 5           | Utility Issue              | ●        | ○   | ○ | ●   | ○ | ○ | ○ | ○ | --- | ●  | ○   | ●   |
| 6           | Contract Item Overrun      | ●        | ●   | ● | ●   | ● | ● | ● | ● | ●   | ●  | ●   | ●   |
| 7           | Geotechnical Issues        | ●        | ○   | ○ | ●   | ● | ● | ● | ○ | ●   | ●  | --- | ●   |
| 8           | Owner Induced Enhancement  | ●        | ●   | ● | ●   | ● | ● | ● | ● | ●   | ●  | ●   | ●   |
| 9           | Environmental Issues       | ---      | --- | ● | --- | ○ | ○ | ● | ● | --- | ●  | ○   | --- |

○ Low Risk of % change from original contract amount    --- Data Insufficient  
 ● Risk of % change from original contract amount  
 ● Extreme Risk of % change from original contract amount

Figure 29: Quick Guide: Risk of Percent Change by Reason Code and District

Figure 30 shows the seventh change order reference card. It looks at the percent change by reason code and new construction vs. maintenance work. Maintenance work has Fuel & Asphalt Adjustment, Contract Item Overrun, and Owner Induced Enhancement as extreme risk. Maintenance work also only has one reason code as low risk (Environmental Issue). New construction has no reason codes with extreme risk and three reason codes with low risk (Asphalt Lot Pay Adjustment, Contract Omission, and Utility Issue). This change order reference card shows that there is more risk involved with maintenance work. Maintenance work needs more planning and better management of change orders.

**Quick Guide: Risk of PERCENT CHANGE by Reason Code and New/Maintenance Projects**

| Reason Code | Description                | New | Maintenance |
|-------------|----------------------------|-----|-------------|
| 1           | Asphalt Lot Pay Adjustment | ○   | ●           |
| 3           | Fuel & Asphalt Adjustment  | ●   | ●           |
| 4           | Contract Omission          | ○   | ●           |
| 5           | Utility Issue              | ○   | ●           |
| 6           | Contract Item Overrun      | ●   | ●           |
| 7           | Geotechnical Issues        | ●   | ●           |
| 8           | Owner Induced Enhancement  | ●   | ●           |
| 9           | Environmental Issues       | ●   | ○           |

- Low Risk of % change from original contract amount
- Risk of % change from original contract amount
- Extreme Risk of % change from original contract amount

**Figure 30: Quick Guide: Risk of Percent Change by Reason Code and New/Maintenance Projects**

Figure 31 shows the eighth and final change order reference card. It looks at the percent change by reason code and construction type (earthwork, road surface, and structures). Earthwork is the type of construction with the least amount of risk. No reason codes for earthwork have extreme risk and Contract Omission and Geotechnical Issue have low risk. Road surface shows extreme risk for Fuel & Asphalt Adjustment and Owner Induced Enhancement, while Utility Issue and Environmental Issue have low risk. Structures show extreme risk for Contract Item Overrun and Owner Induced Enhancement, while Asphalt Lot Pay Adjustment and Utility Issue have low risk. This change order reference card shows there is more risk on road surface and structures work. Road surface and structures work needs more planning and better management of change orders.

Quick Guide: Risk of **PERCENT CHANGE** by Reason Code and Construction Type

| Reason Code | Description                | Earthwork | Road Surface | Structures |
|-------------|----------------------------|-----------|--------------|------------|
| 1           | Asphalt Lot Pay Adjustment | ●         | ●            | ○          |
| 3           | Fuel & Asphalt Adjustment  | ●         | ●            | ●          |
| 4           | Contract Omission          | ○         | ●            | ●          |
| 5           | Utility Issue              | ●         | ○            | ○          |
| 6           | Contract Item Overrun      | ●         | ●            | ●          |
| 7           | Geotechnical Issues        | ○         | ●            | ●          |
| 8           | Owner Induced Enhancement  | ●         | ●            | ●          |
| 9           | Environmental Issues       | ●         | ○            | ●          |

- Low Risk of % change from original contract amount  
 ● Risk of % change from original contract amount  
 ● Extreme Risk of % change from original contract amount
- Earthwork: Grade & Drain, Flood/Slide Repair  
 Road Surface: Asphalt Surfacing, Asphalt Resurfacing, Jointed Plain Concrete  
 Structure: Bridge Work, Culvert Replacement, Guardrail, Pipe Replacement

Figure 31: Quick Guide: Risk of Percent Change by Reason Code and Construction Type

## **5.0 Pricing Change Orders**

Data collection for this project revealed a lack of a consistent and functional method for obtaining consistent pricing for change orders. When presented with the need for a change order by a contractor, engineers turn to a number of different methods to price change orders. Some methods used are fairly simplistic but may not always produce the best estimate for comparison. Other methods may be more accurate but may be cumbersome to use and can be an inefficient use of resources. The question then becomes: can a method for pricing change orders be developed that achieves a balance between timeliness and accuracy?

### **5.1 Literature Review**

A literature review was performed to obtain information about other state departments of transportation change order policies and procedures as well as other construction industry practices concerning change orders. Other information was found concerning issues related to change orders that covered varied areas of construction. Literature was also reviewed with the purpose of finding any information about whether public or private agencies have written policies on how to calculate an estimate for change orders before settling on the price with the contractor.

#### **5.1.1 Change Order Pricing Procedures for Other State Departments of Transportation**

The literature search found that most of the states examined had some written policy on how to process change orders. The level of policy that was detailed varied from state to state. States such as Pennsylvania, Ohio and North Carolina have very detailed procedures about what constitutes the need for a change order and what the proper procedures are for creating, managing and completing one. Other states level of detail on change orders amounted to a general definition of a change order and some details about proper procedures for creating them and who is responsible for signing off on the change order.

From the information, it was decided to prepare a flowchart detailing how a few of the states would prepare a change order. The idea was to follow the change order from the initial

discovery for its need through until the actual change order is written. The states chosen for this were Pennsylvania, Ohio and North Carolina due to their level of process detail. Pricing models developed from interviews with two KTC field engineers are also shown and compared and contrasted to the three states.

A review of North Carolina's Department of Transportation process for handling the pricing of change orders (NCDOT 2010) resembled most of the other processes found during a search on the web of states that had some level of detail on how they priced a change order. These methods were also similar to the methods used by some Kentucky Transportation Cabinet's field engineers who were interviewed as part of this study. After identifying a potential need for a change order, the contractor notifies the resident engineer (RE) who investigates the claim. At this point, the RE decides if the item is claimable as a change order item. If the engineer decides it is not, then the contractor is informed and has the option to appeal the decision at a higher level. If the RE decides the item is claimable, then they request a price with a detailed cost breakdown similar to a force account situation. The RE may also decide at this point to seek additional assistance for review from other units in the Department who prepare estimates on other construction related projects. After receiving the price from the contractor, the RE compares it to the information he has gathered from other sources which can include other projects, equipment rental agencies and state bid average prices. After comparing the information, the RE decides if the contractor's price is acceptable. If the price is acceptable, the change order is written. If the price is not acceptable, the RE will negotiate with the contractor over the price. If a price can be agreed upon then the change order is prepared. If negotiating does not resolve the issue, the RE will resort to tracking the cost of the change through force account measures. A conceptual flowchart of the NCDOT pricing process is shown in Figure 37.



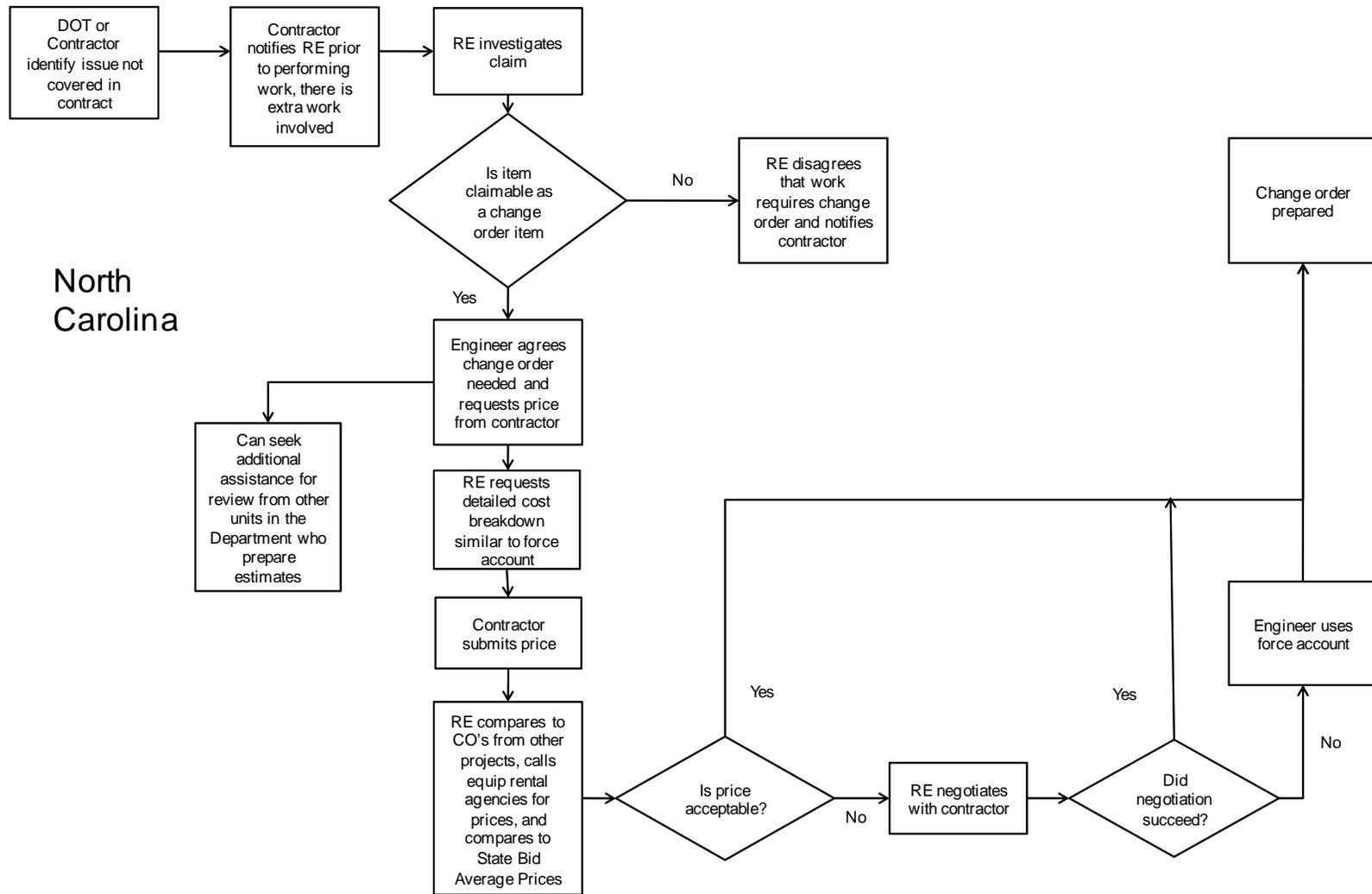


Figure 32: North Carolina Change Order Pricing Process

Pennsylvania's Department of Transportation (PennDOT, 2005) has a different method for determining the validity of a change order and determining the price. After the extra work is identified by either the engineer or the contractor, the District Engineer (DE) determines whether they and the contractor can reach agreement on a tentative price for the work and whether there is sufficient administrative support to keep proper force account records, if the situation arises. If the DE determines both criteria can be met, a request for pricing from the contractor is issued. If the DE determines that force account record can be kept and the price can be negotiated with the contractor, then the request for pricing from the contractor will be issued. After receiving the price from the contractor the DE will do one or more of the following procedures for comparison of the contractor's price: (1) the DE will compare the price to the average price data for the same item(s) of work taken from a historical database, (2) the DE compares the price to a price paid for similar work on at least two other allied contracts, (3) the DE will compute the cost associated with the work using the force account format for comparison, or (4) the DE will compute a price based on an acceptable engineering analysis. From this comparison, the DE will determine if the contractor's price is acceptable to at least one of these methods. If so then the change order is prepared. If it is still not acceptable, force account tracking will be used.

If the DE determines that neither a reasonable price can be agreed upon or there is not sufficient manpower to keep force account records, the DE will produce written authorization that will contain a firm and binding price that the engineer will have determined to be fair and equitable. At this point the change order will be prepared. If the DE determines that force account records can be kept but a fair price cannot be negotiated with the contractor, then force account will be used to track the work and the change order will be written.

A flowchart depicting Pennsylvania's change order pricing process is show in Figure 38.



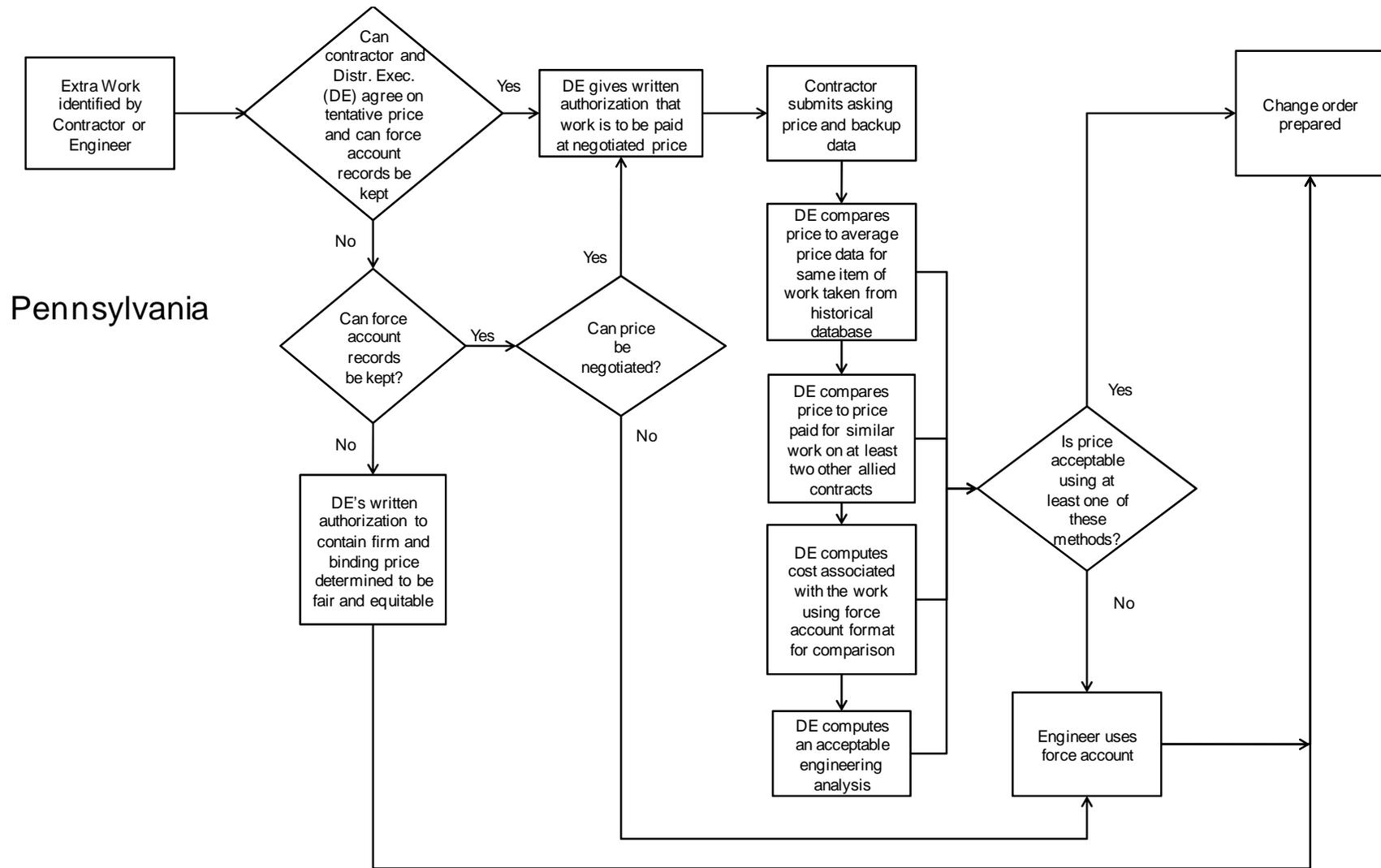


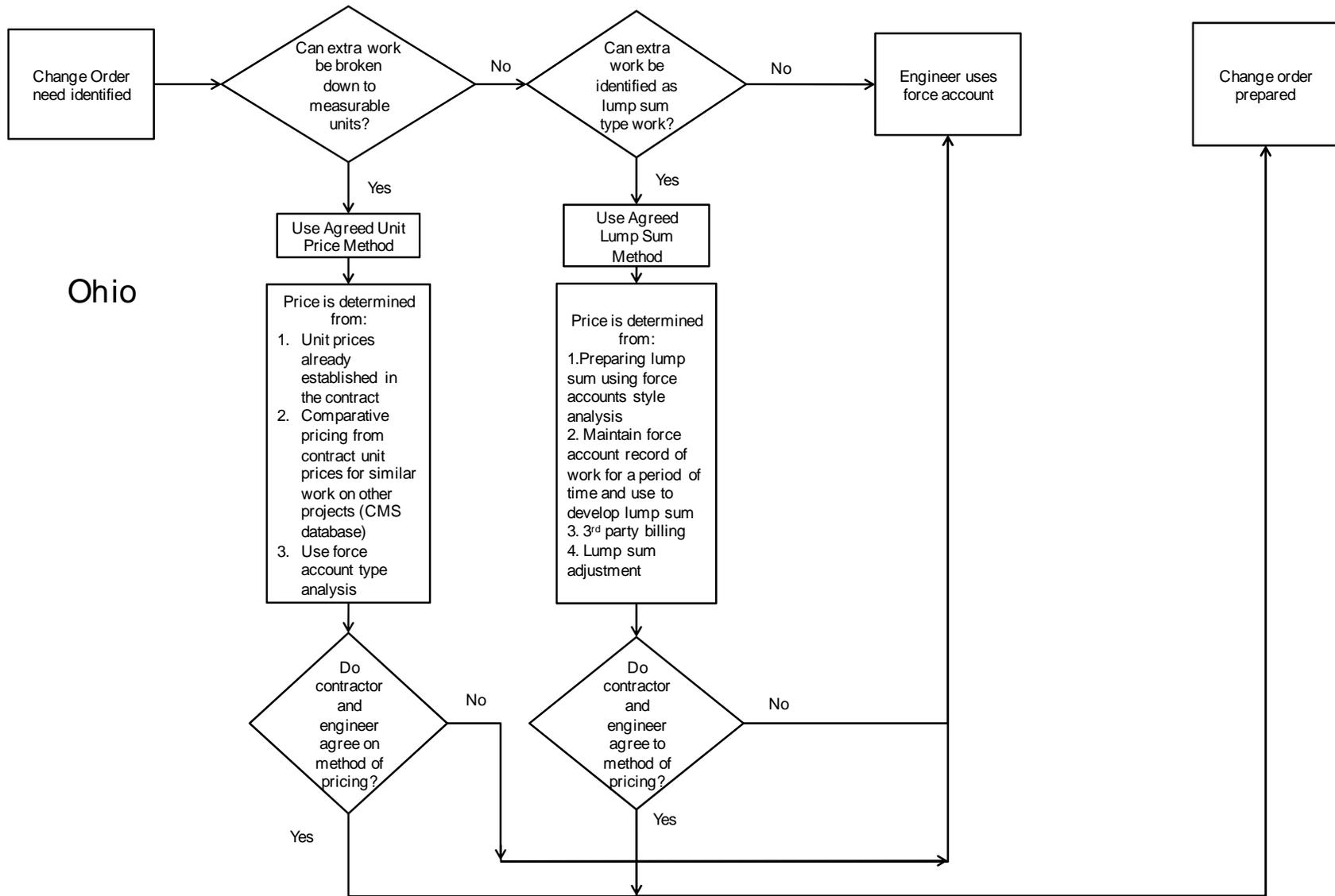
Figure 33: Pennsylvania Change Order Pricing Process



The Ohio Department of Transportation (ODOT, 2010) also has a slightly different method of determining the validity of a change order verifying reasonableness of the price from the contractor. After a change order need has been identified, the engineer decides first if the work could be broken down to measurable units (i.e. tons, linear feet). If it can then the engineer will use the Agreed Unit Price Method where the price is determined from a list of criteria. The price is derived from either unit prices already established in the contract, or comparative pricing from contract unit prices for similar work on other projects (the CMS database) or from a force account type basis. If after this point the engineer and the contractor do not agree on the price, then force account will be used. If they do agree on the method of pricing then the change order is prepared.

If the engineer feels the work cannot be broken down and tracked in measurable units, the engineer decides if the work can be identified as lump sum type of work. If the decision is no, then force account tracking will be used and the change order is prepared. If however the work can be identified in lump sum form, the Agreed Lump Sum Method will be used to determine the price. Using this method, the price is developed from one of four methods. The price is determined from preparing lump sum amount using force account style analysis, or maintaining force account records for a period of time and then using this information to develop a lump sum price, or using a third party billing system to establish the amount, or using a lump sum adjustment. If the contractor and engineer agree on one of these methods, then the change order is prepared. If they cannot reach agreement then force account will be used and the change order is prepared.

The flowchart depicting Ohio's process for handling change orders is shown in Figure 39.



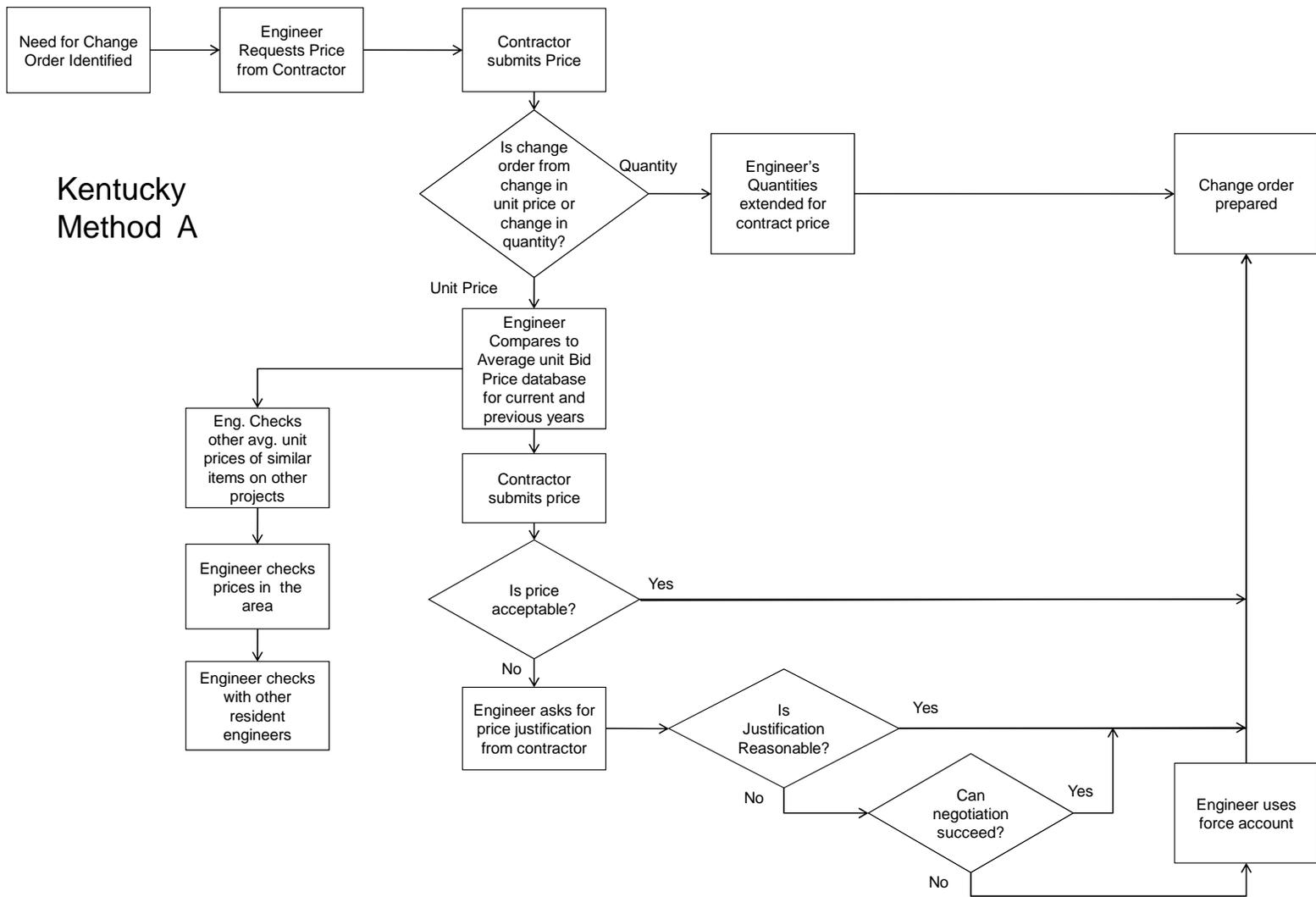
Ohio

Figure 34: Ohio Change Order Pricing Process

Interviews with KTC field engineers produced similar results for change order pricing procedures. Two methods, Method A and Method B, were developed from the processes and procedures used by two of the field engineers. Method A involved the engineer requesting a price for the work once a need for a change order was identified. Once the contractor submitted the price, the engineer then decided whether the change was due to a change in quantities or change in the unit price or scope. If the change was based solely on additional quantities, then the engineer would use the unit price from the original contract and prepare the change order based on that extension of price multiplied by quantity.

If the change involved a unit price change, the engineer would initially compare the price submitted to the most recent average unit bid price list from the Cabinet's website referenced earlier. The engineer would compare the price to any current year data, if available, as well as previous years. This was to give the engineer a couple of prices for comparison as opposed to one price. Simultaneously, the engineer may decide to investigate other sources of pricing information. The engineer would look for other average unit bid prices of similar items on other projects for comparison. The engineer would also check prices of the item in the area from outside sources like local contractors or local equipment dealers. Finally, the engineer may also consider checking with other resident engineers in their area of the state.

After collecting the desired information, the engineer would decide if the contractor's submitted price was acceptable. If the price is acceptable, the change order would be prepared using the contractor's price. If the engineer decided the price was not acceptable, then a price justification would be requested from the contractor. Once received, the engineer would decide if the justification is reasonable. If it is, the change order is prepared. If not, the engineer would decide if they thought successful negotiations over the price could be reached. If so then the engineer and contractor would proceed to negotiate to an agreed upon price. If the engineer determines that a negotiated price cannot be reached then force account is used to determine the change order price. The example flowchart is shown in Figure 35.



**Figure 35: Kentucky Method A Change Order Process**

Kentucky Method B (Figure 36) proceeds in a different manner from Method A. Once a need for a change is identified, the engineer in this situation would walk the area of the site in question with the contractor to identify pay item(s) involved. Once the identification is made, the contractor will develop and submit their price. Simultaneously, the engineer would identify an estimate based on the most recent average unit bid price listing from the Cabinet's website. After receiving the contractor's price, the engineer would decide if the price is acceptable based on a comparison to the estimated price they developed. If the price is acceptable, the change order is written up using the contractor's price. If the price is deemed not acceptable, the engineer requests a detailed price justification from the contractor.

Once the detail is received from the contractor, the engineer decides if the price is acceptable based on the justification. If the price is acceptable, the change order is prepared. If not, the engineer will again walk the site with the contractor and discuss the reasoning of their justification. After this discussion the engineer decides if they can come to an agreement on a reasonable price with the contractor. If they can, the negotiated price is used for preparation of the change order. If negotiations do not produce the desired results for both parties the engineer resorts to using the cost plus method in determining the final amount of the change order.

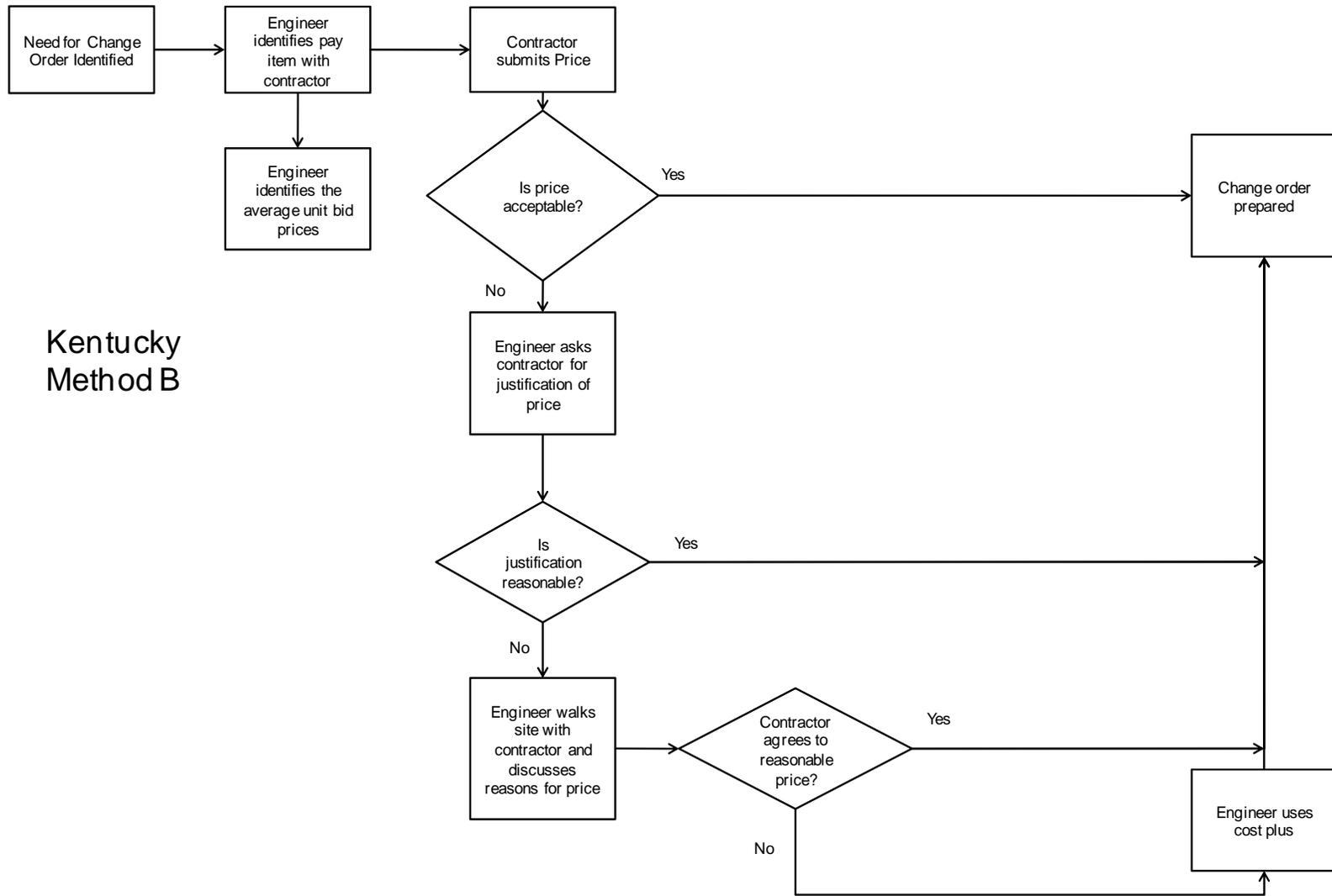


Figure 36: Kentucky Method B Change Order Process

Comparison of the five different flowcharts showed similarities in the manner in which a change order is initiated, a price is identified and agreed upon, and the change order written. Some of the aspects that are similar between one or more of the examples are:

- All of the states use a historical database of prices as a source of comparison at some point in the process. For some (Ohio, Kentucky Methods A& B) it is one of the first sources to consult and for others it is a secondary source (North Carolina) or part of larger group of sources (Pennsylvania).
- All of the examples use Force Account as a last means of determining the price to use for the change order
- Ohio and Pennsylvania list specific sources for finding information on unit prices.
- North Carolina, Pennsylvania and Kentucky Method A will at some point in their process make a decision on whether negotiations with contractors about pricing can succeed.
- Kentucky Method B and Ohio appear to involve the contractor more in the decision making process rather than simply submitting a price and having it examined by the engineer for reasonableness. In the case of Kentucky Method B, the contractor makes a point to walk the site with the contractor to understand exactly what is being included in the change order and why it is being included. If after a price justification is requested by the engineer and the contractor submits a price the engineer feels is still not justified, they again will walk the site together to come to better understanding about how the contractor came up with his price. In the process used by Ohio, the engineer seeks to involve the contractor in determining whether the extra work can be priced using an agreed upon unit price method or if that does not work, using a lump sum method. The engineer and the contractor must agree upon the method of pricing together.
- All of the examples, with the exception of Ohio, will request a price justification/breakdown at some point of the process if the engineer is not satisfied with the price given by the contractor.

There were also a few unique features to some of the different methods shown. These included:

- Only Pennsylvania makes an initial decision as to the possibility of whether the engineer feels they can reach a tentative price to use AND whether there is enough manpower to keep force accounts records if the situation requires it. Only after this decision is made can the engineer proceed to determining pricing for the change order items.
- Ohio's system is unique in that they first determine whether the extra work can be broken down into measurable units. If it can they move on to pricing and agreement between contractor and engineer. If the work cannot be broken down into measurable units, they determine if the work can be grouped and priced as a lump sum item. If so they proceed with another list of methods to determine the price base on the lump sum method. None of the other examples makes this distinction.

### 5.1.2 Change Order Pricing Procedures Outside of DOTs

In the course of searching for documented change order procedures, little information could be found on other areas of construction. Attempts were made to find this documentation for private projects, but most private companies do not publically list their change order pricing policies. For Departments of Transportation and other public agencies, it is usually a requirement for these procedures to be well documented and in most states, readily accessible whether by print or on a public website. For these reasons, comparison of procedures for other construction branches was not easily found.

One source which may encompass the methods in which many private companies handle change orders can be found in the American Institute of Architect (AIA) Contract Documents (American Institute of Architects, 1997). These documents, regarded as the industry standard by many professionals, are a template for many aspects of a construction project and can be modified to suit the individual needs of most projects. Article 7 broadly discusses changes in work with Article 7.2.1 defining a change order as:

A Change Order is a written instrument prepared by the Architect and signed by the Owner, Contractor and Architect, stating their agreement upon all of the following:

- .1 change in the Work;
- .2 the amount of the adjustment, if any, in the Contract Sum; and
- .3 the extent of the adjustment, if any, in the Contract Time.

Section 7.2.2 states that methods used to determine the adjustment amount are listed in Section 7.3.3 outlining adjustments by use of Construction Change Directives. Details of Section 7.3.3 are shown below.

If the Construction Change Directive provides for an adjustment to the Contract Sum, the adjustment shall be based on of the following methods:

- .1 mutual acceptance of a lump sum properly itemized and supported by sufficient substantiating data to permit evaluation;
- .2 unit prices stated in the Contract Documents or subsequently agreed upon;
- .3 cost to be determined in a manner agreed upon by the parties and a mutually acceptable fixed or percentage fee; or
- .4 as provided in Section 7.3.6.

The options for developing the adjustment price are similar to some of the methods outlined in the flowcharts for Ohio, Pennsylvania, North Carolina and the two Kentucky methods. The mutual acceptance of a lump sum price that is detailed is essentially the same method as states requesting price justification or Ohio's methods used when price is determined using a lump sum method. Use of the unit prices in the original contract documents is the process most state DOTs use when change orders are a simple increase in quantities. And determining the cost in a manner agreed to by both

parties could be defined as the same steps in negotiating a price between the engineer and contractor.

Section 7.3.6 refers to the Contractor's responsibilities in case they do not agree with the method for adjustment and is detailed below.

If the Contractor does not respond promptly or disagrees with the method for adjustment in the Contract Sum, the method and the adjustment shall be determined by the Architect on the basis of reasonable expenditures and savings of those performing the Work attributable to the change, including, in case of an increase in the Contract Sum, a reasonable allowance for overhead and profit. In such case, and also under Section 7.3.3.3, the Contractor shall keep and present, in such form as the Architect may prescribe, an itemized accounting together with appropriate supporting data. Unless otherwise provided in the Contract Documents, costs for the purpose of this Section 7.3.6 shall be limited to the following:

- .1 costs of labor, including social security, old age and unemployment insurance, fringe benefits required by agreement or custom and worker's compensation insurance;
- .2 costs of materials, supplies and equipment, including cost of transportation, whether incorporated or consumed;
- .3 rental costs of machinery and equipment, exclusive of hand tools, whether rented from the Contractor or others;
- .4 costs of premiums for all bonds and insurance, permit fees, sales, use or similar taxes related to the Work; and
- .5 additional costs of supervision and field office personnel directly attributable to the change.

Section 7.3.6 details those tasks the Contractor is to perform in the instance they do not agree with the price established by the Architect. Many of these items bear a

striking resemblance to the method of force account used by many state DOTs. By their very nature, the AIA documents favor the discretion of the Architect over the Contractor. Statements taken from Section 7.3.6 such as “the method and the adjustment shall be determined by the Architect on the basis of reasonable expenditures and savings of those performing the Work attributable to the change” put the advantage of determining what the final price for the change order in the hands of the Architect, also defined as the Owner’s representative. This is similar in nature to the resident engineer (or other owner’s representative) having the final decision about pricing in the DOT hierarchy.

Similar to the examples of the DOT flowcharts, the option to use force account to determine the adjustment price appears to be one of last options to be considered.

Other documents similar to the AIA documents have been developed by the American General Contractors (AGC). As is the case with the AIA documents favoring the interests of the Architects and the owners, the AGC documents tend to favor the Contractor’s interests. To help reach a middle ground, a third set of documents have been developed to act as a neutral option. ConsensusDOCS have developed documents based on both party’s documents and address many of the same issues. These documents were not able to be accessed for this review and therefore cannot be compared in depth for comparability to methods used elsewhere in construction.

## **5.2 Interviews**

Interviews were conducted with Kentucky Transportation Cabinet (KTC) personnel during the fall of 2009. The interviews were mainly with field engineers located in different regions around the Central and Southern Kentucky area. Interviews were also conducted with personnel in the Frankfort offices. One interview was conducted with a University of Kentucky employee in charge of facility maintenance that had experience with change orders.

A list of questions was developed by the researchers that focused on how the engineers handled change orders presented to them by contractors. The questions

covered processes, techniques and methodologies used to prepare estimates that involved changes in contract costs and time adjustment items. The full questionnaire is located in Appendix N.

Interviews were arranged with the field engineers at their convenience and took place at their regional offices. Interviews were conducted with all or combination of the project's investigators in attendance or in some cases by conference call to allow for note taking. Some interviews took place with only the field engineer in attendance but in some instances another field engineer would attend as well.

Many differences and similarities were discovered about how the engineers handled change orders presented to them by contractors. From a compilation of the interview notes, we were able to break down most of the comments from the interviewees into three main categories: policies, procedures and practices. Two other categories were used, examples and opinions given by the engineers, that listed most of the other statements given. By segregating the comments into these categories, it was more likely to be able to see similarities in the methods used by each of the engineers and also determine where some of the more significant differences existed. A breakdown of the information given in each category follows.

### 5.2.1 Policies

Some common themes from some of the comments with regards to policies included situations where the engineer and the contractor cannot agree on a price, the contractor will be asked to provide justification to support his price. Another common item was to use the change order ratio of  $(\text{change cost} / \text{original cost}) * \text{original duration}$  when issues of time adjustments are presented by the contractor. Most of the other comments classified as policies did not conflict between the different engineers. The statements were singular items that reflected what they knew to be policies that should be used when different situations arose with regards to change orders.

### 5.2.2 Procedures

Comparing the different statements classified under procedures reflected agreement on some different items by two or three of the interviewees while other

subjects may produce agreement among a combination of two or three other participants. Topics such as the use of Site Manager software to access other similar projects for relevant pricing was preferred by two interviewees and reference to critical path items in determining adjustments for time were discussed by three of the participants. Similar to the policies, there were not many instances of direct conflict of statements in the procedures category. Most of the engineers had different methods they used for different aspects of handling a change order. Much of the information gathered from each engineer's statements reflected the level of detail each provided to the interviewers. Some were more in depth while others provided only basic information. The procedures classification was a direct reflection of this gap.

### 5.2.3 Practices

The researchers were able to break down the statements from the participants into smaller categories for further comparison. These categories included *Anticipation of Change Orders*, *Identification of Price*, *Price Breakdown*, *Scope Control Issues*, *Use of Cost Plus/Force Account*, *Determination of Prices/Average Unit Bid Price*, *Time Extension Issues*, *Verbal Approvals*, *Special Work*, *Change Order/Funding Process*, and *Other Issues*. Similar to the statements from the procedures category, a number of the statements reflect the depth of information provided.

A consensus was shown that by being familiar with site conditions and being proactive about anticipating change orders, the engineer could better prepare for what the contractor might present to them. They could even have the change order written ahead of time to avoid anticipated delays. Agreement between two to three engineers was reflected in statements about the importance of identifying the pay item and the price as soon as possible to avoid delays. Statements were also made about comparing the contractor's price to the average unit bid price list. If the price given was within 10% of the average unit bid price, the engineer was comfortable using the contractor's price. While two contractors talked about the need for requesting and using price breakdowns when the contractor's price was in question, one engineer stated he felt price breakdowns were practically useless as a basis for comparison of price because in his opinion, the contractor can justify about anything.

With regard to scope control issues, no general consensus was reached on any particular aspect. This sub-category reflected different theories and approaches by a few of the engineers, usually in how they communicate with the contractor. The statements given by the engineers concerning use of the cost/plus method for force account work showed the level of importance placed on proper record keeping and the hindrance it can be in having the work performed. In determining fair pricing for change order items and using the average unit bid price as a tool, many of the engineers will use pricing from previous contracts found either through the use of Site Manager or their own files. Three of the interviewees stated their use of the average unit bid price list as a second or third source of price comparison. One engineer stated his use of a weighted average system when using the average unit bid price list to adjust for smaller quantity items. One engineer also cautioned that it was better to use previous contracts for comparison of materials

For three of the interviewees, time extension issues were predominantly handled using the cost/time ratio developed from the entire project as a basis for allowing extra work time and developing a cost. Also, two of the engineers spoke of consulting with central office about the reasonableness of time extension requests on their projects. Differences on how to determine the need for time extensions varied between a few of the engineers. Some preferred to wait closer to the end of the project and see if the earlier request for additional time is warranted before giving it. His theory was that the time may be made up in due course of completing the project, so why waste time on paperwork and extra money if the time extension is not needed. Others preferred to go ahead and give the extension of time as long as it was acceptable. Two engineers commented that verbal approvals are sometimes needed, and given, to facilitate the work being done as quickly as possible on an as needed basis. Another engineer commented on special work the contractor's price simply because he had nothing he could readily compare it to. He also commented that he would check for price gouging by analyzing the cost breakdown carefully.

The comments provided for change order funding process offered no comparison because the comments were provided by one engineer about his interpretation of the process. Another interviewee offered his perspective on some funding issues that were

unrelated to the engineer's comments. The other issues category mainly encompassed some of the engineer's thoughts on how they like to handle different aspects of change orders and what they do to anticipate them. These comments covered a number of different areas and were difficult to come to any consensus on any one or two topics.

#### 5.2.4 Opinions and Suggestions

The comments offered in this classification reflected what we thought were the interviewees unsolicited feelings about good and bad aspects of a few different topics. We were able to group them into a few different categories that included *Young Engineers, Site Manager Software/Old System vs. New System, Average Unit Bid Prices, Biggest Issue, Better Up Front Planning and Work, Documentation, Verification of Quantities, Contractor Relations, and Other Issues.*

The general opinion of the new engineers that were one or two years out of college and working in the field was they were too inexperienced to make knowledgeable decisions with regard to change orders. One engineer commented that they tend to get caught up in "horse trading" when negotiating the price with the contractor and lose sight of what the price should be. Some felt they needed to be more detailed on the paperwork and another commented they should have more training on the Site Manager software. Most of the comments concerning the Site Manager software and use of other software focused on the need to update and/or modify it. Other engineers expressed sentiment to return to the time when spreadsheets were used, citing it was useful.

Most engineers offering opinions on the use of the average unit bid price list agreed it was probably the easiest and most fair source to compare contractor's prices with. Some offered suggestions for improving it such as using multiple year averages or excluding outliers in the price list. When discussion of the interviewees' biggest issue they feel affects their work, most offered a comment different from the other participants. Answers ranged from time needed to execute the change order to challenges involving estimates of cost and time while another engineer focused the challenges of tracking force account costs. A common theme with better up front planning was to improve the communication between the designer and the contractor. The need for better designs was cited by two engineers while two others said the use of old or mothballed plans needs to be discontinued.

Documentation had only two comments but one from an engineer expressed his concern for the importance of documenting delays in being fair to both the contractor and the engineer. The need to verify quantities was said to be of great importance to the accuracy of the change order and to avoid delays from disputes. Discussions about contractor relations had no common themes, but engineers talked about need to approve the change orders as soon as possible to avoid unsureness of payment for the contractor. One engineer also discussed the level of trust he has with some contractors but the need to verify items from others. Other comments related more to what to expect with certain types of change orders when utilities are involved and one engineer noted the importance of including all parties that will be affected by the change order.

### 5.2.5 Examples

Three of the interviewees offered some examples of either instances that illustrate their issues concerning change orders or some case that represents their frustration with the change order system. The examples listed in the Appendix illustrate some of the challenges they face while processing a change order.

### 5.2.6 Other Comments

This section was a collection of all other items not previously classified. While some of these comments could be listed under the Opinions and Suggestions section, most of these comments listed seem to be off-handed comments that simply are the interviewees' train of thought at that moment. Similar to previous sections, we were able to divide the comments into some additional subcategories. These included *Average Unit Bid Prices*, *Cost Plus*, *Change Order Approval*, *Contractor Relations*, *Software Issues*, *Funding/Monetary Issues*, and *Other Issues*.

Most of the comments related to the average unit bid prices cautioned about quantity issues as well as contractors who knowingly inflate their price to 10% higher than the average unit bid price because that is the threshold most engineers will use. Comments for the remaining categories varied and had no general theme within each category.

### 5.2.7 Discussion

From analyzing the interviews we were able to see a number of different views on what works and what does not work when a change order is initiated. Most of the engineers had their own unique aspects of how they handle a change order but there were some common themes as well. Themes such as consulting the average unit bid price list for comparison of prices and acknowledgement of the importance of good organization, recordkeeping and anticipation of change orders were common to a number of the participants. The interviews offered insight that we were not able to find by performing literature review and helped give some ideas into what was needed to develop a proper pricing flowchart that would assist new and experienced engineers in the field when pricing change orders.

## 5.3 Defining the Need for a Pricing Procedure

After performing interviews with cabinet personnel and others in the field, a common theme appeared to emerge: there was no formal procedure for developing a price for change orders to compare to what was presented by the contractor. In comparing notes from the interviews, it was clear that each of the interviewees had their own methods and ideas of how to derive a price they thought would be comparable to the price given by the contractor. What was found was the inconsistency for developing the price could sometimes be a hindrance to the change order process and could cause delays in processing the request.

A total of 18 states were reviewed online to determine what, if any, pricing procedures were documented. Most of the states reviewed were located on the east side of the Mississippi River with a concentration on the states bordering Kentucky. This was viewed as a way to better compare procedures for states with comparable climates and regional access to materials and labor. California and Texas were looked at for comparison to what procedures larger states may have in comparison to a relatively smaller state like Kentucky.

In performing the search it was found almost all of the states that were examined had some sort of change order process listed in their online documentation. What they

lacked was a listing of how to attain or calculate a reasonable price for the change order to use for comparison. Of the states that were reviewed, Pennsylvania's Department of Transportation (PennDOT) was the only state found to have a list of steps to use to obtain or calculate a price from a list of specified sources. PennDOT listed four steps that outlined how to attain a price that would be a reasonable basis for comparison to a contractor's request. The instructions suggested using the steps in order when estimating and proceeding to the next step if a price could not be developed from the previous step. While the steps listed were not all inclusive and cover every possible aspect of what could be used to get the most accurate price, it was a template available to all field engineers that if used consistently, could be a valuable tool to cut the amount of time used in processing change orders.

In reviewing Cabinet change order procedures and conducting interviews with the cabinet personnel, it was discovered there was a general misunderstanding about what methods and sources should be used to derive a comparable price. Engineers that had more work experience with the Cabinet would tend to use more informal procedures simple in nature such as a comparison of whether the contractor's price was within 10% of the average unit bid price from the most recent year's list. Other engineers with less experience may use this method as well but would maybe use one or two other methods of comparison. This inconsistency, while sometimes nominal in the difference of the price used, could lead to estimates that are not as accurate as needed to properly price change order items.

In speaking to Cabinet personnel in the home office, they felt there were recommended procedures that should be followed when developing an estimate for comparison. However, the understanding by field personnel was found to be lacking and their methods did not always match what was believed to be used.

Because of this inconsistency, the need for a formal pricing procedure could help in the following areas:

- Provide a consistent basis of price estimation
- Remove confusion about the estimation process for new engineers
- Help streamline the change order process

- Provide an estimate that can help achieve a fair compromise for the contractor and the engineer

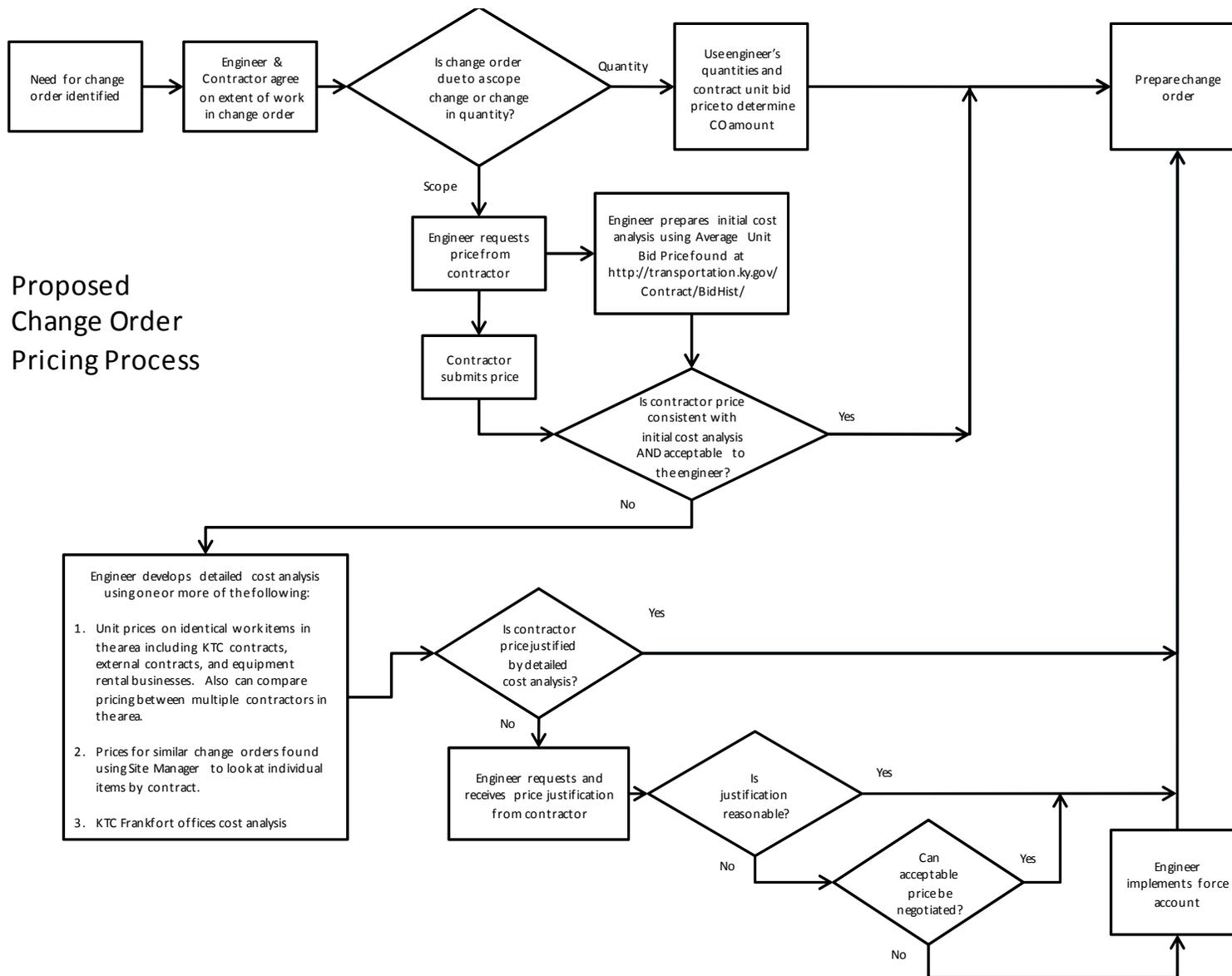
By addressing these issues, the development of a formal pricing procedure, with the use of a pricing template, would provide a tool that can act as a quick reference for all field personnel that will be the same if they are located in the farthest regions of eastern Kentucky or across the state in the western regions. The template could be adjusted for some regional differences, but the idea would be to create something that an engineer with hardly any knowledge of how to develop an estimate could perform this estimate simply by following the template.

#### **5.4 Pricing Flowchart Development Procedure**

The development of the pricing flowchart originated with the creation of flowcharts based on the current methods used by three of the engineers that were interviewed. The best aspects of each of the flowcharts were kept and then through a number of iterations, a final product was developed that covers a number of issues discussed.

The flowchart (Figure 37) was intentionally kept to one page in size to be able to serve as a tool of convenience, without a number of different pages to be referenced. It was developed to follow the process from the point of discovery for a change order through the point where the change order is given approval and created. The flowchart was created with the idea there would be a few options for developing a price that would take advantage of as many resources as possible without having the engineer have to spend excessive amounts of time researching a reasonable price.





**Figure 37: Proposed Change Order Pricing Process**

### 5.4.1 Chart Elements

The flowchart begins with the identification of the need for a change order. The need may be discovered by either the contractor or the engineer depending upon the situation. From discussions with field engineers, it is not uncommon for more experienced engineers to be proactive in the discovery of items requiring a written change order. At this point a consensus may be reached that the issue might not require a change order and can be resolved in some other manner.

The next action involves the engineer and the contractor coming to an agreement on the extent of the work to be included in the change order. The decision as to the extent of the work is important in controlling the scope of the additional work. Many of the interviewees agreed that establishing the list of work to be done is important to avoiding scope creep. They commented on how contractors have a tendency to add items into a change order that should have already been included in the initial contract bid. As change order work proceeds, having an established list of work to be done and how it will be performed can help to keep prices in check and avoid delays.

A decision must now be made whether the change order is due to a change in scope of the project or if the need is due to a change in quantity. This decision will determine whether a change order can be written quickly or whether more evaluation may be needed. If it is determined the change order is due to a change in quantity, the decision arrow leads to an action block where an extension of quantities times the original contract price of the item is performed to determine the change order amount. It is recommended the engineer independently verify the quantities presented by the contractor to help avoid excessive cost. After quantities are verified, the change order can be prepared.

If the decision is made there is a change in the scope of the project, the decision arrow leads to an action block for the engineer to request a price from the contractor. At this point a simultaneous action block indicates the engineer should prepare their own initial cost analysis for the change order item(s). The first source of information should be the most recent average unit bid price list found on the Kentucky Transportation Cabinet's website at <http://transportation.ky.gov/Contract/BidHist/>. This site provides access to the most recent average unit bid price lists as well as previous years going back

to 1994. If the item cannot be found in the most recent year, the next most recent year should be viewed to obtain a comparable price for the item(s). This will present an opportunity for the engineer to use professional judgment as to whether using a price from two years prior (or older) would be an acceptable comparison.

After the contractor submits his price, the engineer reaches another decision. Is the contractor's submitted price consistent with the engineer's initial cost analysis using the average unit price list AND is it acceptable to the engineer? In comparing the price for reasonableness, many of the engineers that were interviewed commented this was the point where they determined whether the contractor's price was within 10% of the average unit bid price they had looked up. If it is within this limit, most of the engineers saw no reason to proceed any further with price research and would write up the change order. The engineer not only has to decide if the price is in line with their estimate, but also whether it is acceptable. Acceptable in this case may refer to if the engineer feels there is something unique about the situation that may invalidate their estimate. If this is the case then they may want to proceed to a deeper level of price comparison. Again, this offers the engineer some room for professional judgment that may not be afforded using a rigid flowchart. If the price is acceptable then the engineer will prepare the change order. If however the engineer decides the price is not acceptable in comparison to their initial cost analysis, then the decision arrow directs them to an action box with multiple items they can use for cost comparison.

From this point the engineer should develop a detailed cost analysis that will give them a much broader set of estimates to compare to the contractor's price. The action box has three options presented for developing a more detailed price. These are recommended to be tried in successive order but the engineer should not be constrained from using all three to develop as accurate a price as possible. The first option is to look up relevant unit prices on identical work items in the immediate area including KTC contracts, external contracts and equipment rental businesses. It is also recommended to compare pricing between multiple contractors in the area. By checking on pricing in the immediate area, this allows the engineer to compare pricing relevant to where the contractor would assumedly be getting his materials, labor and equipment.

The second option is to research prices for similar change orders using Site Manager, the Cabinet's construction management software. This software allows access to other contracts throughout the state and lets the engineer look for similar items to compare costs. The engineer can look for contracts in surrounding regions or look in regions that are not as close to compare variations in the pricing.

The third option listed in the block would be for the engineer to consult with staff in the KTC offices in Frankfort. There are people dedicated to helping engineers in the field with pricing concerns and issues with regard to change orders. This option does not seem to be exercised as much and could be a valuable tool if the staff is available to the engineer when called upon.

Once the engineer has been able to develop an estimate using one or more of the proceeding options, the flowchart proceeds to another decision: is the contractor's price justified by the detailed cost analysis developed by the engineer? If the engineer decides at this point the contractor's price is fair and is acceptable, then they proceed to prepare the change order. If the price is still judged to be unacceptable by the engineer, the engineer should request a detailed price justification from the contractor. This detail should include the breakdown of materials, labor and equipment and what the sources of these would be. After receiving the detailed price justification the engineer again needs to decide if the price justification is reasonable enough to allow the change order. If the decision is yes, then the change order is written. If the decision is that the price is still not acceptable, the engineer must decide if he can successfully negotiate with the contractor and agree upon a price. If the engineer can successfully come to an agreement upon the price, then the change order is prepared using the negotiated price. If a price cannot be negotiated, the engineer has no choice but to have the work performed under a force account basis.

Force account is the last option the engineer and contractor want to use. During the interviews, many of the participants noted how difficult force account work is to track and the amount of time wasted through designation of extra staff to observe the work and handle the paperwork. A few of the engineers commented how they will sometimes use the "threat" of force account as a tool of forcing compromise from the contractor because they know in what regard contractors hold the use of force account work as well.

## 5.4.2 Discussion

The change order pricing flowchart has also been developed with the idea to be used as a training tool for incoming engineers that have little or no experience with pricing. As with current engineers, it was developed to be a one sheet, quick reference guide tool that could be laminated or fit inside training or procedures manual to allow for easy access.

This tool was developed also to narrow the focus of producing a reasonable and fair price to the contractor as well as the engineer. The time spent on finding a price that is acceptable to both parties can consume a large amount of the engineer's time. This flowchart can help guide them in where to look and when to make decisions about price reasonability. The flowchart is not meant to be an all inclusive list of options. Other engineers may include other sources in their decision making. But the chart will help them establish a consistent basis in how to proceed when change orders develop.

## 6.0 Conclusion

The research set out to analyze the leading causes of change orders on Kentucky transportation projects, to identify project characteristics correlated with higher frequency and magnitude of construction change orders, to develop change order reference cards that identify the risk levels of various reasons for change orders, and to develop a structured methodology for pricing change orders. After completing these objectives, it was determined the causes of change orders on Kentucky transportation projects with the greatest risk are:

- Contract Omission;
- Contract Item Overrun;
- Owner Induced Enhancement; and
- Fuel & Asphalt Adjustment

To minimize the impact of construction change orders, the Cabinet should focus their efforts on:

- Contract Omission;
- Contract Item Overrun; and
- Owner Induced Enhancement

The focus should be on these change order causes because they are more easily corrected and the Cabinet has more control over these causes. Fuel & Asphalt Adjustment is partially out of the Cabinet's control due to market prices. Other causes such as Utility Issue and Geotechnical Issue occur, but do not have near the impact. GIS mapping was used with the hope of developing trends in change orders throughout the state. Change orders vs. geological conditions were mapped out, but there were no significant trends.

It was also determined that the greatest risk of change orders with regard to impact and percent change occur on the road types listed below. The reason codes of greatest risk on the specific road types are also listed:

- Kentucky roadways

- Contract Omission;
  - Contract Item Overrun;
  - Owner Induced Enhancement; and
  - Fuel & Asphalt Adjustment
- US roadways
    - Contract Omission;
    - Owner Induced Enhancement; and
    - Fuel & Asphalt Adjustment

At the beginning of the research, it was thought that Interstates would be an area to focus efforts to minimize change orders, but this was not the case. Interstates actually show the least amount of risk out of the different road types. The reason for this could be Interstate projects have larger original contract amounts compared to smaller roadways. For example a \$50,000 change order will not be as significant on a \$5,000,000 (a 1% change) Interstate project as compared to a \$500,000 (a 10% change) US roadway project. Another reason for the smaller risk on Interstate projects could be the attention given to larger projects. As mentioned above, change orders have negative impacts on projects such as decreased productivity, schedule delays, and higher dollar costs. In general, more people travel on Interstates than Kentucky and US roadways so the public and the Cabinet feel a greater effect when Interstate projects have change orders. Due to this reasoning, change orders might be managed more efficiently on Interstate projects.

Project characteristics were also examined. The breakdown of the projects into new construction and maintenance work showed some interesting results. Prior to the analysis, it was thought new construction would have greater risks when dealing with change orders. However, it was found that maintenance work has as much if not more risk than new construction.

In total, the data analysis revealed that earthwork items tend to have lower percentages of change from their original contract. For all of the change order reason codes analyzed, none were classified as extreme risk concerns. All but two codes, Contract Omissions and Geotechnical Issues, were considered medium risk. The other

two were considered low risk. Road surfaces had codes that covered all three areas of concern. Fuel & Asphalt Adjustment and Owner Induced Enhancement were categorized as extreme risk items. Fuel & Asphalt Adjustment items have a high risk due to the unpredictable nature of fuel prices which the Cabinet has no control over. Utility Issues and Environmental Issues were classified as low risk concern and this is expected due to the lack of intrusion into areas of concern (i.e. wetlands) or having to excavate to any significant depth. Finally, Structures had two reason codes which were classified as extreme risk. Contract Item Overruns and Owner Induced Enhancement were shown to be areas of great concern in relation to the cost of the changes required in these categories. These areas tend to show the need for better up front planning that could help to lower or eliminate these items. Of the three categories, Road Surfaces and Structures reflected the highest need for concern.

From the research, it is important that the Cabinet begins to focus on minimizing change orders on Kentucky transportation projects. To minimize the risk of change orders, the Cabinet should focus their efforts on Contract Omission, Contract Item Overrun, and Owner Induced Enhancement on Kentucky and US roadways. Also, change orders on maintenance work needs more attention. While these are the areas where the Cabinet can see the greatest improvement in the percent change from original contract amount and impact of change orders, the other reason codes should not be ignored. By increasing front-end planning and using the change order reference cards on future transportation projects, the Cabinet can address areas of risk, efficiently allocate resources, and improve project success.

From the interviews we were able to see different methods and procedures used by field engineers. The interviews enabled us to create flowcharts based on our interpretation of their methods for developing a price to compare to the contractor's. The comparison revealed some similarities between the different methods. We found that all of the states used a historical database as a reference for pricing at some point in their process and all of the states used force account as a last resort of determining the price.

Of the states used as examples, only Ohio and Pennsylvania listed specific sources to access for pricing information.

From analyzing the different methods used in these examples, a standardized pricing flowchart was developed for use by Cabinet field engineers. The flowchart was designed to be a one page quick reference that could be used for most situations involved in preparing an estimated price for comparison to the contractor's submission. The flowchart still allows for the engineer to use some professional judgment but gives enough pricing options to take away some of the uncertainty in producing a price. A standardized pricing procedure implanted across the state will improve change order pricing consistency among districts. This tool can be used also in training new engineers to allow them to progress in their decision making process.

## 7.0 References

American Institute of Architects. (1997). *AIA Document A201 - General Conditions of the Contract for Construction*. American Institute of Architects.

Bryant, P. A. (2004). *Single Audit Management Report and Other Audit Findings for the Mississippi Department of Transportation - Office of State Aid Road Construction for the Fiscal Year 2003*.

Chen, M. (1992). Change Control and Tracking. *Transactions of the American Association of Cost Engineers* .

Cox, R. K. (1997). Managing Change Orders and Claims. *Journal of Management in Engineering* , 24-29.

Diekmann, J. E., & Nelson, M. C. (1985). Construction Claims: Fequency and Severity. *Journal of Construction Engineering and Managament* , 74-81.

DOTD. (2005). Department of Transportation and Development. *Construction Contract Administration Manual* .

Environmental Systems Research Institute. (2009, November 17). *What is GIS*. Retrieved from Environmental Systems Research Institute:  
<http://www.gis.com/whatisgis/index.html>

FDOT. (n.d.). Florida Department of Transportation, Office of Construction, Construction Project Administration Manual.

Finke, M. R. (1998). A Better Way to Estimate and Mitigate Disruption. *Journal of Construction Engineering and Management* , 490-497.

Hanna, A., Camlic, R., Peterson, P., & Nordheim, E. (2002). Quantitative Definition of Projects Impacted by Change Orders. *Journal of Construction Engineering and Management* , 57-64.

Ibbs, W., Nguyen, L., & Lee, S. (2007). Quantified Impacts of Project Change. *Journal of Professional Issues in Engineering Education and Practice* , 45-52.

IDOT. (2006). Illinois Department of Transportation , 2006 Construction Manual.

InDOT. (n.d.). Indiana Department of Transportation, Exhibit A, Policy for Construction Change Orders on Highway Construction Contracts.

KDOT. (n.d.). Kansas Department of Transportation, Construction Manual.

McCaskill, C. M. (2002). *Missouri Department of Transportation, Performance Audit on Contract Change Orders*.

Moselhi, O., Assem, I., & El-Rayes, K. (2005). Change Orders Impact on Labor Productivity. *Journal of Construction Engineering and Management* , 354-359.

Mosellhi, O., Leonard, C., & Fazio, P. (1991). Impact of Change Order on Construction Productivity. *Canadian Journal of Civil Engineering* .

NCDOT. (2010). *North Carolina Department of Transportation*. Retrieved October 2010, from Construction Unit:

[http://www.ncdot.gov/doh/operations/dp\\_chief\\_eng/constructionunit/default.html#0](http://www.ncdot.gov/doh/operations/dp_chief_eng/constructionunit/default.html#0)

NDOT. (n.d.). Nevada Department of Transportation, Construction Manual.

ODOT. (2010). *Ohio Department of Transportation*. Retrieved January 2010, from Office of Construction Administration:  
<http://www.dot.state.oh.us/Divisions/ConstructionMgt/Admin/Pages/default.aspx#>

PennDOT. (2005). *Pennsylvania Department of Transportation*. Retrieved January 2010, from Bureau of Construction and Materials:  
<ftp://ftp.dot.state.pa.us/public/bureaus/design/pub408/Pub%20408%20Chg%207/Sections/110.pdf>

Rosner, B. (2005). *Fundamentals of Biostatistics 6th Edition*. Pacific Grove, CA: Duxbury Press.

Swift, J., Ross, J., & Omachonu, V. (1998). Control Charts for Variables. In J. Swift, J. Ross, & V. Omachonu, *Principles of Total Quality* (pp. 269-282). Boca Raton, FL: St. Lucie Press.

Wu, C., Hsieh, T., & Cheng, W. (2005). Statistical analysis of causes for design change in highway construction on Taiwan. *International Journal of Project Management* , 554-563.

Wu, C., Hsieh, T., Cheng, W., & Lu, S. (2004). Grey relation analysis of causes for change orders in highway construction. *Construction Management and Economics* , 509-520.

**8.0 Appendix A: Change Order Reason Codes**

**Table A- 1 Kentucky Transportation Cabinet Change Order Reason Codes**

| <b>Explanation ID</b> | <b>KYTC Defined Standard Text</b>   |
|-----------------------|---|
| 001                   | Asphalt Lot Pay Adjustments according to Standard Specifications  |
| 005                   | Utility Issue – Extra Work is required as a result of a Utility Issue   |
| 004                   | Contract Omission – Extra Work is required as a result of a Contract Omission.  |
| 003                   | Fuel and Asphalt Adjustments.   |
| 006                   | Contract Item Overrun – Extra Work is required as a result of a Contract Item Overrun.  |
| 007                   | Geotechnical Issues – Extra Work is required as a result of Geotechnical Issues.  |
| 008                   | Owner Induced Enhancement – Extra Work is required to improve or enhance the project.   |
| 009                   | Environmental Issues – Extra Work is required to comply with environmental laws and specifications.   |
| 010                   | Contract Incentive – The Project Proposal requires the Contractor to be compensated by the Department for the agreed upon prescribed Incentive. |
| 011                   | Project renewal for the subsequent calendar year.   |
| 012                   | Accounting Adjustment.  |
| 013                   | Value Engineering Proposal.   |
| 014                   | Cost is less than or equal to 110% of the average unit bid price.   |
| 015                   | Itemized cost breakdown supplied by the contractor including equipment, labor materials, and time needed to perform proposed work.              |
| 016                   | Cost comparison to the competitive bid contracts in an area or district for items similar to scope of work.                                     |
| 017                   | Item special in nature, unit price/cost justified by the Contractor.  |

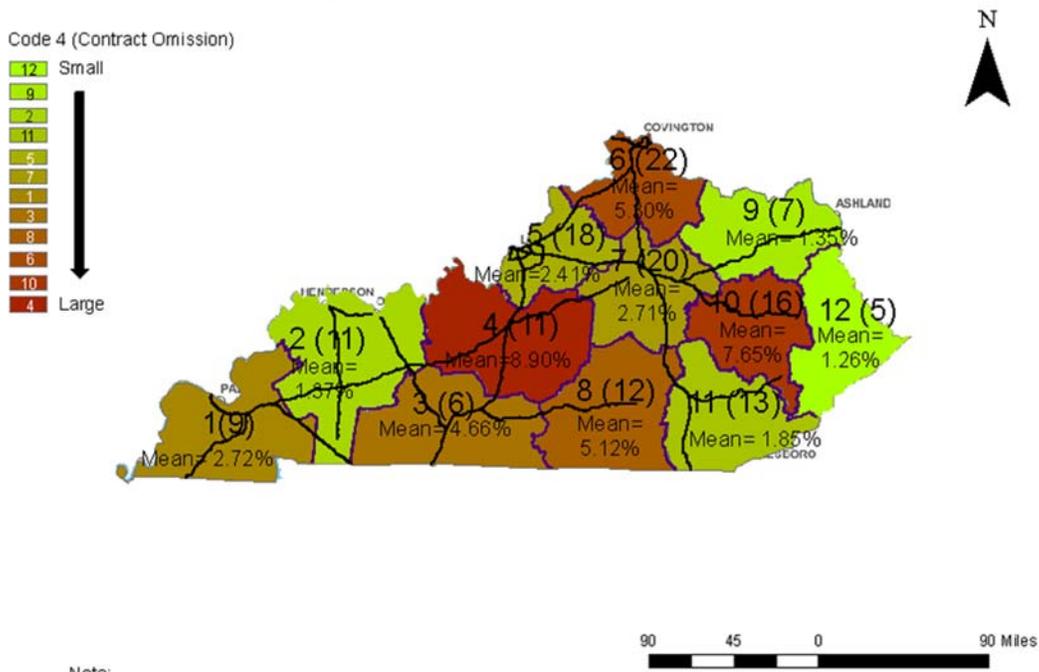
|     |   |
|-----|---|
| 018 | Cost Plus Worksheets (Documentation for cost plus worksheet attached to the change order as supplemental data.)   |
| 002 | Ride Quality Adjustment.  |
| 019 | Formal Partnering.  |
| 020 | Contract Item underrun.   |
| 021 | Claim Settlement.   |
| 022 | Steel Price Adjustment  |
| 050 | Contract renewal as agreed upon in the current contract for the subsequent calendar year. All provisions of the original contract will apply to this renewal.   |
| 040 | Fuel and asphalt adjustment will be calculated using 1/1/06 Supplemental to the Standard Specification for Section 109.07 Price Adjustments for work performed after 7/1/05 per 5/1/06 memo.                                      |
| 030 | The Fuel and Asphalt Adjustments difference between supplemental specification Section 109.07 from 1/1/06 and standard specification Section 109.07 of applicable specification book will be non-participating Federal Funds      |
| 023 | Liquidated Damages  |
| 025 | Non-Specification Material to Remain in Place   |
| 024 | Specification/Special Note Change   |
| 026 | Incorrect Project Wage Rates were included in the contract when let. This item is to reimburse the contractor the difference between wage rates as bid and the correct wage rates that should have been included in the contract. |
| 027 | This item shall include all labor, equipment, materials and overhead necessary to complete this item of work.   |

**9.0 Appendix B: Top 5 Reason Codes on GIS Maps**

|  |     |
|--|-----|
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Which districts experience the largest change orders on new projects considering the top 5?

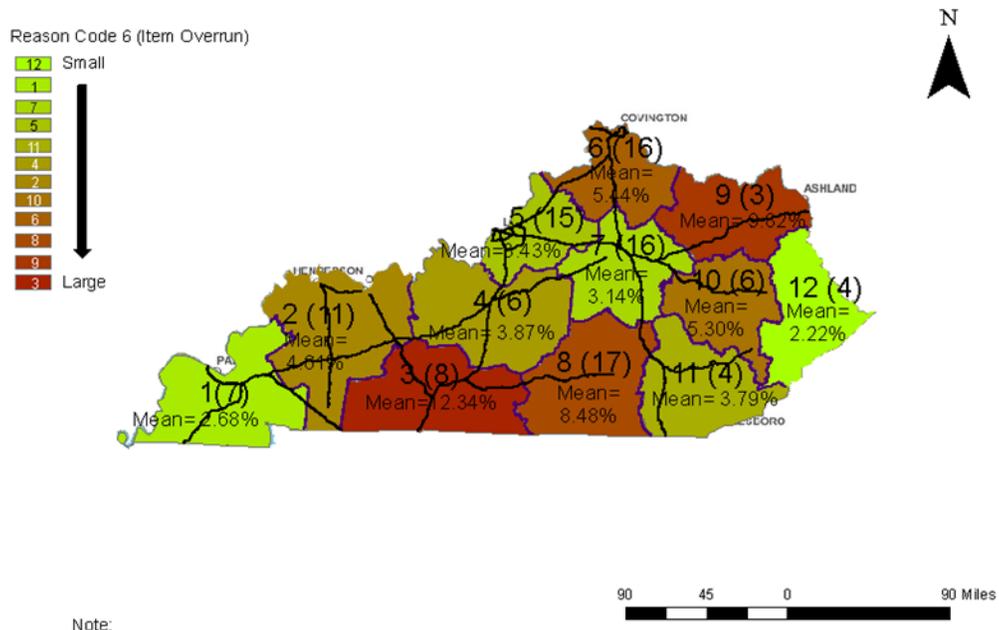
### Average Percent of Contract Change Due to Reason No. 1 Contract Omission on New Construction



Note: 11 (13) denotes 13 projects in District 11

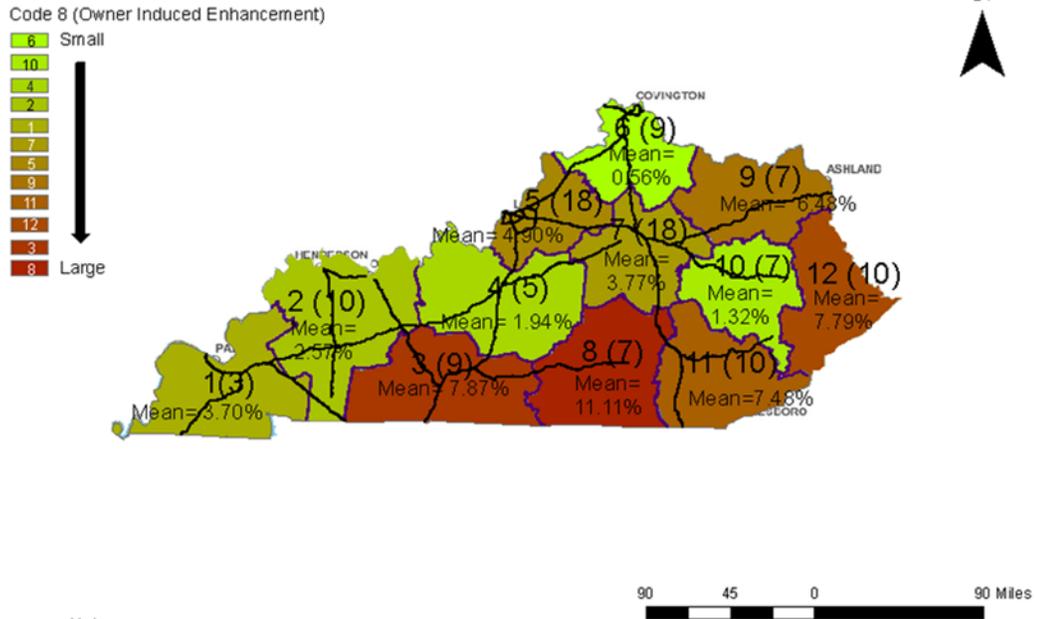
Figure B. 1 Average Percent of Contract Change Due to Reason No.1 Contract Omission on New Construction

# Average Percent of Contract Change Due to Reason No. 2 Contract Item Overrun on New Construction



**Figure B. 2 Average Percent of Contract Change Due to Reason No.2 Contract Item Overrun on New Construction**

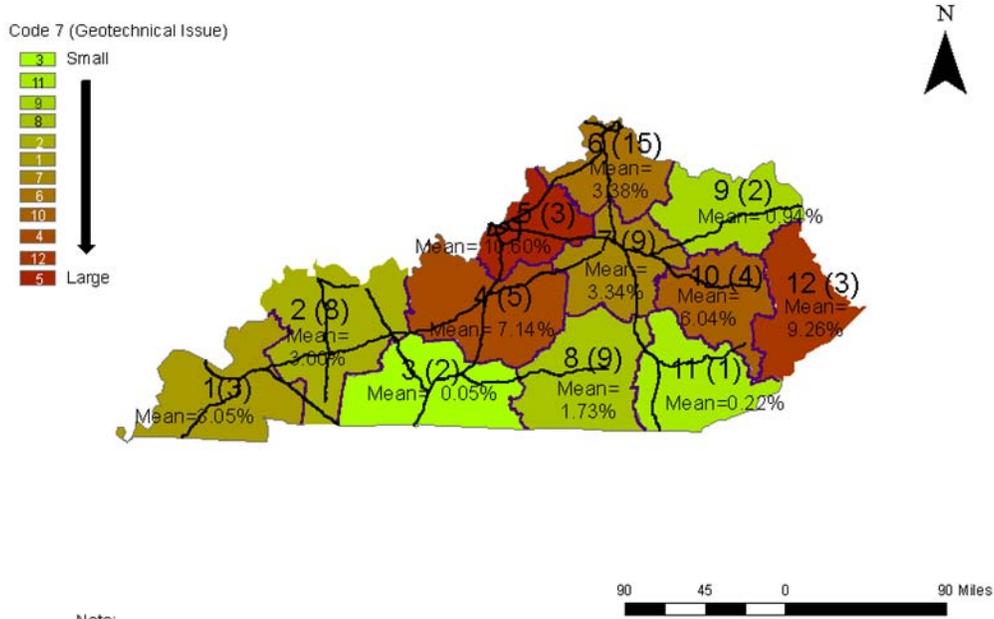
# Average Percent of Contract Change Due to Reason No. 3 Owner Induced Enhancement on New Construction



Note:  
11 (10) denotes 10 projects in District 11

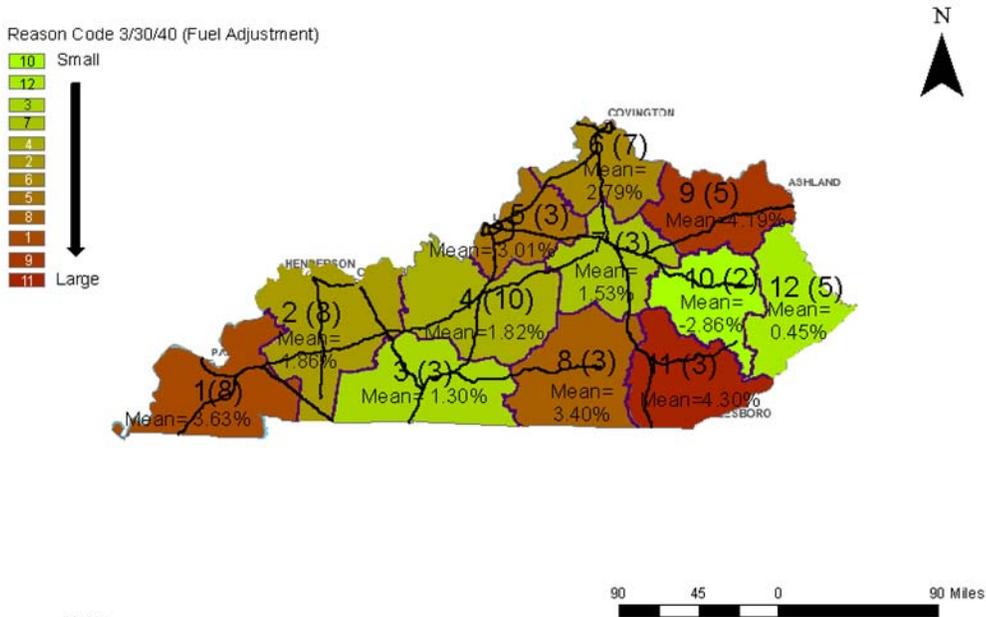
**Figure B. 3 Average Percent of Contract Change Due to Reason No.3 Owner Induced enhancement on New Construction**

# Average Percent of Contract Change Due to Reason No. 4 Geotechnical Issue on New Construction



**Figure B. 4 Average Percent of Contract Change Due to Reason No.4 Geotechnical Issue on New Construction**

# Average Percent of Contract Change Due to Reason No. 5 Fuel & Asphalt Adjustment on New Construction



**Figure B. 5 Average Percent of Contract Change Due to Reason No. 5 Fuel & Asphalt Adjustment on New Construction**

## Average Ranking Per Percentage Change of Contract across Reason Codes by District (New Construction)

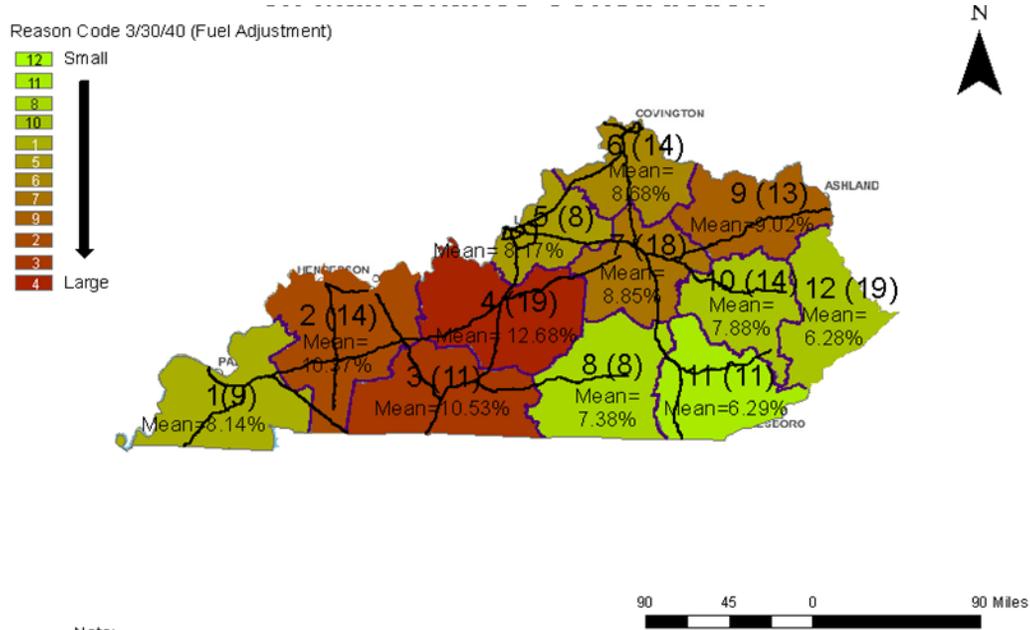
| Reason Code<br>District | Ranking           |                       |                           |                    |                           |     | Average Ranking   | Ranking   |
|-------------------------|-------------------|-----------------------|---------------------------|--------------------|---------------------------|-----|---|-----------|
|                         | Contract Omission | Contract Item Overrun | Owner Induced Enhancement | Geotechnical Issue | Fuel & Asphalt Adjustment |     |   |           |
| 2                       | 3 (1.37%)         | 7 (4.61%)             | 4 (2.57%)                 | 5 (3.00%)          | 6 (1.86%)                 | 5   | 1 Highest   |           |
| 12                      | 1 (1.26%)         | 1 (2.22%)             | 10 (7.79%)                | 11 (9.26%)         | 2 (0.45%)                 | 5   |  |           |
| 7                       | 6(2.71%)          | 3 (3.14%)             | 6 (3.77%)                 | 7 (3.34%)          | 4 (1.53%)                 | 5.2 |   |           |
| 1                       | 7(2.72%)          | 2 (2.68%)             | 5 (3.70%)                 | 6 (3.05%)          | 10 (3.63%)                | 6   |   |           |
| 10                      | 11 (7.65%)        | 8 (5.30%)             | 2 (1.32%)                 | 9 (6.04%)          | 1 (-2.86%)                | 6.2 |   |           |
| 11                      | 4 (1.85%)         | 5 (3.79%)             | 9 (7.48%)                 | 2 (0.22%)          | 12 (4.30%)                | 6.4 |   |           |
| 3                       | 8 (4.66%)         | 12 (12.34%)           | 11 (7.87%)                | 1 (0.05%)          | 3 (1.30%)                 | 7   |   |           |
| 6                       | 10 (5.30%)        | 9 (5.44%)             | 1 (0.56%)                 | 8 (3.38%)          | 7 (2.79%)                 | 7   |   |           |
| 9                       | 2 (1.35%)         | 11 (9.82%)            | 8 (6.48%)                 | 3 (0.94%)          | 11 (4.19%)                | 7   |   |           |
| 4                       | 12 (8.90%)        | 6 (3.87%)             | 3 (1.94%)                 | 10 (7.14%)         | 5 (1.82%)                 | 7.2 |   |           |
| 5                       | 5 (2.41%)         | 4 (3.43%)             | 7 (4.90%)                 | 12 (10.60%)        | 8 (3.01%)                 | 7.2 |   |           |
| 8                       | 9 (5.12%)         | 10 (8.48%)            | 12 (11.11%)               | 4 (1.73%)          | 9 (3.40%)                 | 8.8 |   | 12 Lowest |

Numbers in the parentheses are average percentage change order amount for corresponding reason codes

Figure B. 6 Average Ranking Per Percentage Change of Contract across Reason Codes by District (New Construction)

Which districts experience the largest change orders on *maintenance* projects considering the top 5?

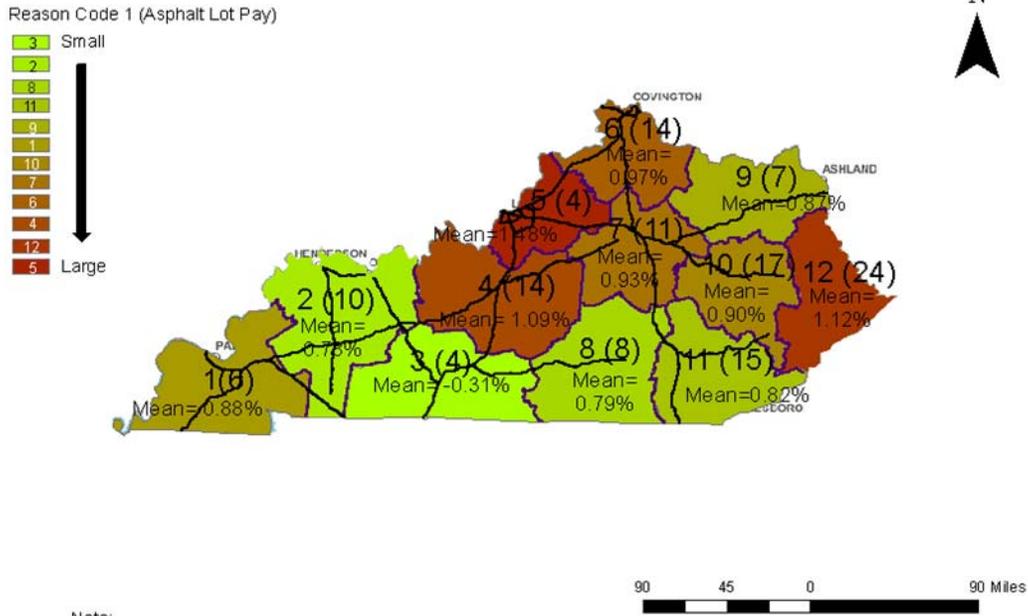
## Average Percent of Contract Change Due to Reason No. 1 Fuel and Asphalt Adjustment on Maintenance Construction



Note:  
11 (11) denotes 11 projects in District 11

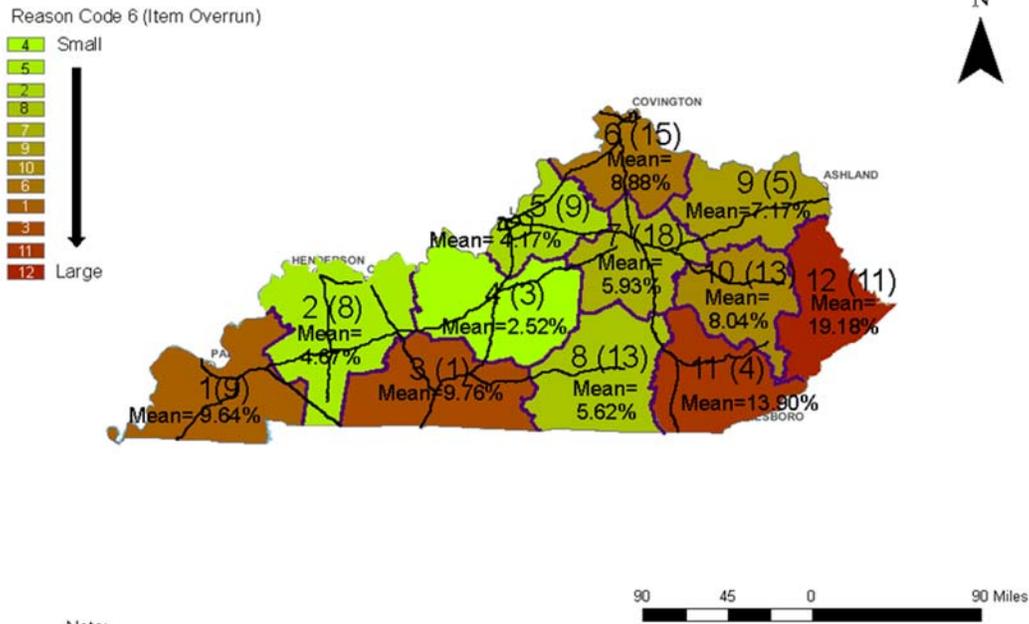
**Figure B. 7 Average Percent of Contract Change Due to Reason No.1 Fuel and Asphalt Adjustment on Maintenance Construction**

# Average Percent of Contract Change Due to Reason No. 2 Asphalt Lot Pay Asphalt Adjustment on Maintenance Construction



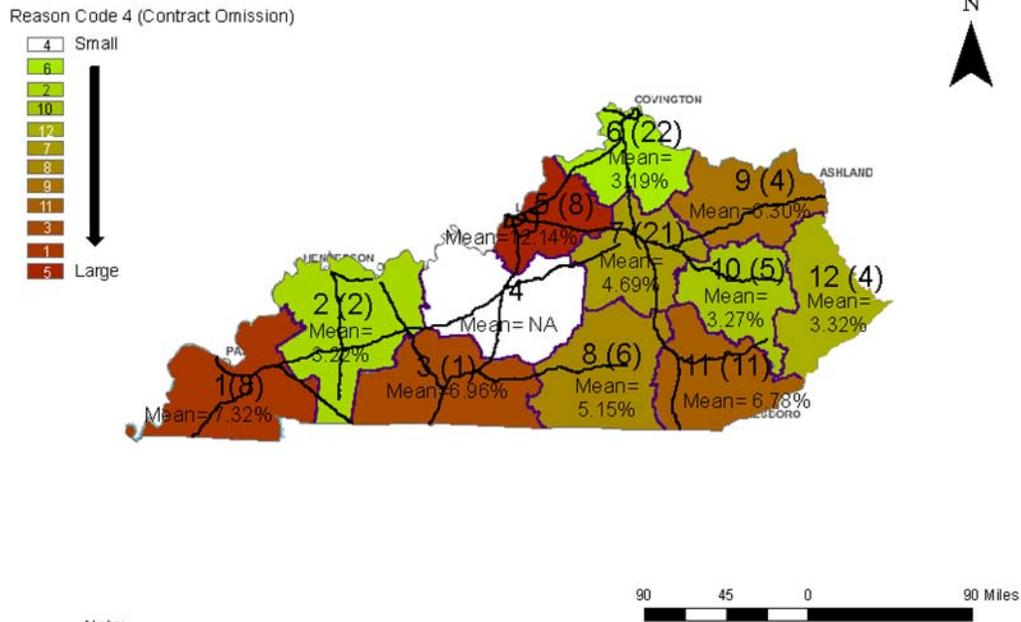
**Figure B. 8 Average Percent of Contract Change Due to Reason No.2 Asphalt Lot Pay Asphalt Adjustment on Maintenance Construction**

# Average Percent of Contract Change Due to Reason No. 3 Contract Item Overrun on Maintenance Construction



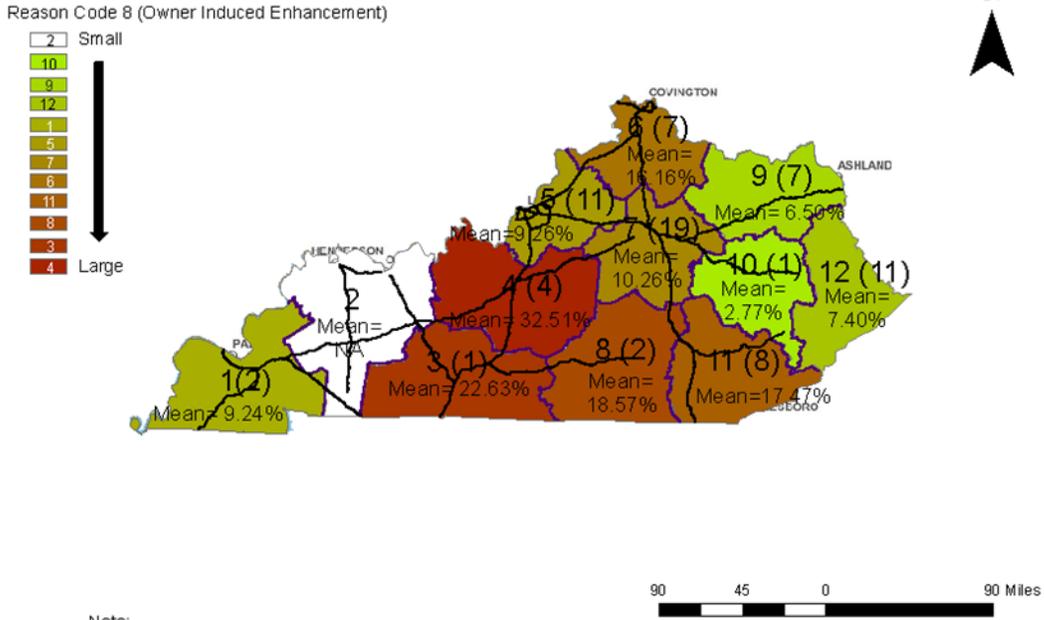
**Figure B. 9 Average Percent of Contract Change Due to Reason No.3 Contract Item Overrun on Maintenance Construction**

# Average Percent of Contract Change Due to Reason No. 4 Contract Omission on Maintenance Construction



**Figure B. 10 Average Percent of Contract Change Due to Reason No.4 Contract Omission on Maintenance Construction**

# Average Percent of Contract Change Due to Reason No. 5 Owner Induced Enhancement on Maintenance Construction



**Figure B. 11 Average Percent of Contract Change Due to Reason No.5 Owner Induced Enhancement on Maintenance Construction**

## Average Ranking Per Percentage Change of Contract across Reason Codes by District (Maintenance)

| Reason Code<br>District | Ranking                   |                 |                       |                   |                           |                 | Average Ranking   | Ranking   |
|-------------------------|---------------------------|-----------------|-----------------------|-------------------|---------------------------|-----------------|---|-----------|
|                         | Fuel & Asphalt Adjustment | Asphalt Lot Pay | Contract Item Overrun | Contract Omission | Owner Induced Enhancement | Average Ranking |   |           |
| 2                       | 10 (10.37%)               | 2 (0.78%)       | 3 (4.67%)             | 3 (3.22%)         | 1 (0.00%)                 | 3.8             | 1 Highest   |           |
| 10                      | 4 (7.88%)                 | 7 (0.90%)       | 7 (8.04%)             | 4 (3.27%)         | 2 (2.77%)                 | 4.8             |  |           |
| 8                       | 3 (7.38%)                 | 3 (0.79%)       | 4 (5.62%)             | 7 (5.15%)         | 10 (18.57%)               | 5.4             |   |           |
| 9                       | 9 (9.02%)                 | 5 (0.87%)       | 6 (7.17%)             | 8 (6.30%)         | 3 (6.50%)                 | 6.2             |   |           |
| 12                      | 1 (6.28%)                 | 11 (1.12%)      | 12 (19.18%)           | 5 (3.32%)         | 4 (7.40%)                 | 6.6             |   |           |
| 6                       | 7 (8.68%)                 | 9 (0.97%)       | 8 (8.88%)             | 2 (3.19%)         | 8 (16.16%)                | 6.8             |   |           |
| 7                       | 8 (8.85%)                 | 8 (0.93%)       | 5 (5.93%)             | 6 (4.69%)         | 7 (10.26%)                | 6.8             |   |           |
| 11                      | 2 (6.29%)                 | 4 (0.82%)       | 11 (13.90%)           | 9 (6.78%)         | 9 (17.47%)                | 7               |   |           |
| 1                       | 5 (8.14%)                 | 6 (0.88%)       | 9 (9.64%)             | 11 (7.32%)        | 5 (9.24%)                 | 7.2             |   |           |
| 4                       | 12 (12.68%)               | 10 (1.09%)      | 1 (2.52%)             | 1 (0.00%)         | 12 (32.51%)               | 7.2             |   |           |
| 5                       | 6 (8.17%)                 | 12 (1.48%)      | 2 (4.17%)             | 12 (12.14%)       | 6 (9.26%)                 | 7.6             |   |           |
| 3                       | 11 (10.53%)               | 1 (-0.31%)      | 10 (9.67%)            | 10 (6.96%)        | 11 (22.63%)               | 8.6             |   | 12 Lowest |

Numbers in the parentheses are average percentage change order amount for corresponding reason codes  
 Maintenance project with Project Code 72251 has an extreme value on owner induced enhancement

Figure B. 12 Average Ranking Per Percentage Change of Contract across Reason Codes by District (Maintenance)

**10.0 Appendix C: Control Charts - % Change from Original Contract Amount by Road Type**

|   |     |
|---|-----|
| Figure C. 1 Overall % Change from Original Contract Amount.....                               | 161 |
| Figure C. 2 Sub - Code 1 % Change from Original Contract Amount.....                          | 162 |
| Figure C. 3 Sub - Code 1 % Change from Original Contract Amount – Standard<br>Deviation.....  | 163 |
| Figure C. 4 Sub - Code 3 % Change from Original Contract Amount.....                          | 164 |
| Figure C. 5 Sub - Code 3 % Change from Original Contract Amount – Standard<br>Deviation.....  | 165 |
| Figure C. 6 Sub - Code 4 % Change from Original Contract Amount.....                          | 166 |
| Figure C. 7 Sub - Code 4 % Change from Original Contract Amount – Standard<br>Deviation.....  | 167 |
| Figure C. 8 Sub - Code 5 % Change from Original Contract Amount.....                          | 168 |
| Figure C. 9 Sub - Code 5 % Change from Original Contract Amount – Standard<br>Deviation.....  | 169 |
| Figure C. 10 Sub - Code 6 % Change from Original Contract Amount.....                         | 170 |
| Figure C. 11 Sub - Code 6 % Change from Original Contract Amount – Standard<br>Deviation..... | 171 |
| Figure C. 12 Sub - Code 7 % Change from Original Contract Amount.....                         | 172 |
| Figure C. 13 Sub - Code 7 % Change from Original Contract Amount – Standard<br>Deviation..... | 173 |
| Figure C. 14 Sub - Code 8 % Change from Original Contract Amount.....                         | 174 |
| Figure C. 15 Sub - Code 8 % Change from Original Contract Amount – Standard<br>Deviation..... | 175 |
| Figure C. 16 Sub - Code 9 % Change from Original Contract Amount.....                         | 176 |
| Figure C. 17 Sub - Code 9 % Change from Original Contract Amount – Standard<br>Deviation..... | 177 |

Control Chart: Change\_1through9

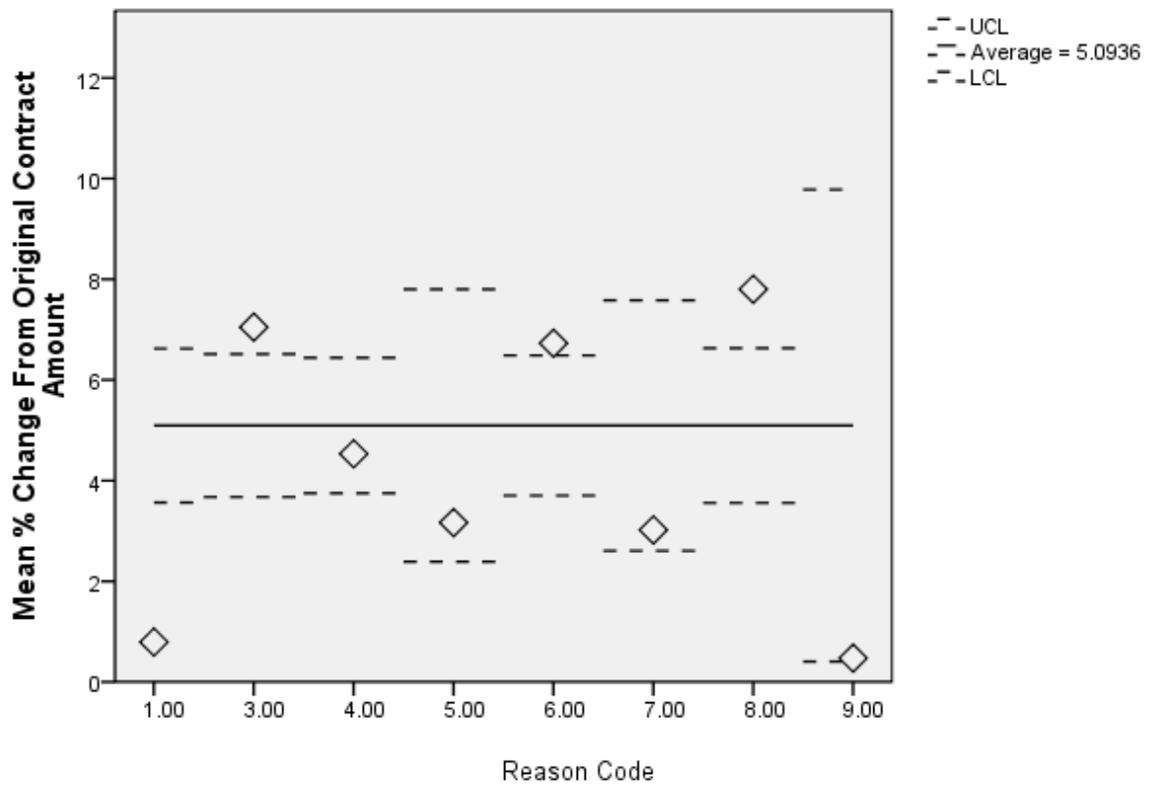


Figure C.1 Overall % Change from Original Contract Amount

### Control Chart: Code1Change

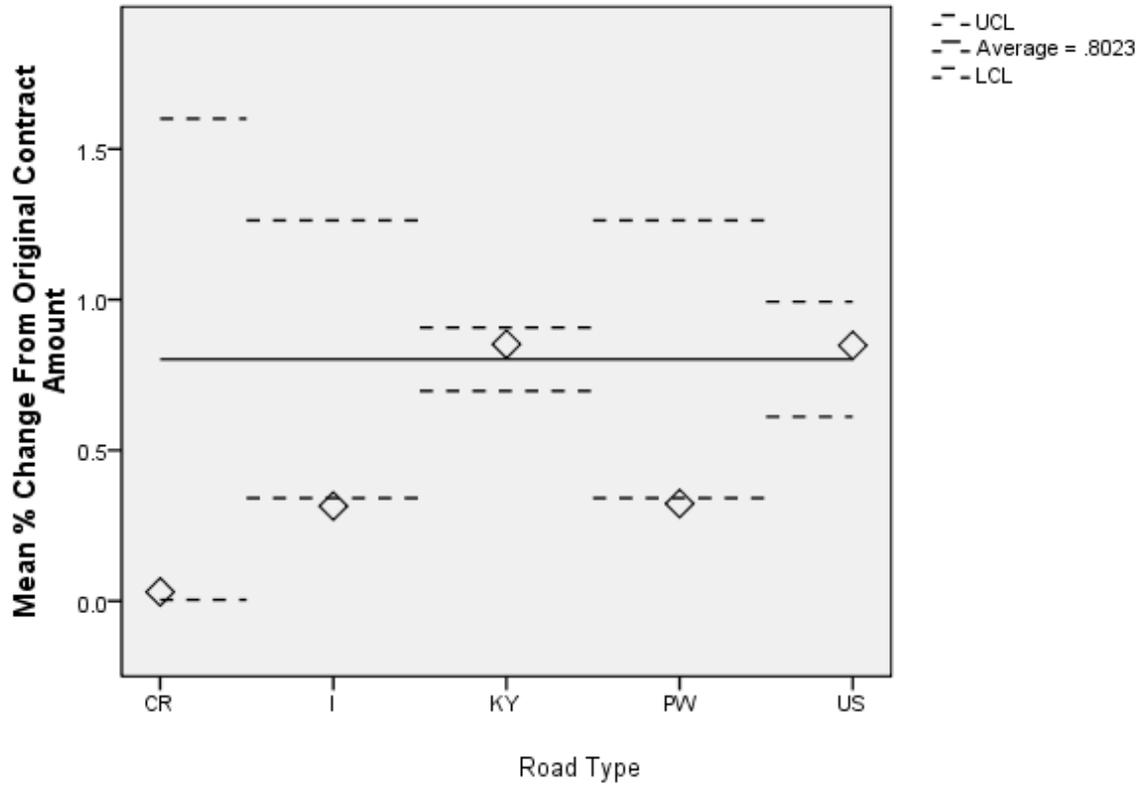


Figure C. 2 Sub - Code 1 % Change from Original Contract Amount

### Control Chart: Code1Change

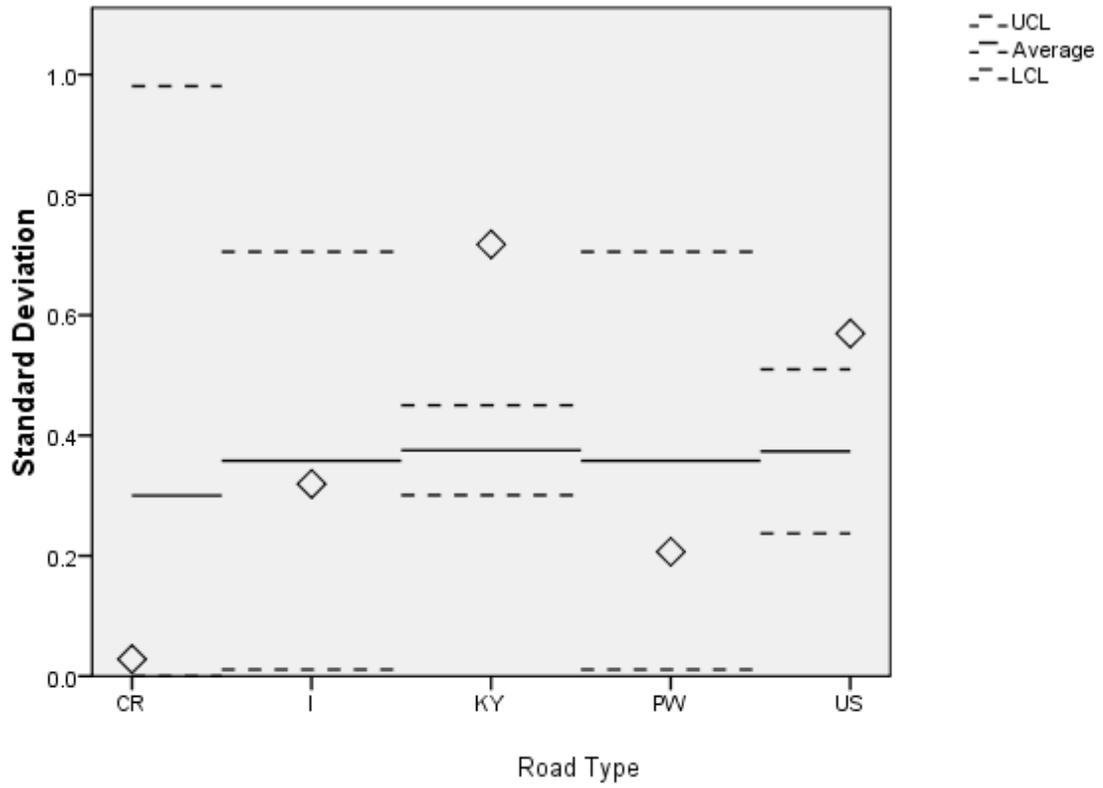


Figure C. 3 Sub - Code 1 % Change from Original Contract Amount – Standard Deviation

### Control Chart: Code3Change

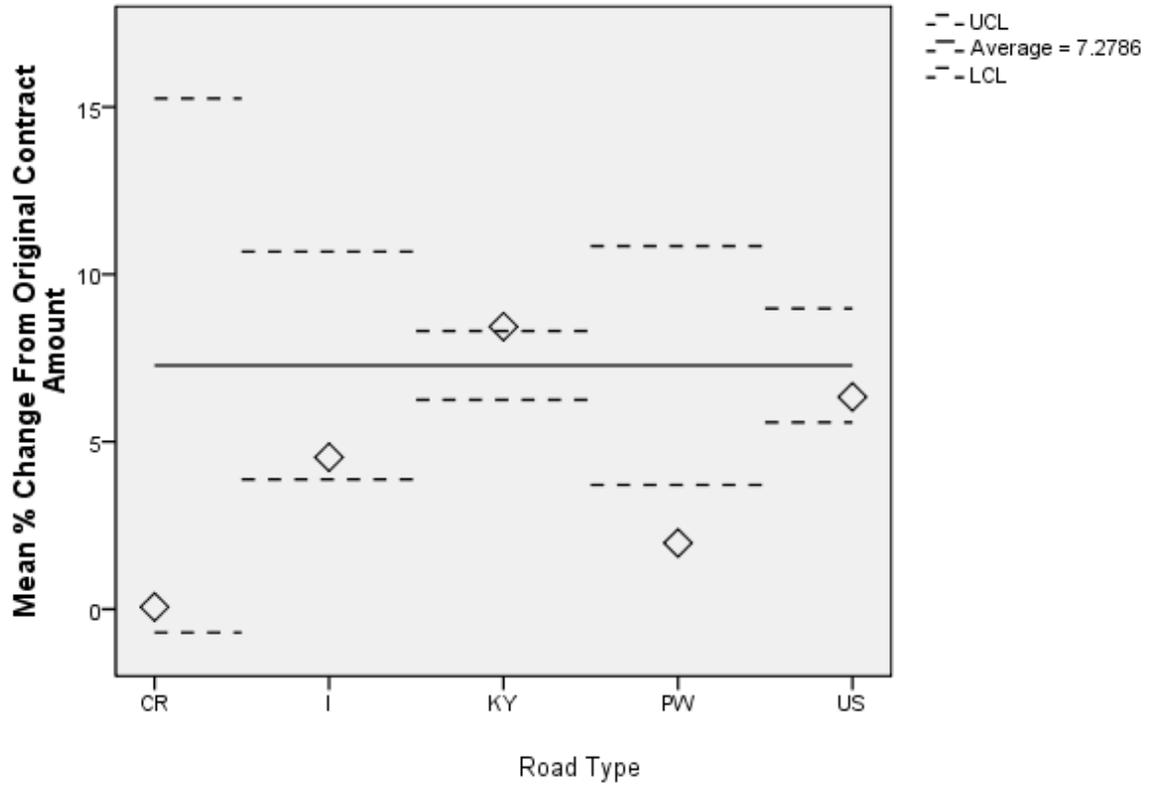


Figure C. 4 Sub - Code 3 % Change from Original Contract Amount

### Control Chart: Code3Change

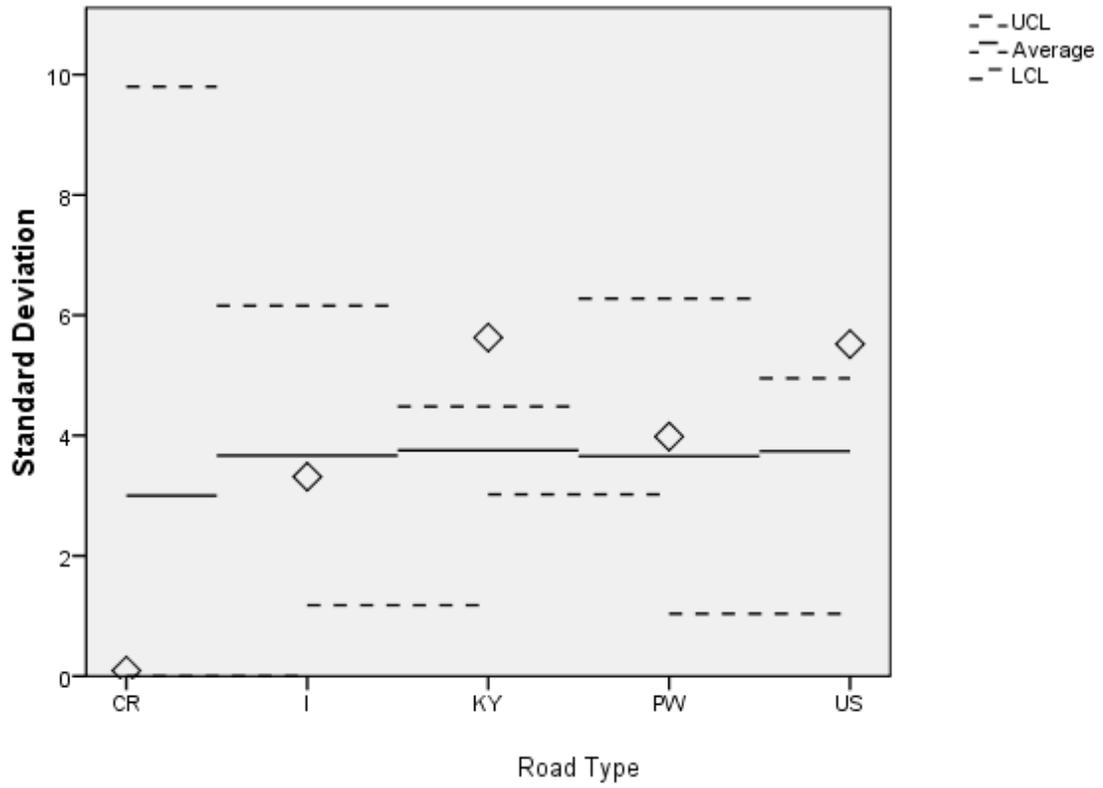


Figure C. 5 Sub - Code 3 % Change from Original Contract Amount – Standard Deviation

**Control Chart: Code4Change**

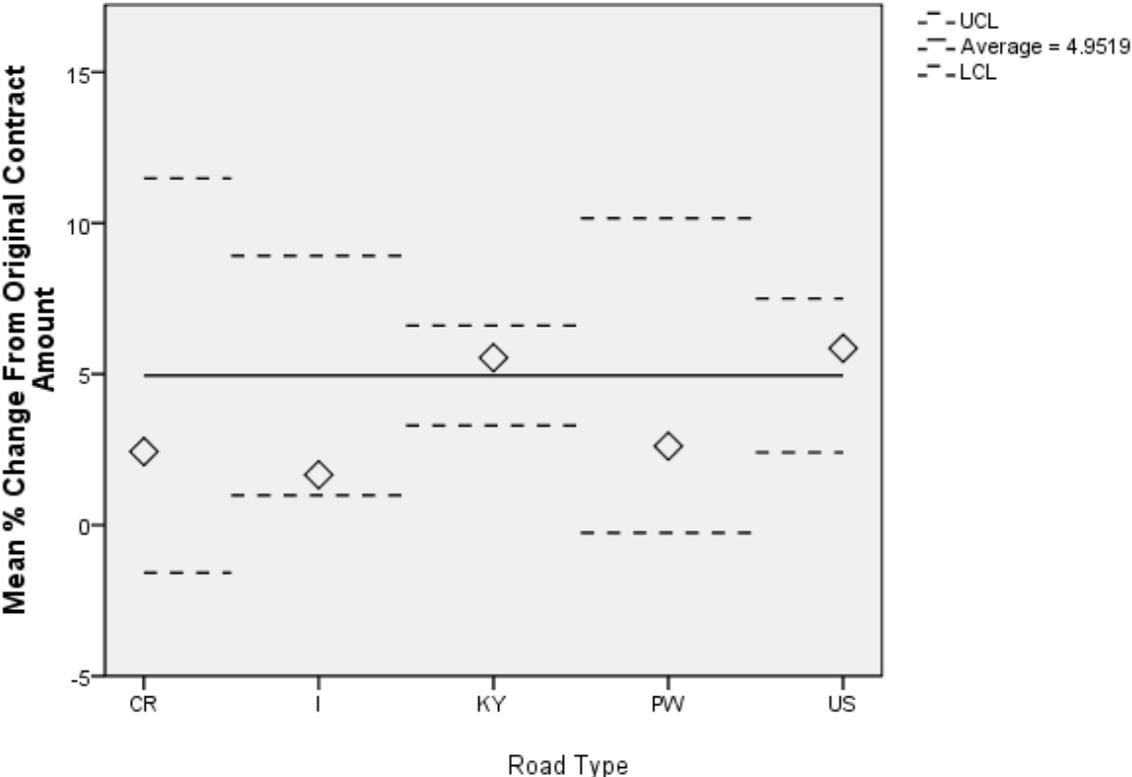


Figure C. 6 Sub - Code 4 % Change from Original Contract Amount

### Control Chart: Code4Change

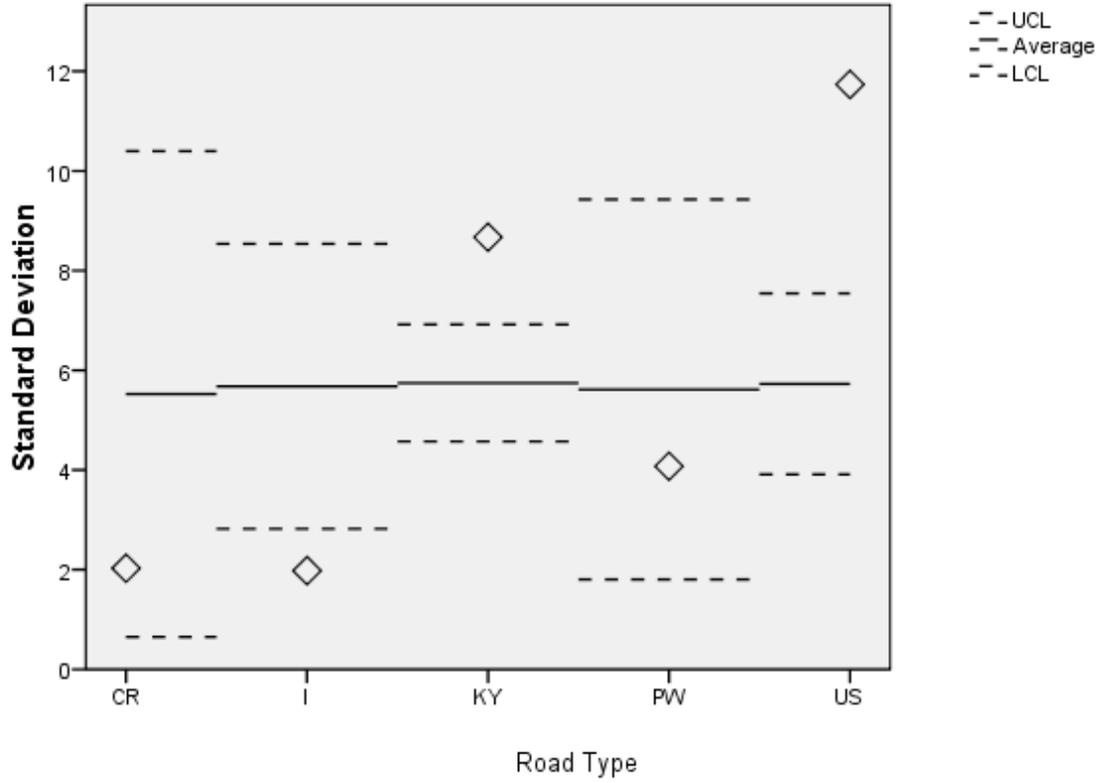


Figure C.7 Sub - Code 4 % Change from Original Contract Amount – Standard Deviation

### Warnings

One or more subgroups do not contain the minimum sample size required and have been excluded from the analysis.

### Control Chart: Code5Change

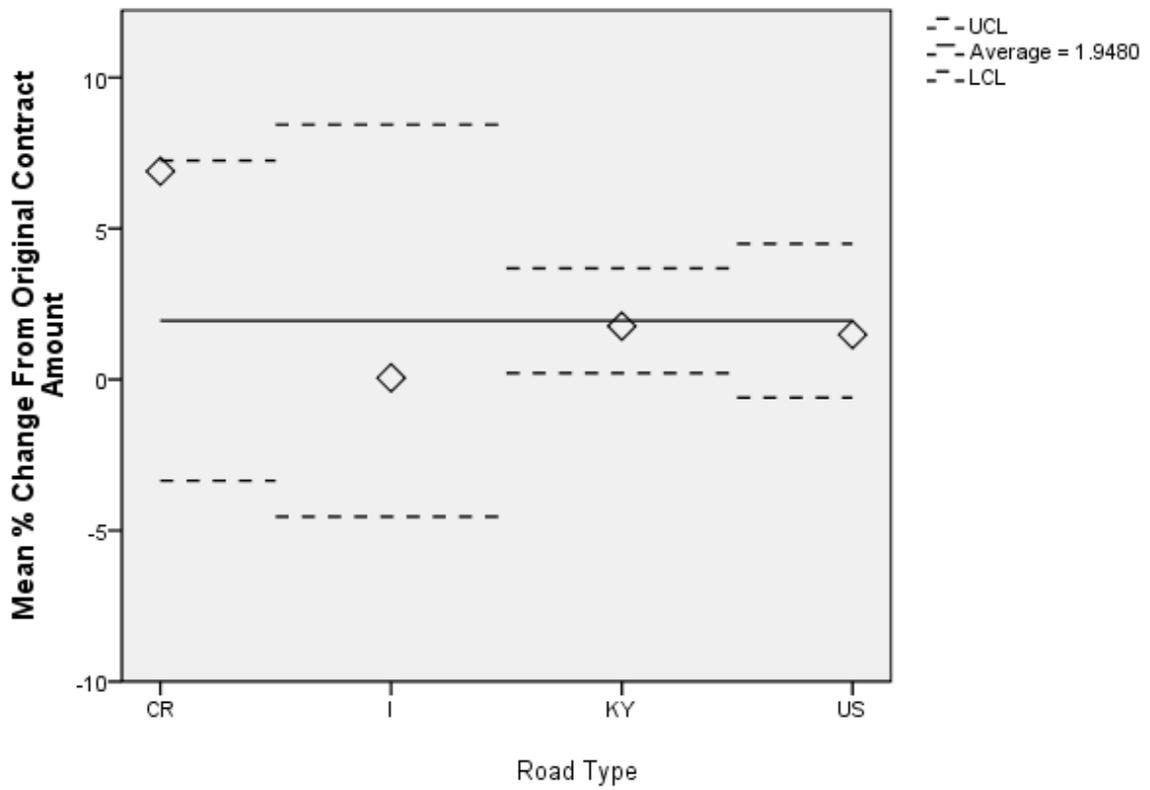


Figure C. 8 Sub - Code 5 % Change from Original Contract Amount

### Control Chart: Code5Change

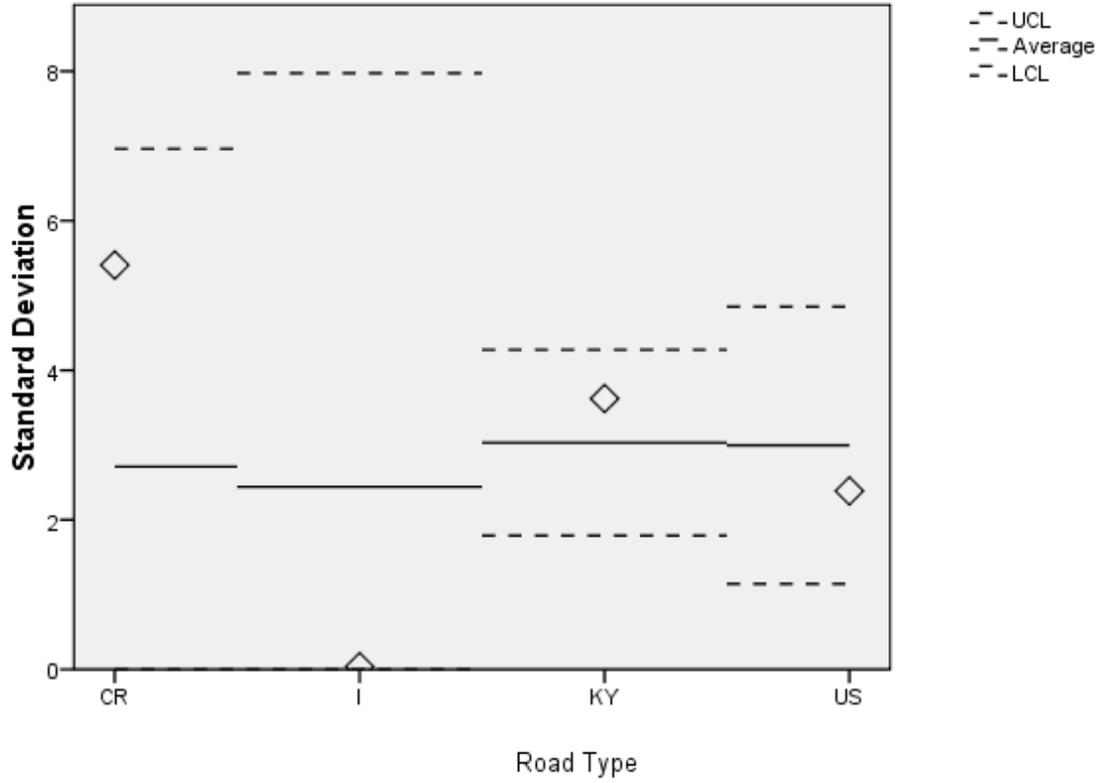


Figure C.9 Sub - Code 5 % Change from Original Contract Amount – Standard Deviation

Control Chart: Code6Change

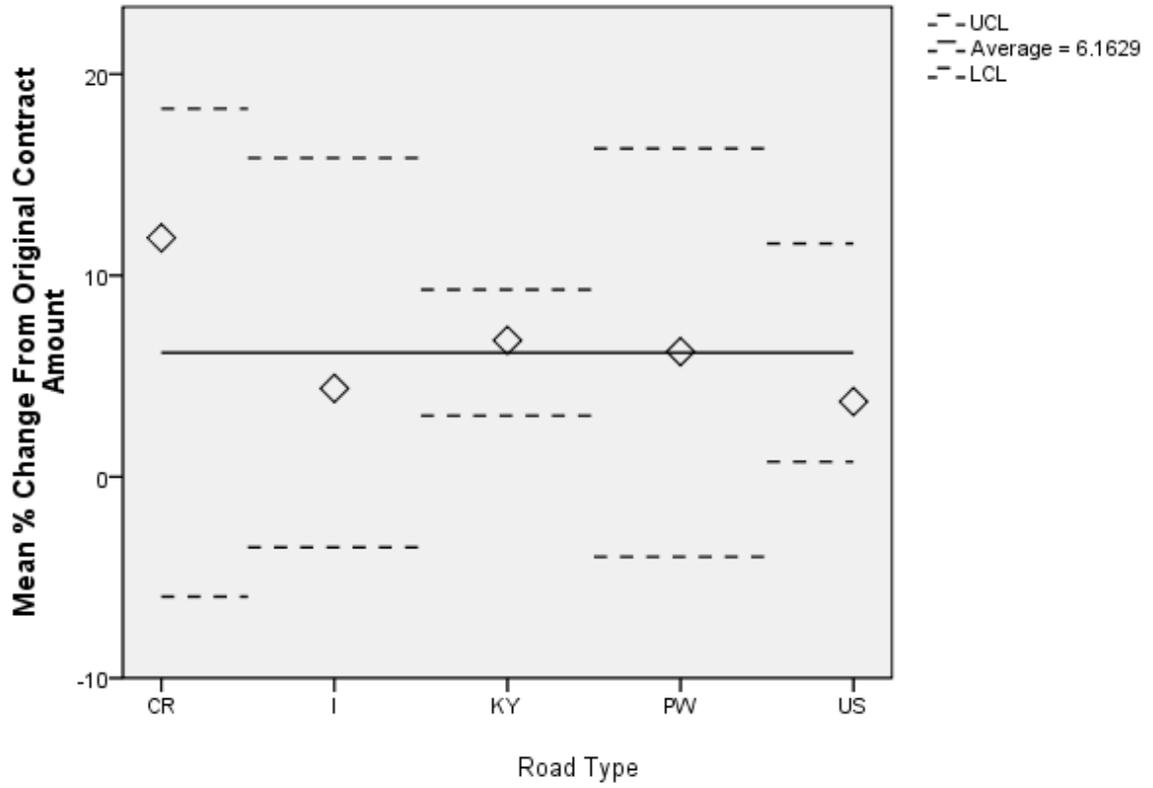
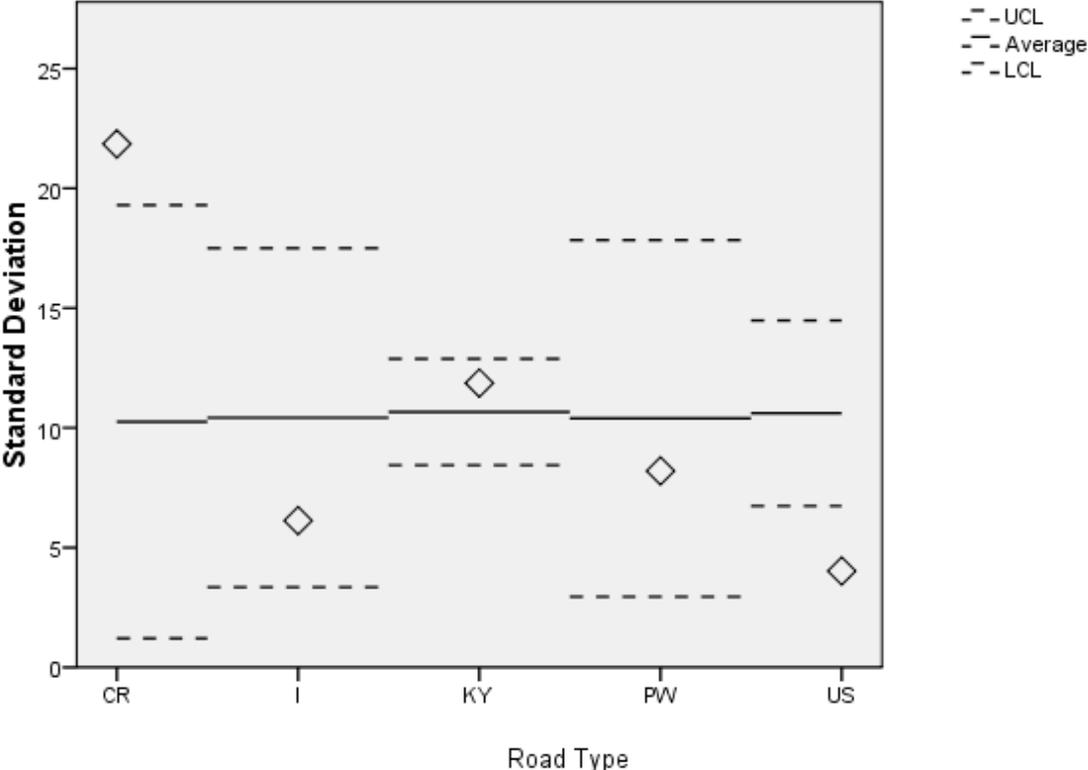


Figure C. 10 Sub - Code 6 % Change from Original Contract Amount

**Control Chart: Code6Change**



**Figure C. 11 Sub - Code 6 % Change from Original Contract Amount – Standard Deviation**

### Warnings

One or more subgroups do not contain the minimum sample size required and have been excluded from the analysis.

### Control Chart: Code7Change

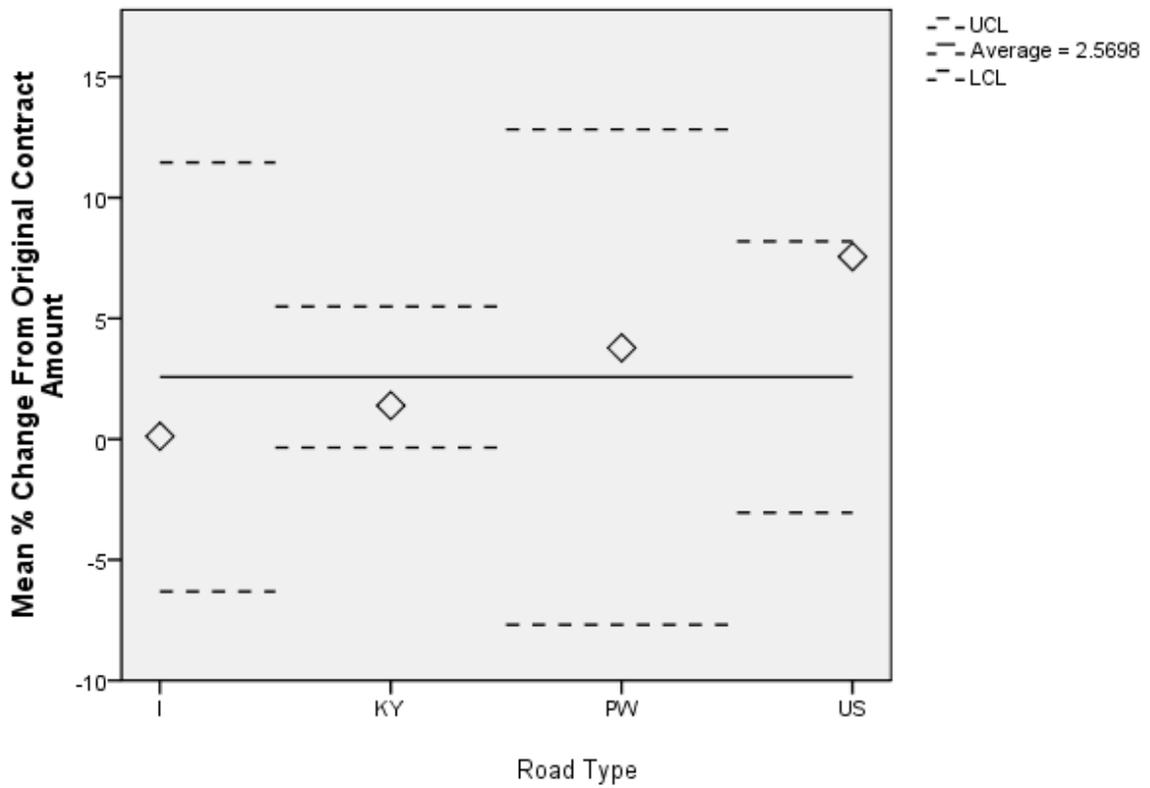
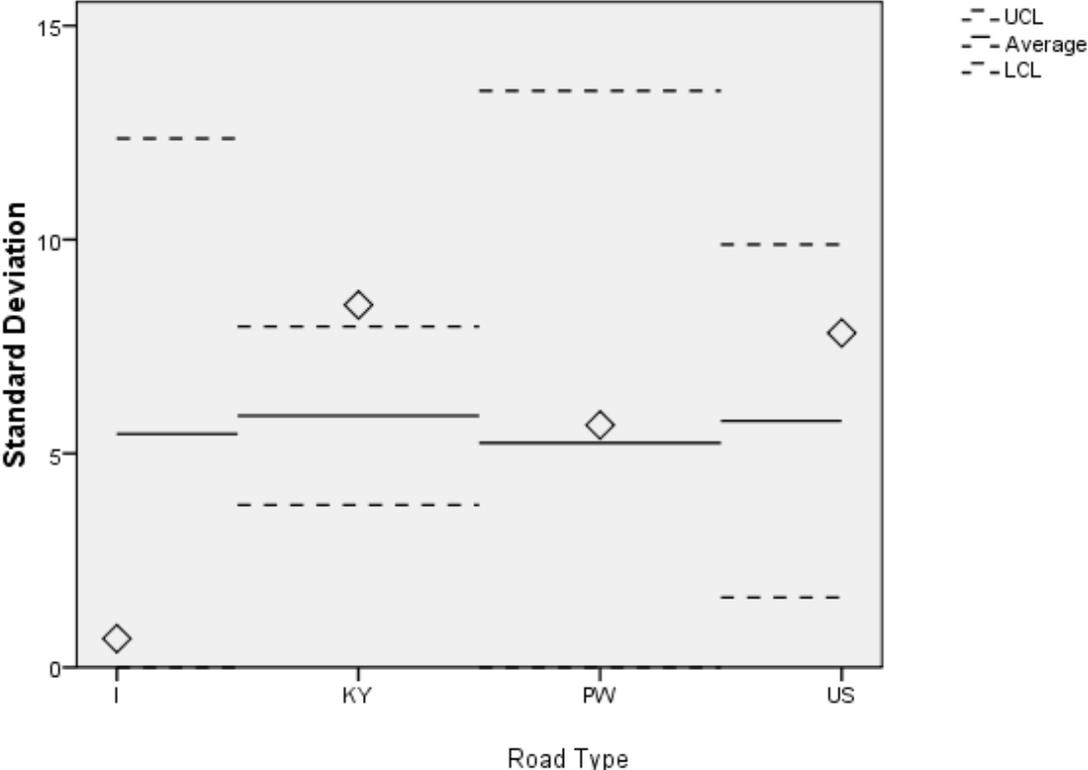


Figure C. 12 Sub - Code 7 % Change from Original Contract Amount

**Control Chart: Code7Change**



**Figure C. 13 Sub - Code 7 % Change from Original Contract Amount – Standard Deviation**

Control Chart: Code8Change

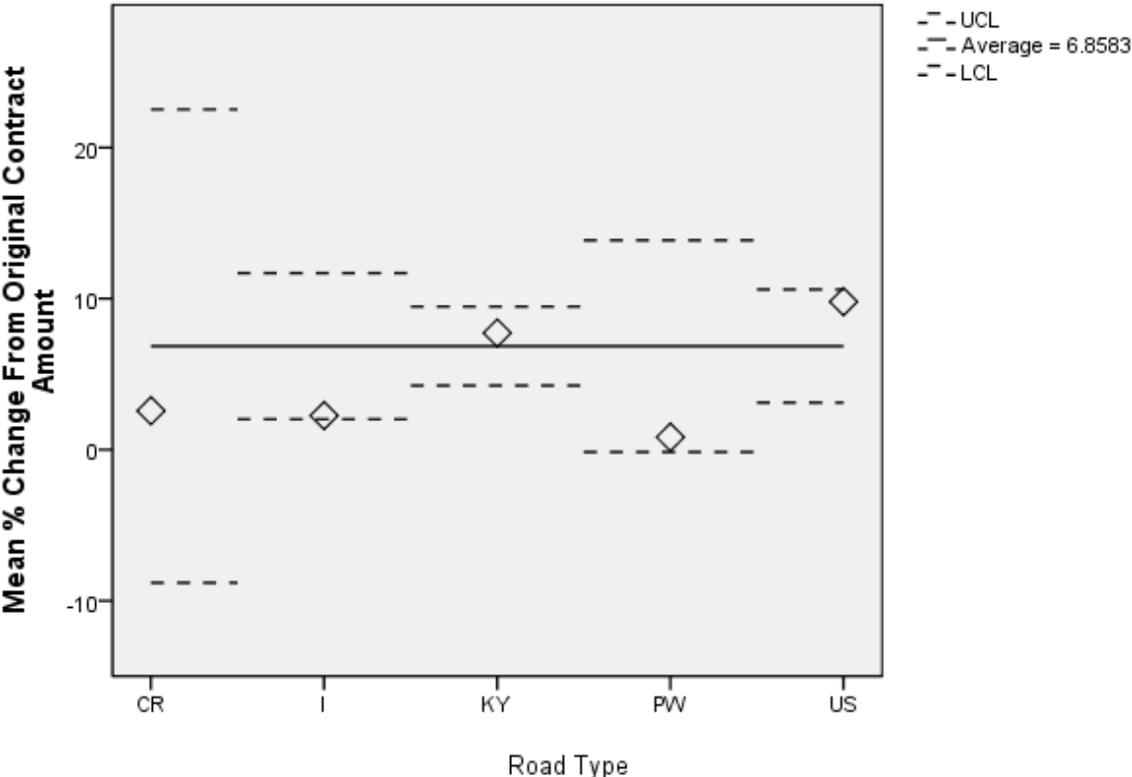


Figure C. 14 Sub - Code 8 % Change from Original Contract Amount

Control Chart: Code8Change

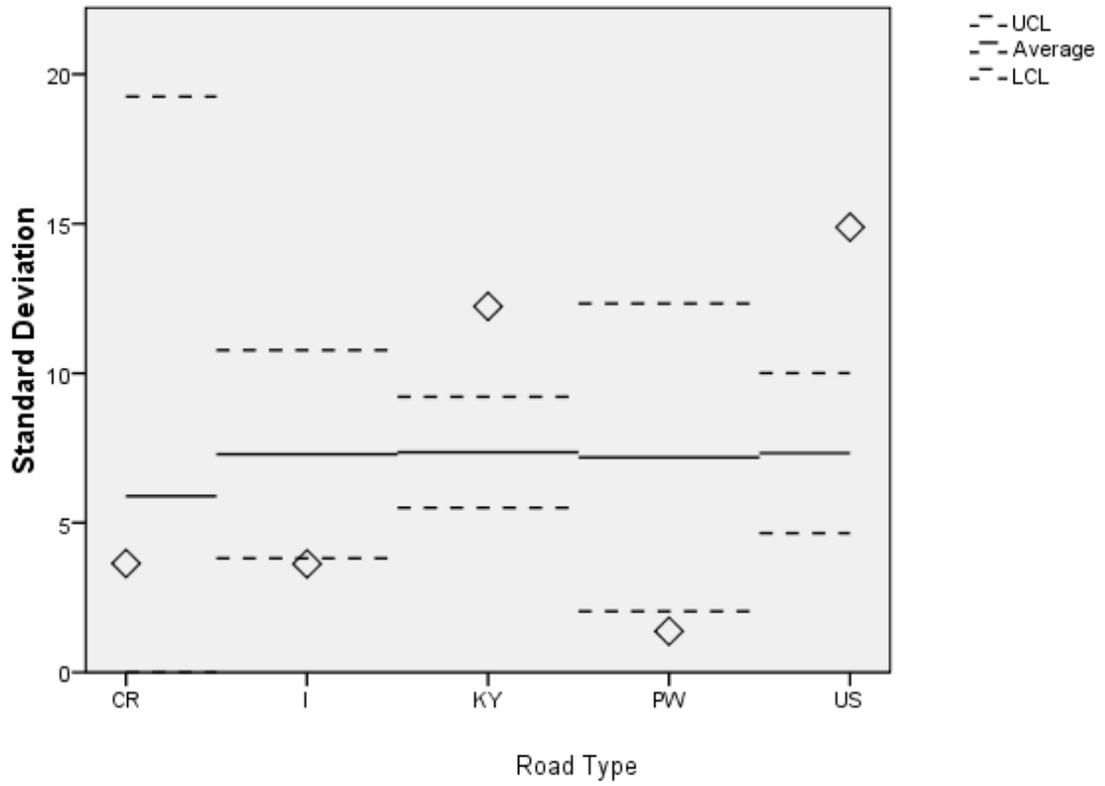


Figure C. 15 Sub - Code 8 % Change from Original Contract Amount – Standard Deviation

### Warnings

One or more subgroups do not contain the minimum sample size required and have been excluded from the analysis.

### Control Chart: Code9Change

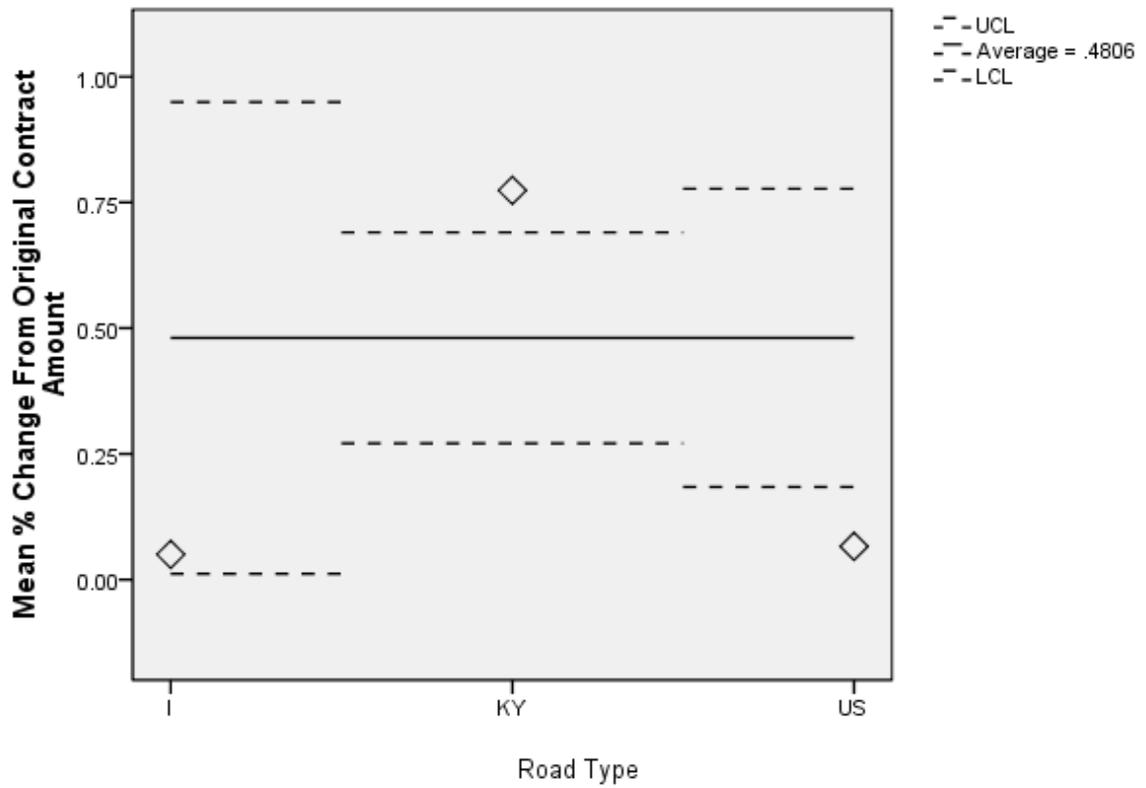


Figure C. 16 Sub - Code 9 % Change from Original Contract Amount

Control Chart: Code9Change

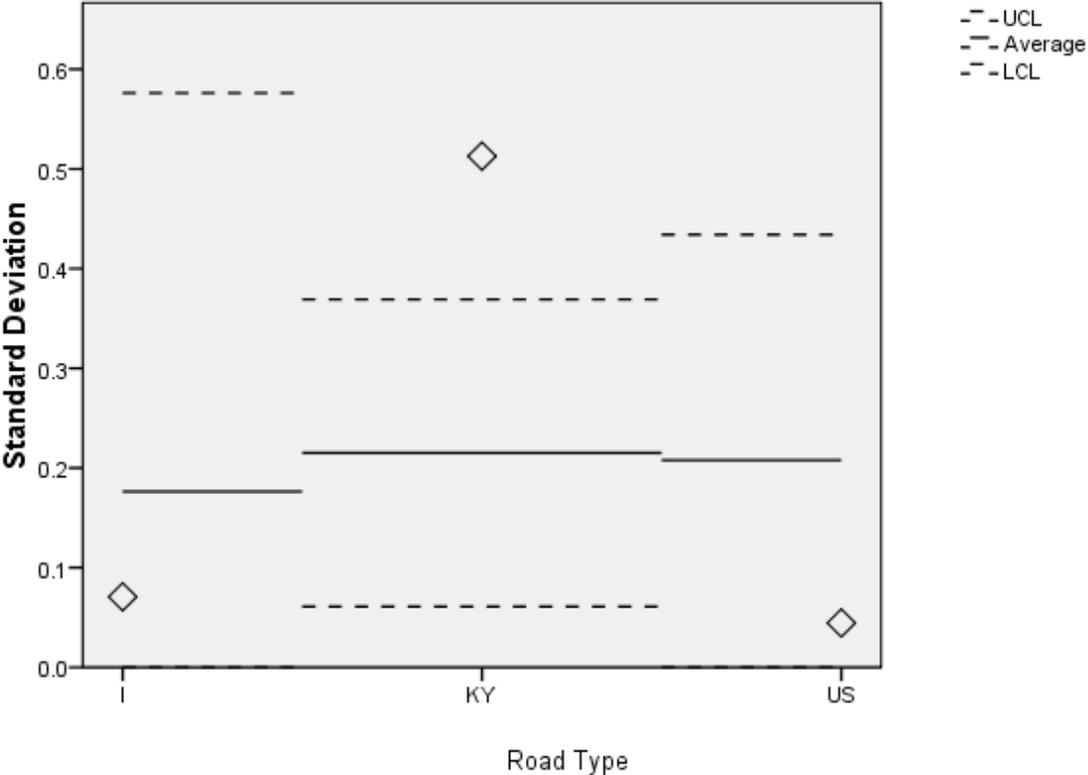


Figure C. 17 Sub - Code 9 % Change from Original Contract Amount – Standard Deviation

**11.0 Appendix D: Control Charts - % Change from Original Contract Amount by District**

|   |     |
|---|-----|
| Figure D. 1 Overall % Change from Original Contract Amount.....                                     | 180 |
| Figure D. 2 Sub - Code 1 % Change from Original Contract Amount.....                                | 181 |
| Figure D. 3 Sub - Code 1 % Change from Original Contract Amount – Standard<br>Deviation.....        | 182 |
| Figure D. 4 Sub - Code 3 Percent Change from Original Contract Amount.....                          | 183 |
| Figure D. 5 Sub - Code 3 Percent Change from Original Contract Amount – Standard<br>Deviation.....  | 184 |
| Figure D. 6 Sub - Code 4 Percent Change from Original Contract Amount.....                          | 185 |
| Figure D. 7 Sub - Code 4 Percent Change from Original Contract Amount – Standard<br>Deviation.....  | 186 |
| Figure D. 8 Sub - Code 5 Percent Change from Original Contract Amount.....                          | 187 |
| Figure D. 9 Sub - Code 5 Percent Change from Original Contract Amount – Standard<br>Deviation.....  | 188 |
| Figure D. 10 Sub - Code 6 Percent Change from Original Contract Amount.....                         | 189 |
| Figure D. 11 Sub - Code 6 Percent Change from Original Contract Amount – Standard<br>Deviation..... | 190 |
| Figure D. 12 Sub - Code 7 Percent Change from Original Contract Amount.....                         | 191 |
| Figure D. 13 Sub - Code 7 Percent Change from Original Contract Amount – Standard<br>Deviation..... | 192 |
| Figure D. 14 Sub - Code 8 Percent Change from Original Contract Amount.....                         | 193 |
| Figure D. 15 Sub - Code 8 Percent Change from Original Contract Amount – Standard<br>Deviation..... | 194 |
| Figure D. 16 Sub - Code 9 Percent Change from Original Contract Amount.....                         | 195 |
| Figure D. 17 Sub - Code 9 Percent Change from Original Contract Amount – Standard<br>Deviation..... | 196 |

Control Chart: Change\_1through9

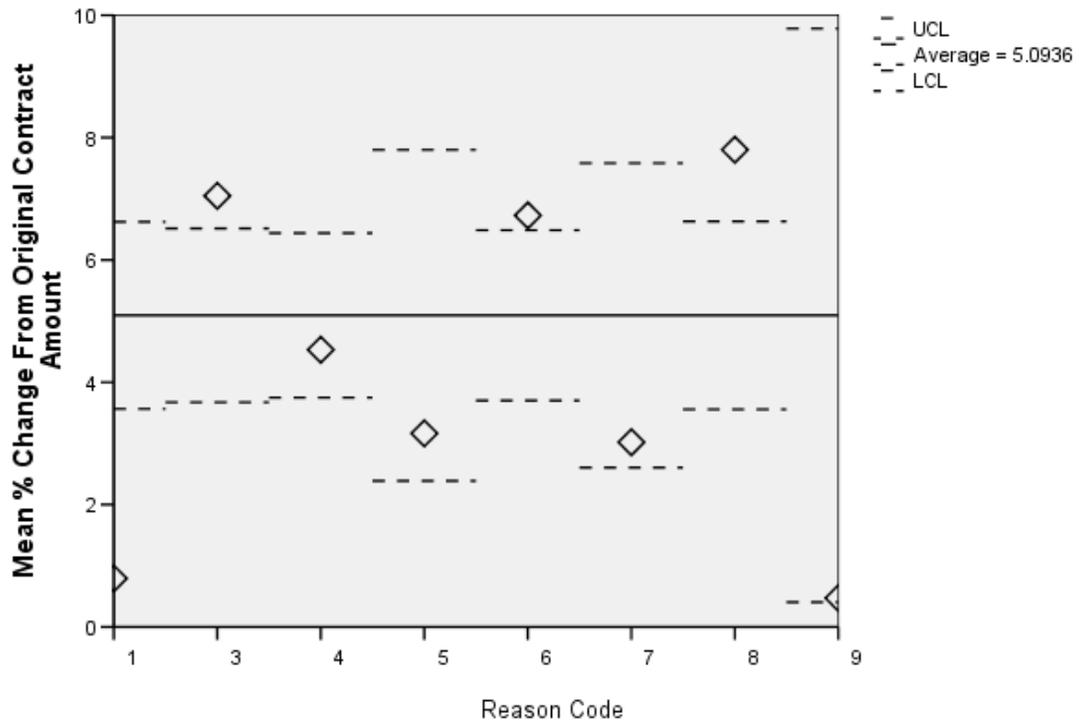


Figure D. 1 Overall % Change from Original Contract Amount

Control Chart: Code1Change

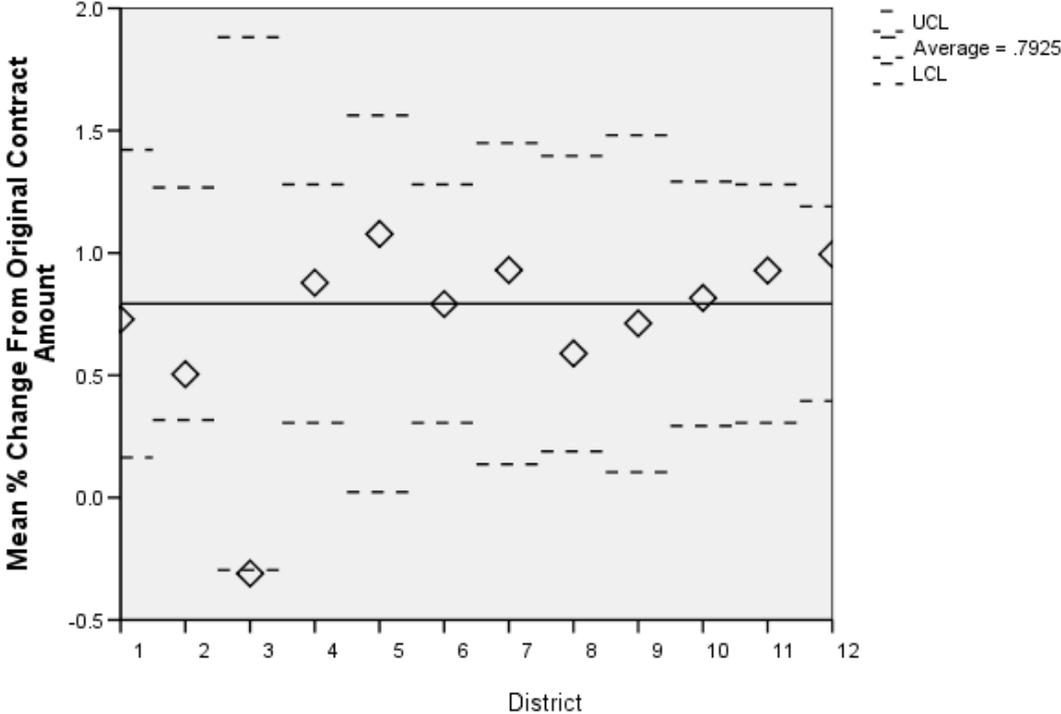


Figure D. 2 Sub - Code 1 % Change from Original Contract Amount

Control Chart: Code1Change

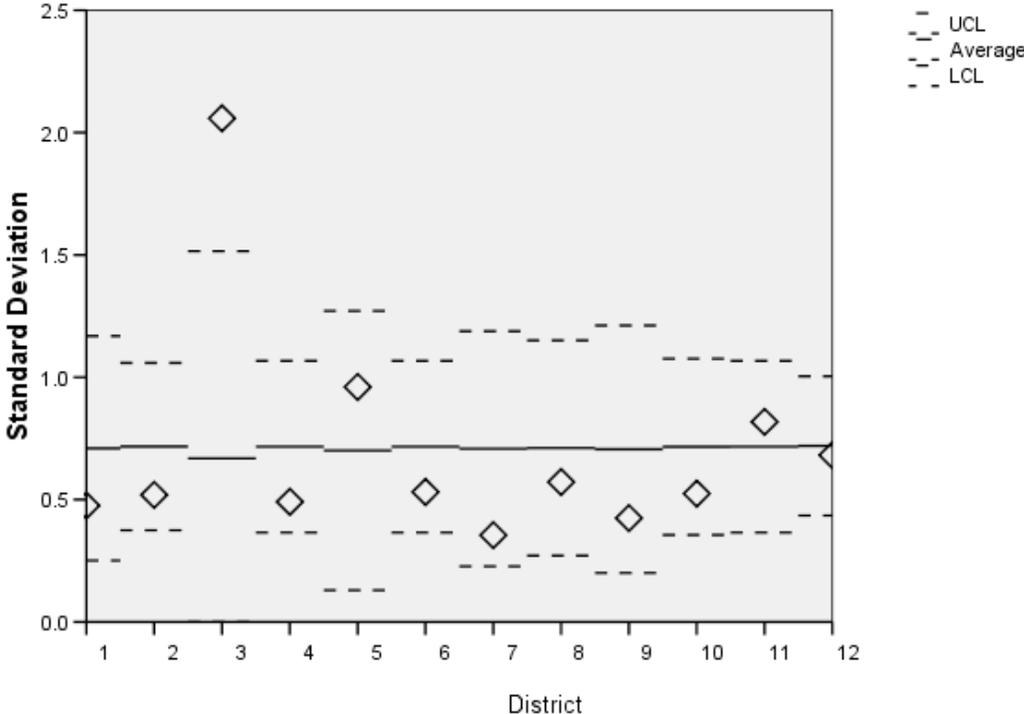


Figure D.3 Sub - Code 1 % Change from Original Contract Amount – Standard Deviation

Control Chart: Code3Change

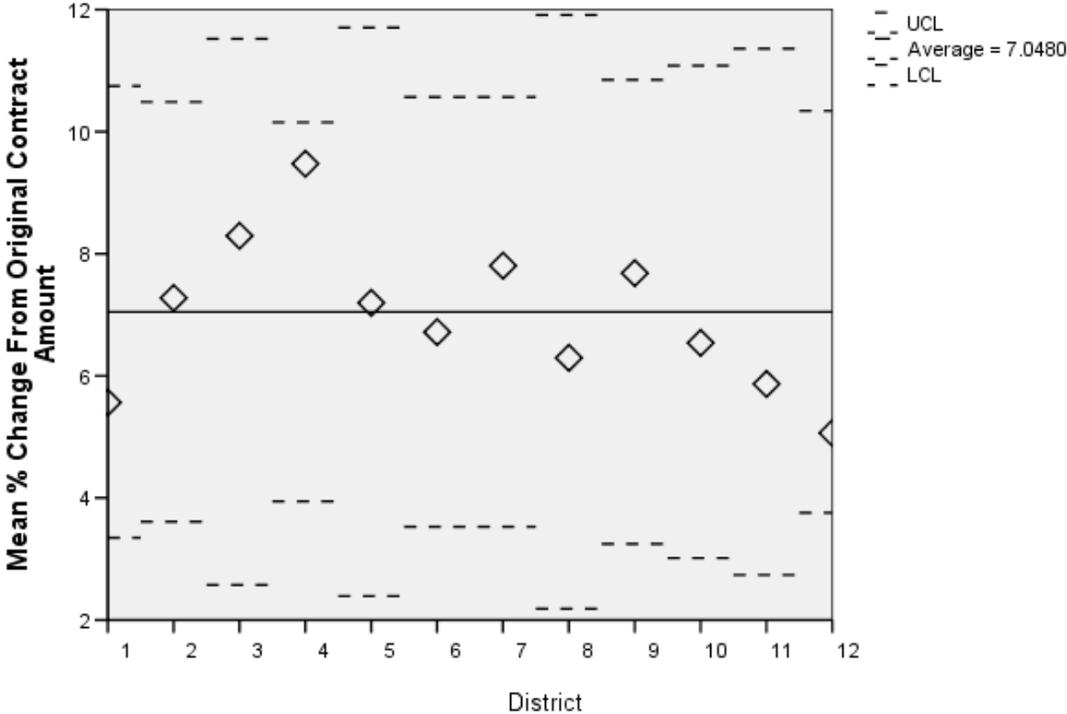


Figure D. 4 Sub - Code 3 Percent Change from Original Contract Amount

Control Chart: Code3Change

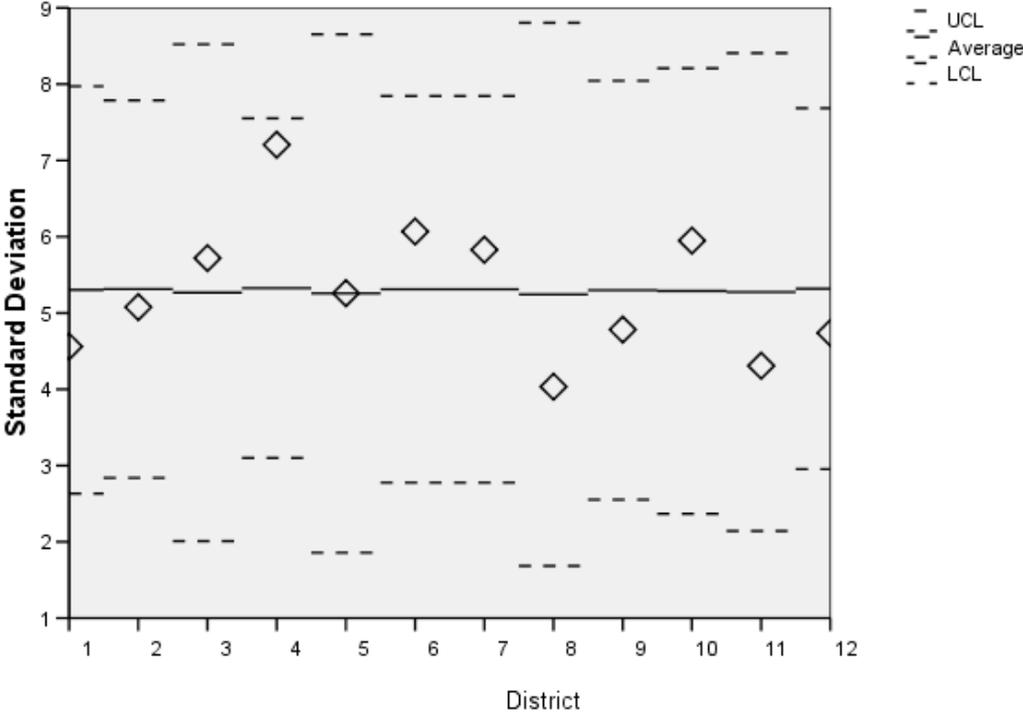


Figure D. 5 Sub - Code 3 Percent Change from Original Contract Amount – Standard Deviation

Control Chart: Code4Change

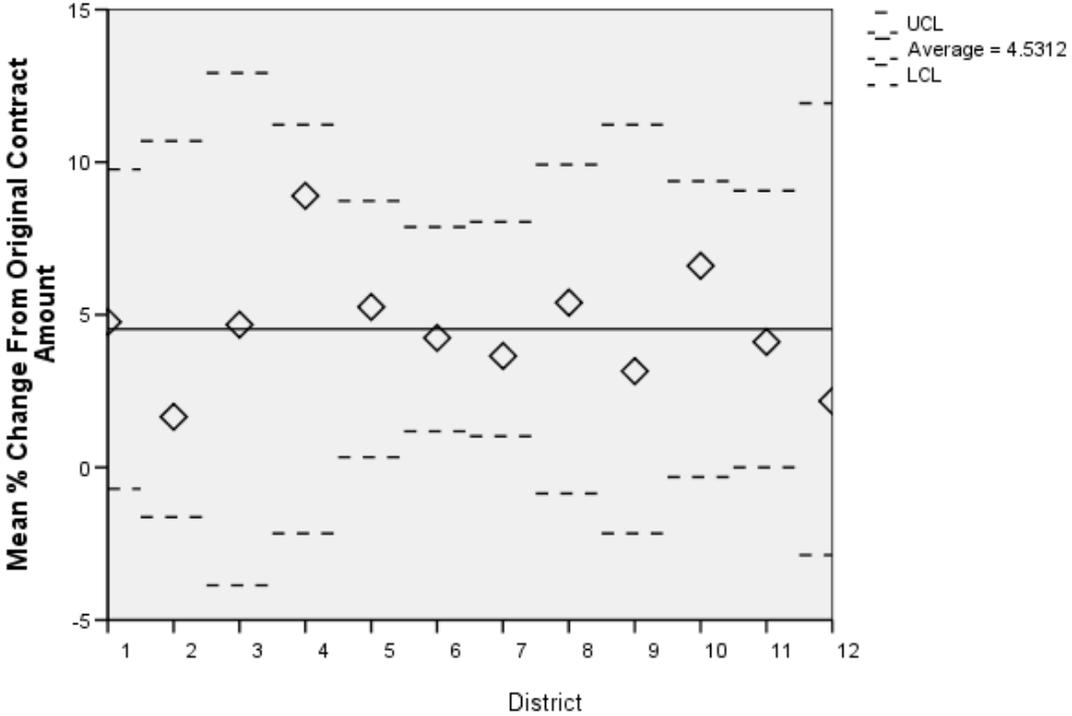
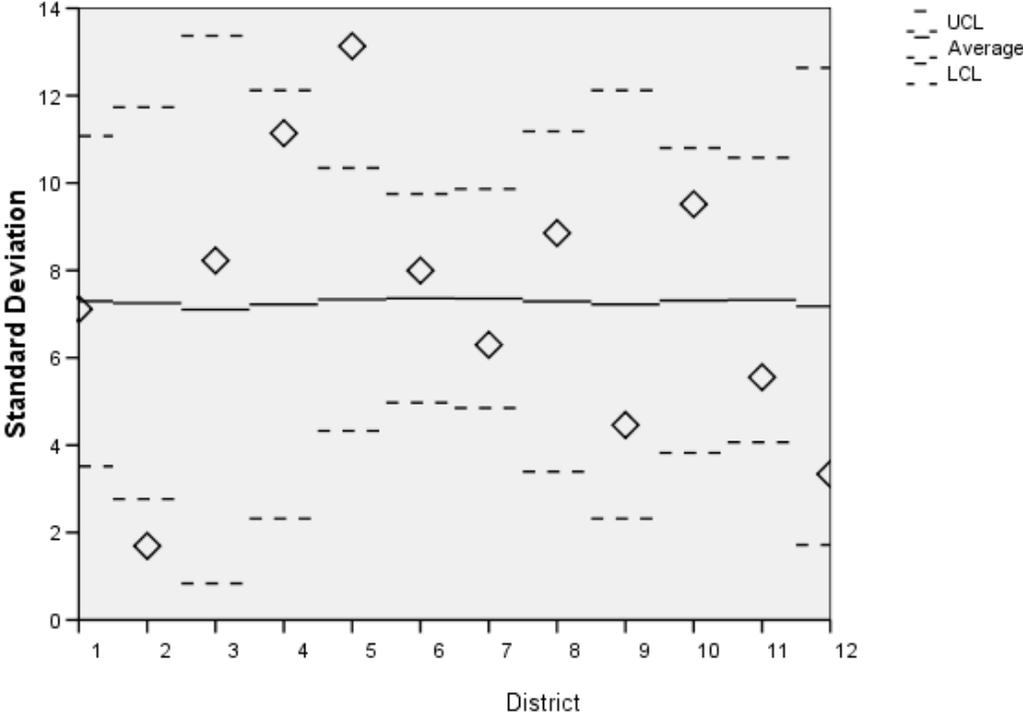


Figure D. 6 Sub - Code 4 Percent Change from Original Contract Amount

**Control Chart: Code4Change**



**Figure D. 7 Sub - Code 4 Percent Change from Original Contract Amount – Standard Deviation**

### Warnings

One or more subgroups do not contain the minimum sample size required and have been excluded from the analysis.

### Control Chart: Code5Change

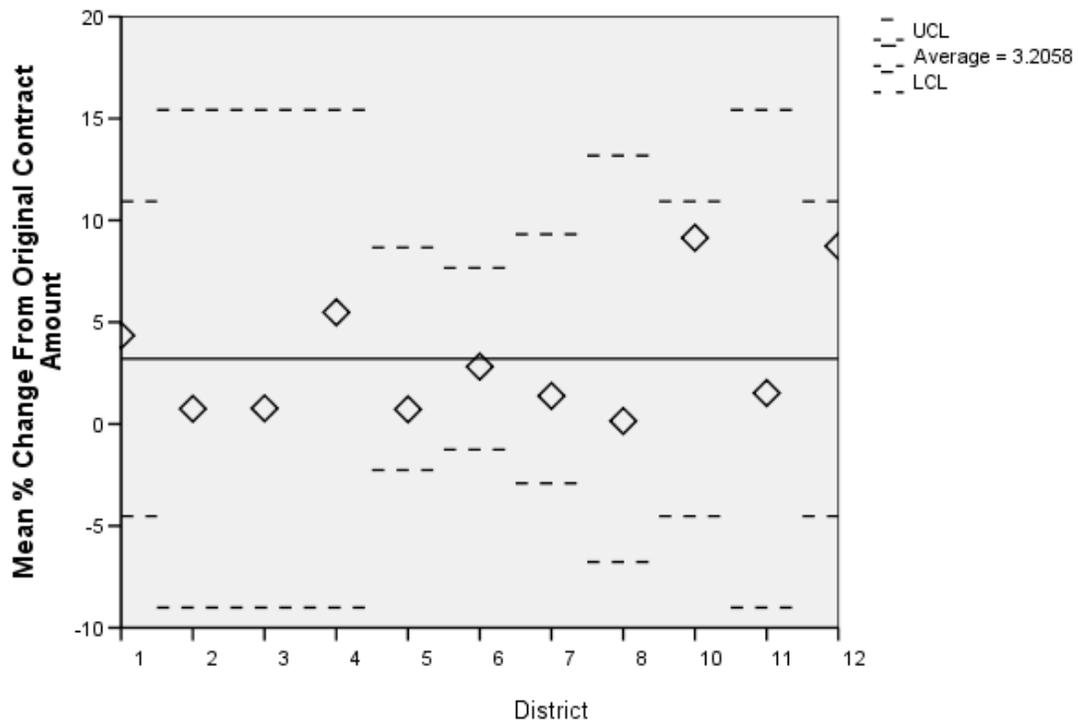
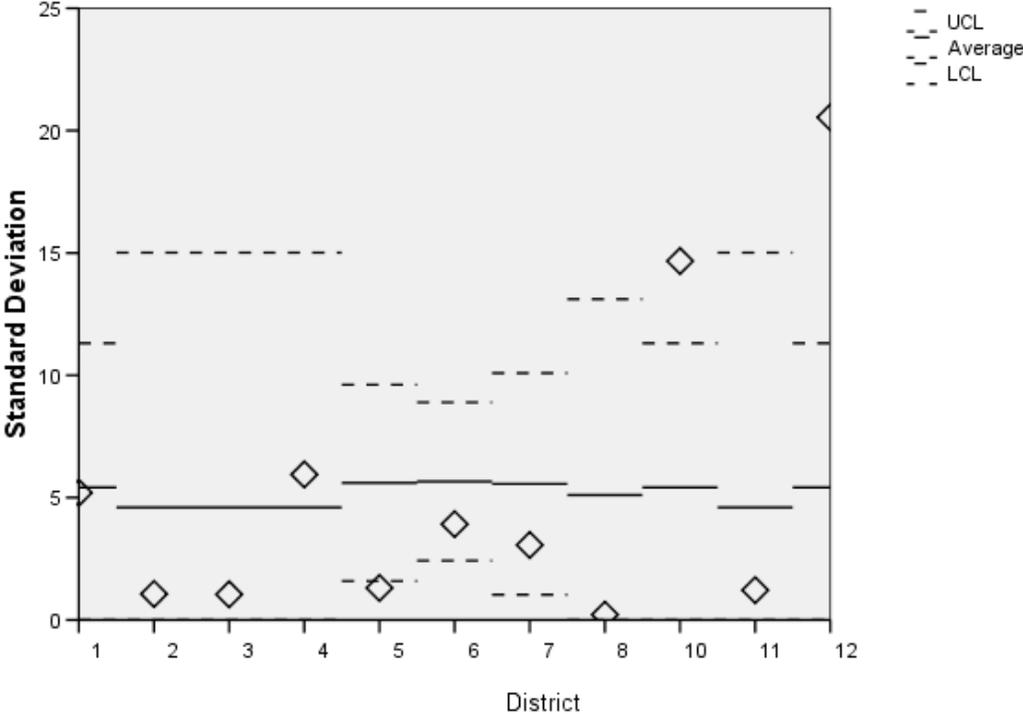


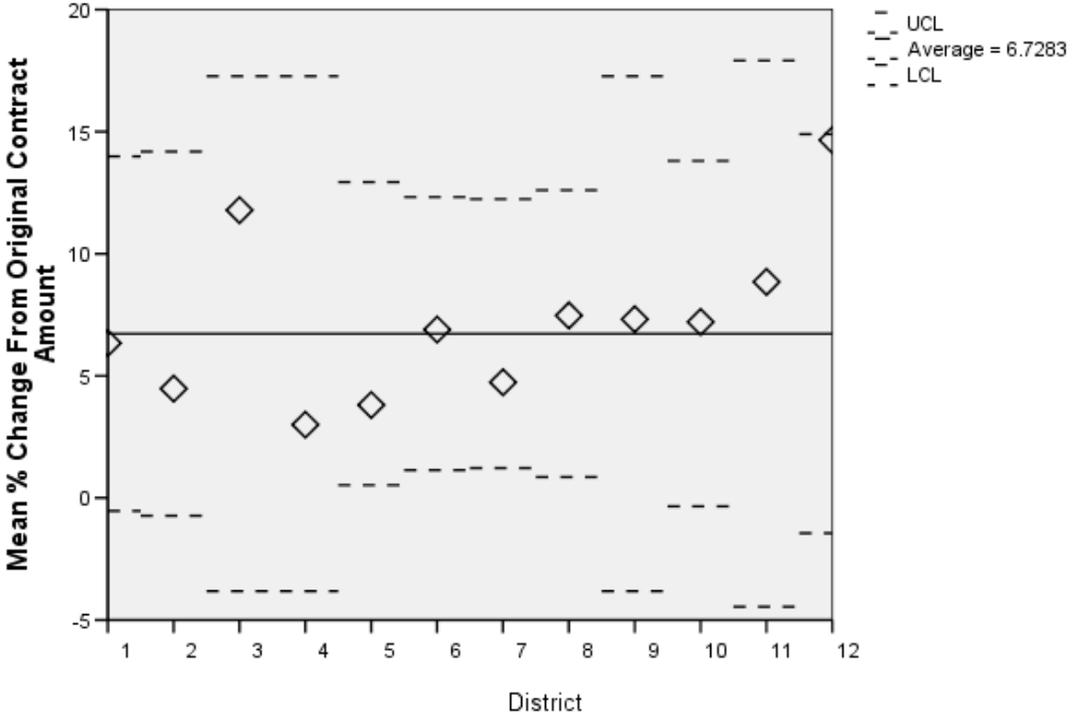
Figure D. 8 Sub - Code 5 Percent Change from Original Contract Amount

**Control Chart: Code5Change**



**Figure D.9 Sub - Code 5 Percent Change from Original Contract Amount – Standard Deviation**

**Control Chart: Code6Change**



**Figure D. 10 Sub - Code 6 Percent Change from Original Contract Amount**

Control Chart: Code6Change

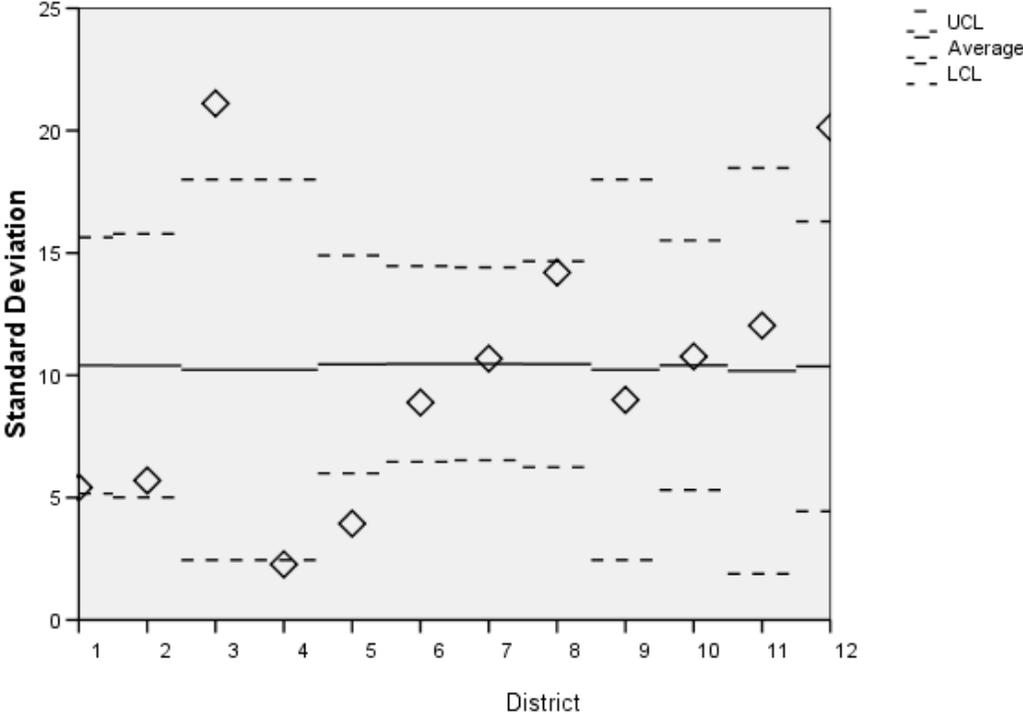


Figure D. 11 Sub - Code 6 Percent Change from Original Contract Amount – Standard Deviation

### Warnings

One or more subgroups do not contain the minimum sample size required and have been excluded from the analysis.

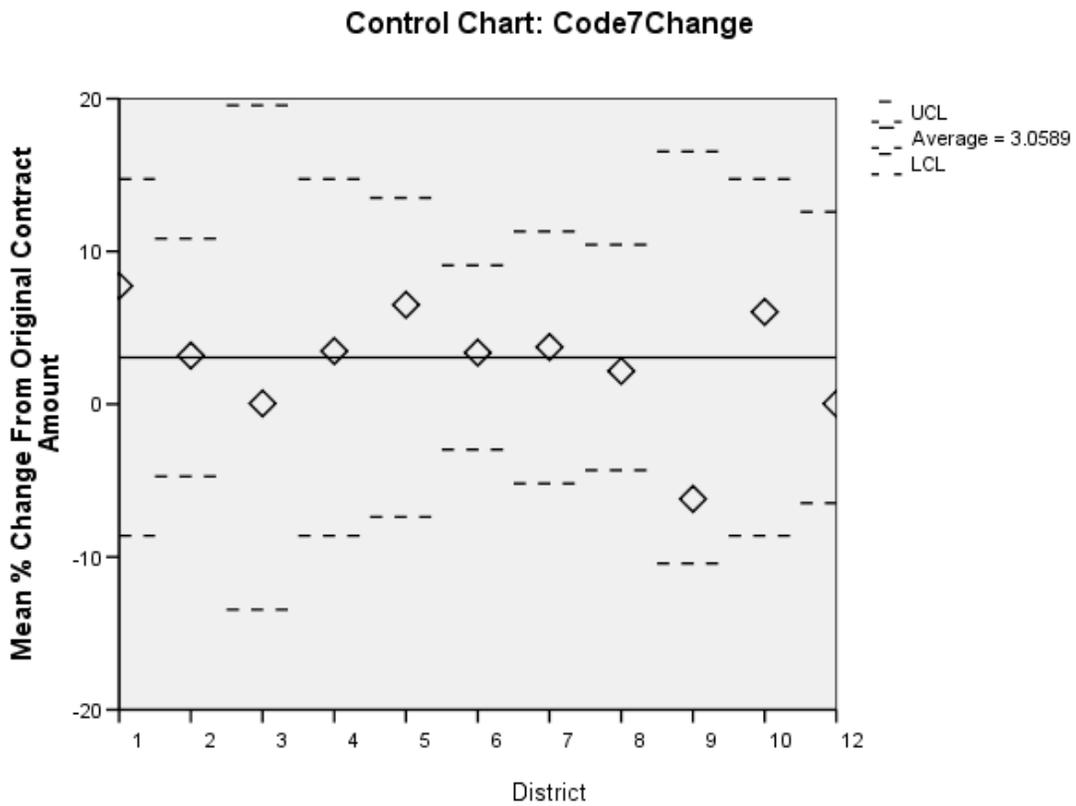
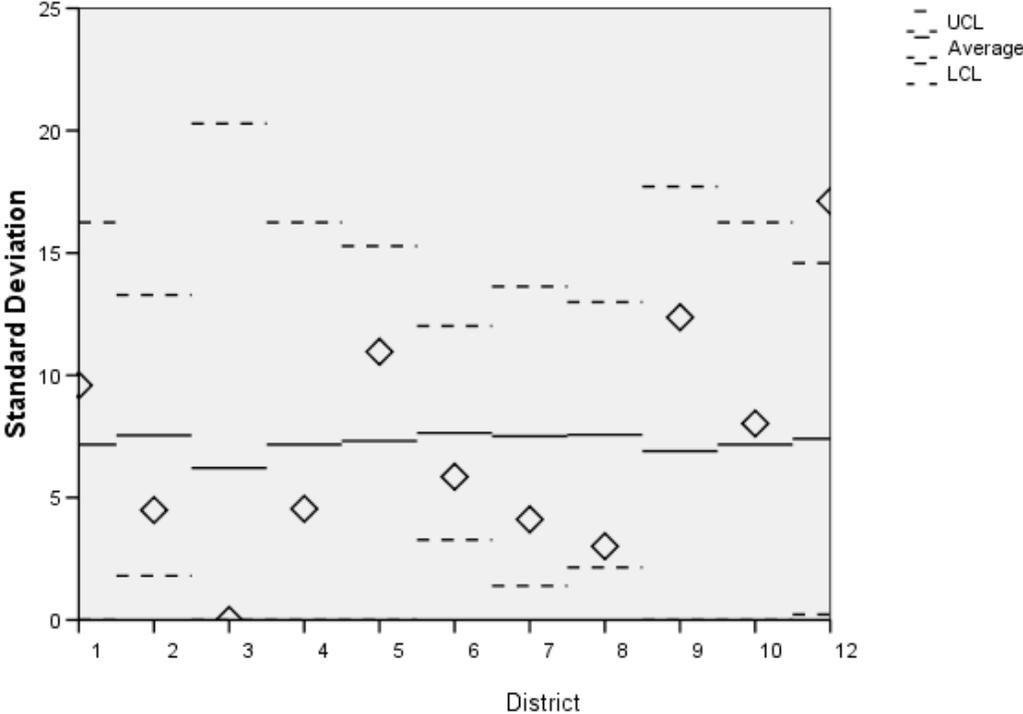


Figure D. 12 Sub - Code 7 Percent Change from Original Contract Amount

**Control Chart: Code7Change**



**Figure D. 13 Sub - Code 7 Percent Change from Original Contract Amount – Standard Deviation**

Control Chart: Code8Change

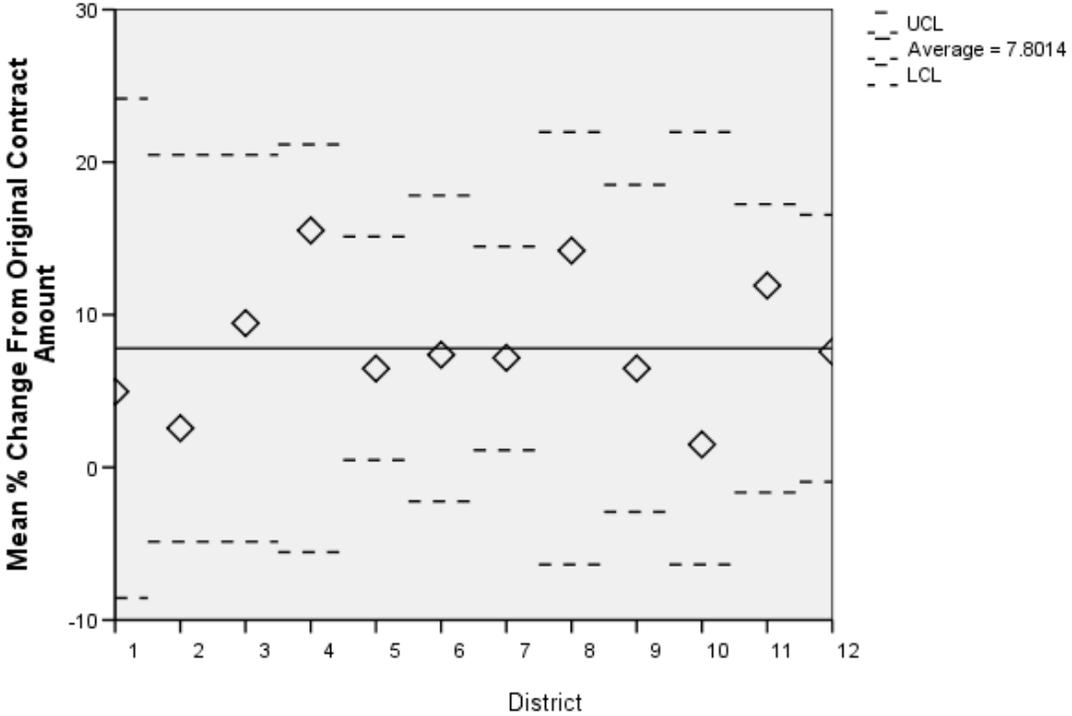


Figure D. 14 Sub - Code 8 Percent Change from Original Contract Amount

Control Chart: Code8Change

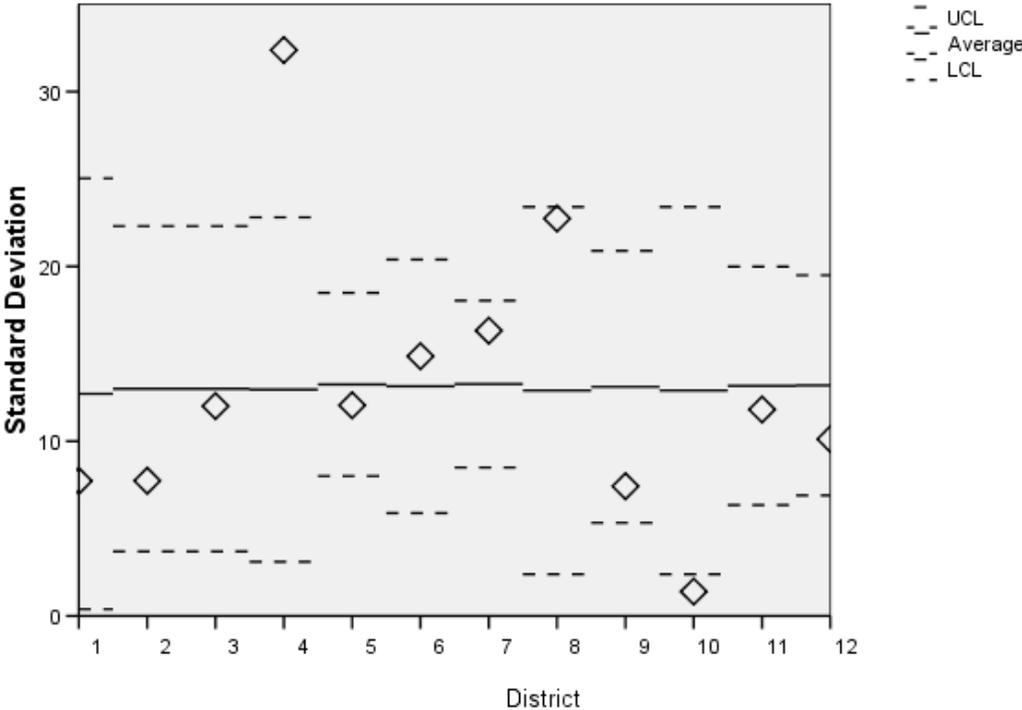


Figure D. 15 Sub - Code 8 Percent Change from Original Contract Amount – Standard Deviation

### Warnings

One or more subgroups do not contain the minimum sample size required and have been excluded from the analysis.

### Control Chart: Code9Change

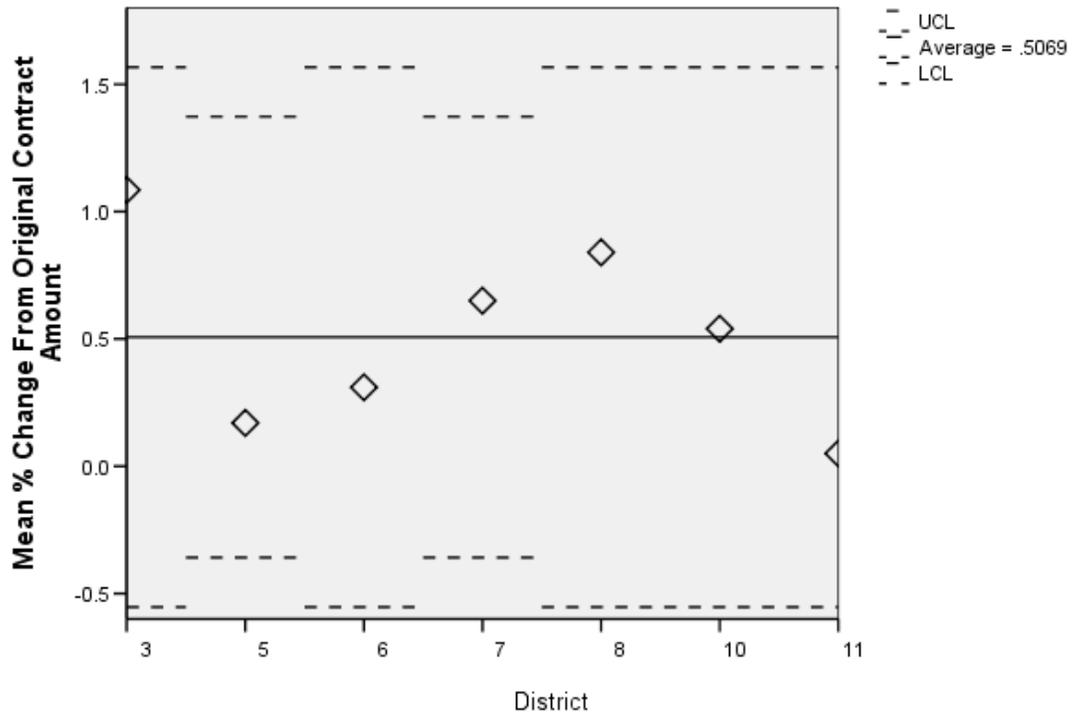


Figure D. 16 Sub - Code 9 Percent Change from Original Contract Amount

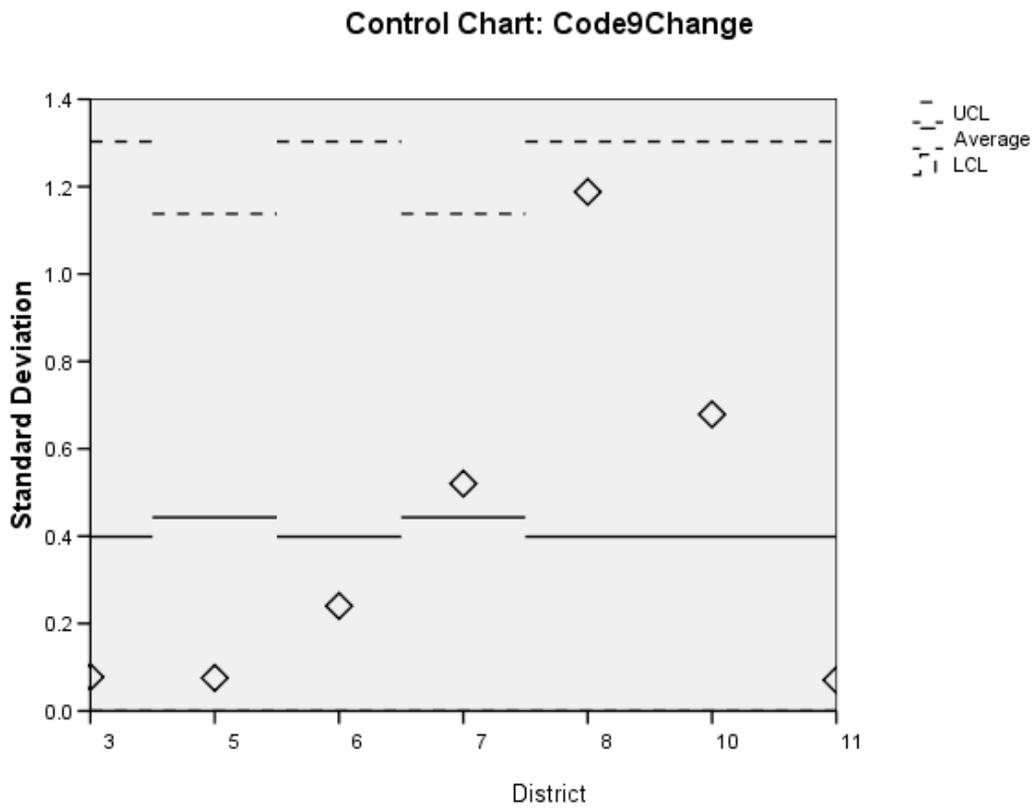


Figure D. 17 Sub - Code 9 Percent Change from Original Contract Amount – Standard Deviation

**12.0 Appendix E: Control Charts – % Change from Original Contract Amount by New/Maintenance Projects**

|   |     |
|---|-----|
| Figure E. 1 Overall Percent Change from Original Contract Amount .....  | 200 |
| Figure E. 2 Sub - Code 1 Percent Change from Original Contract Amount by<br>New/Maintenance .....                       | 192 |
| Figure E. 3 Sub - Code 1 Percent Change from Original Contract Amount by<br>New/Maintenance – Standard Deviation .....  | 202 |
| Figure E. 4 Sub - Code 3 Percent Change from Original Contract Amount by<br>New/Maintenance .....                       | 203 |
| Figure E. 5 Sub - Code 3 Percent Change from Original Contract Amount by<br>New/Maintenance – Standard Deviation .....  | 204 |
| Figure E. 6 Sub - Code 4 Percent Change from Original Contract Amount by<br>New/Maintenance .....                       | 205 |
| Figure E. 7 Sub - Code 4 Percent Change from Original Contract Amount by<br>New/Maintenance – Standard Deviation .....  | 206 |
| Figure E. 8 Sub - Code 5 Percent Change from Original Contract Amount by<br>New/Maintenance .....                       | 207 |
| Figure E. 9 Sub - Code 5 Percent Change from Original Contract Amount by<br>New/Maintenance – Standard Deviation .....  | 208 |
| Figure E. 10 Sub - Code 6 Percent Change from Original Contract Amount by<br>New/Maintenance .....                      | 209 |
| Figure E. 11 Sub - Code 6 Percent Change from Original Contract Amount by<br>New/Maintenance – Standard Deviation ..... | 210 |
| Figure E. 12 Sub - Code 7 Percent Change from Original Contract Amount by<br>New/Maintenance .....                      | 211 |
| Figure E. 13 Sub - Code 7 Percent Change from Original Contract Amount by<br>New/Maintenance – Standard Deviation ..... | 212 |
| Figure E. 14 Sub - Code 8 Percent Change from Original Contract Amount by<br>New/Maintenance .....                      | 213 |
| Figure E. 15 Sub - Code 8 Percent Change from Original Contract Amount by<br>New/Maintenance – Standard Deviation ..... | 214 |
| Figure E. 16 Sub - Code 9 Percent Change from Original Contract Amount by<br>New/Maintenance .....                      | 215 |

Figure E. 17 Sub - Code 9 Percent Change from Original Contract Amount by  
New/Maintenance – Standard Deviation ..... 216

Control Chart: Change\_1through9

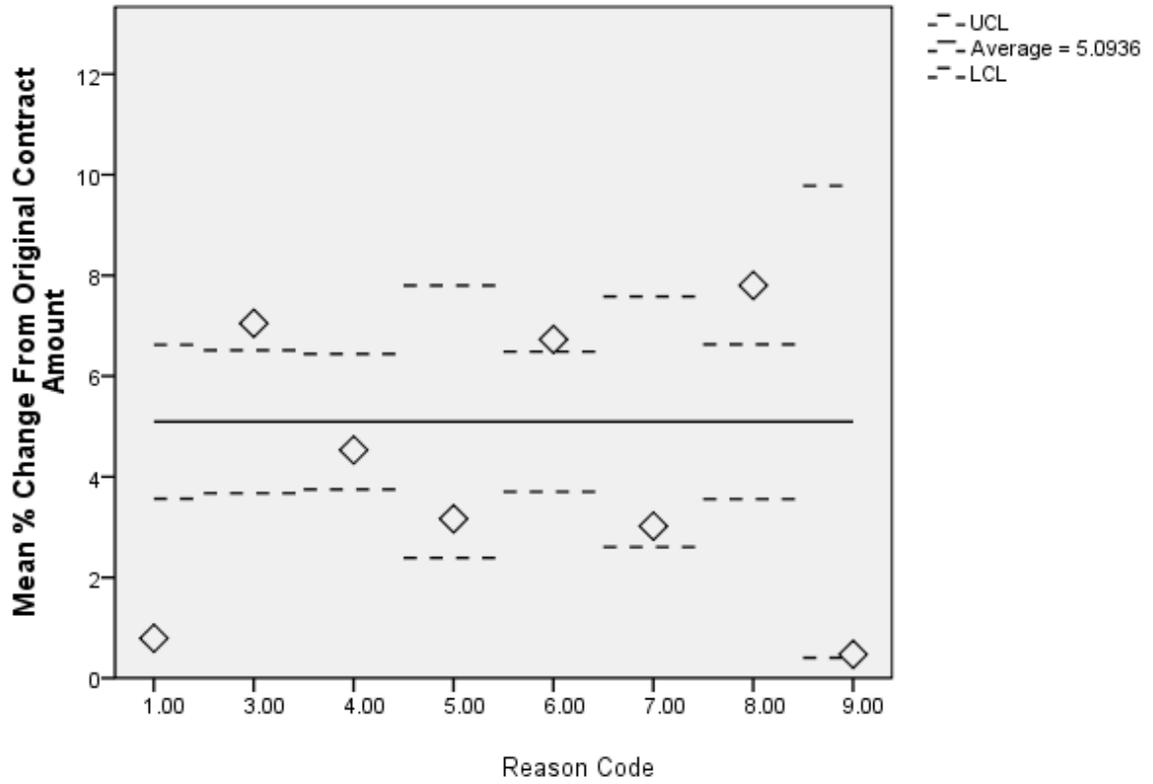
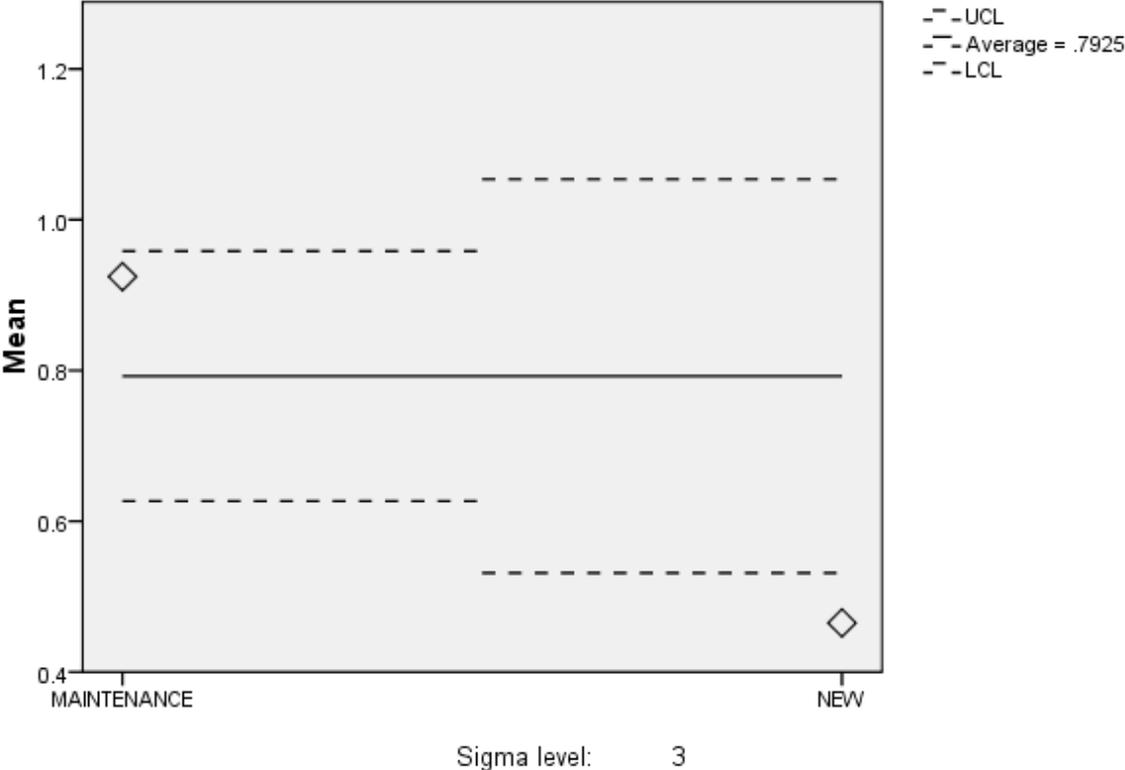


Figure E. 1 Overall Percent Change from Original Contract Amount

**Control Chart: Code1Change**



**Figure E. 2 Sub - Code 1 Percent Change from Original Contract Amount by New/Maintenance**

### Control Chart: Code1Change

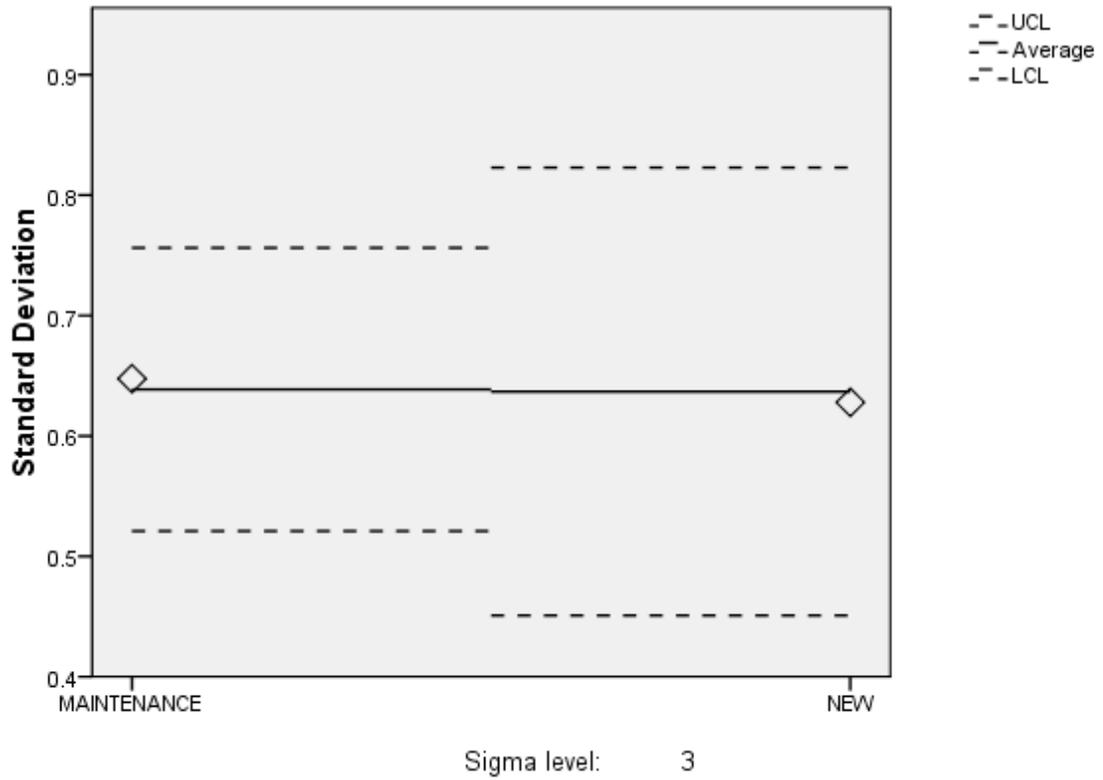


Figure E. 3 Sub - Code 1 Percent Change from Original Contract Amount by New/Maintenance – Standard Deviation

### Control Chart: Code3Change

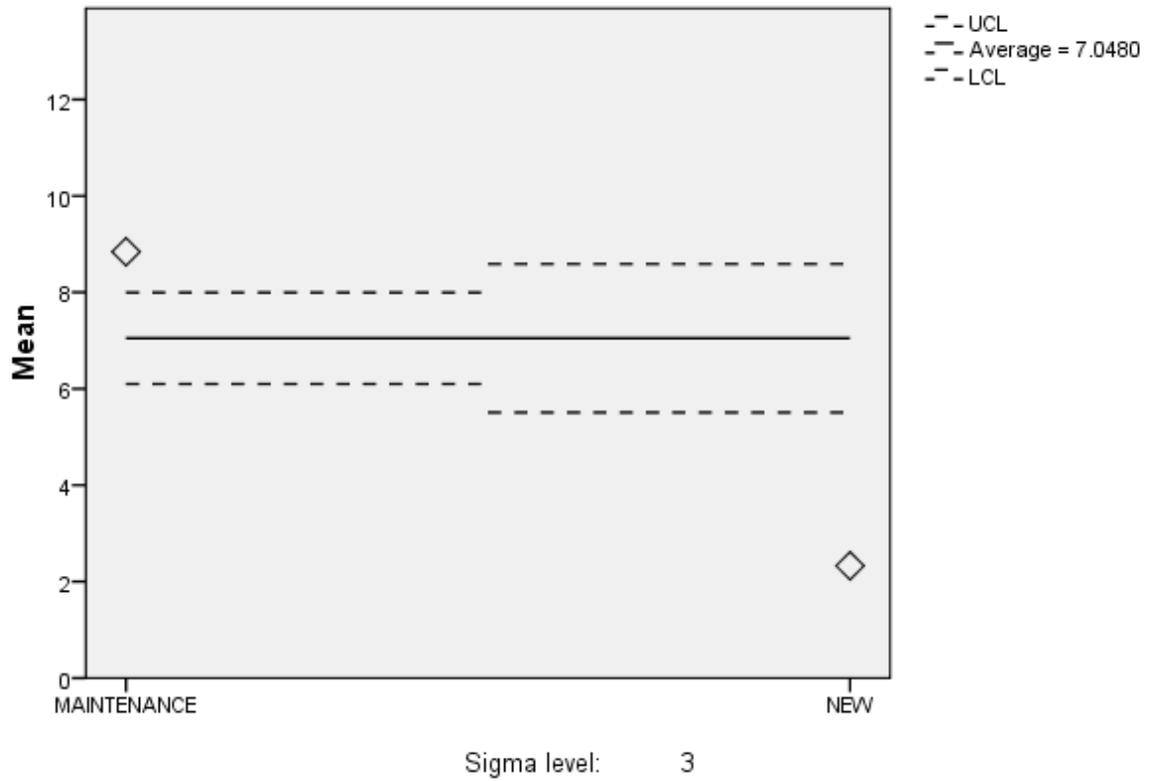


Figure E. 4 Sub - Code 3 Percent Change from Original Contract Amount by New/Maintenance

### Control Chart: Code3Change

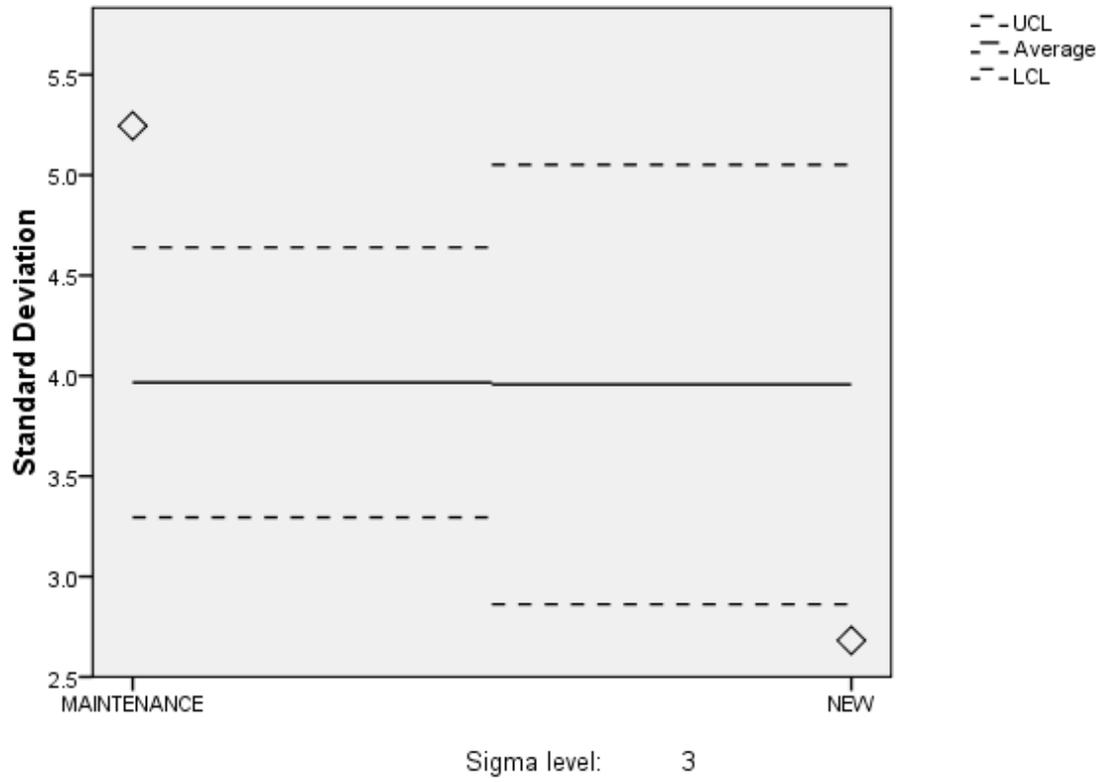


Figure E. 5 Sub - Code 3 Percent Change from Original Contract Amount by New/Maintenance – Standard Deviation

### Control Chart: Code4Change

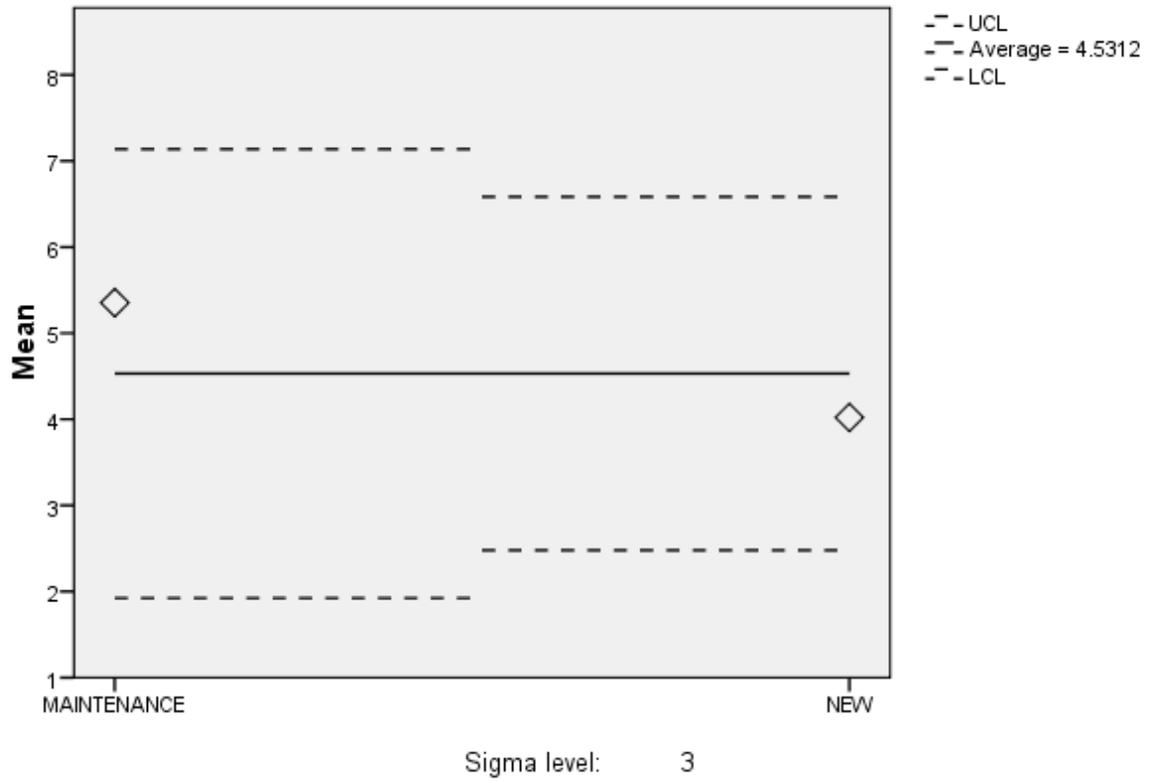


Figure E. 6 Sub - Code 4 Percent Change from Original Contract Amount by New/Maintenance

### Control Chart: Code4Change

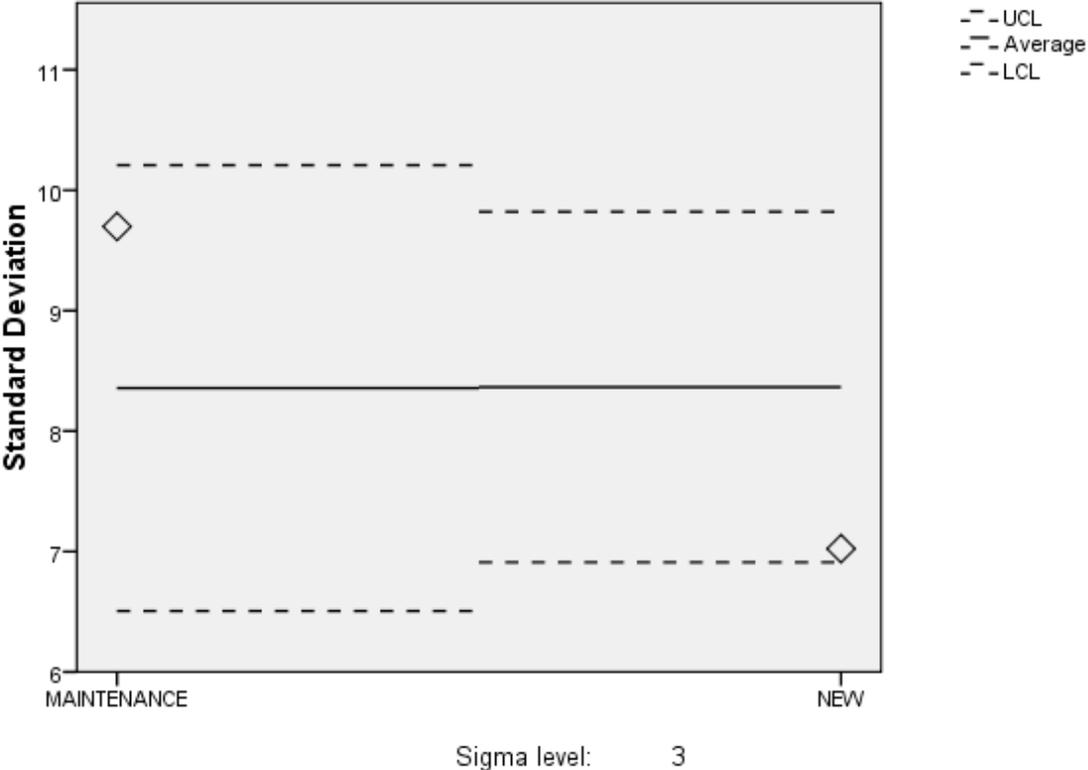


Figure E. 7 Sub - Code 4 Percent Change from Original Contract Amount by New/Maintenance – Standard Deviation

### Control Chart: Code5Change

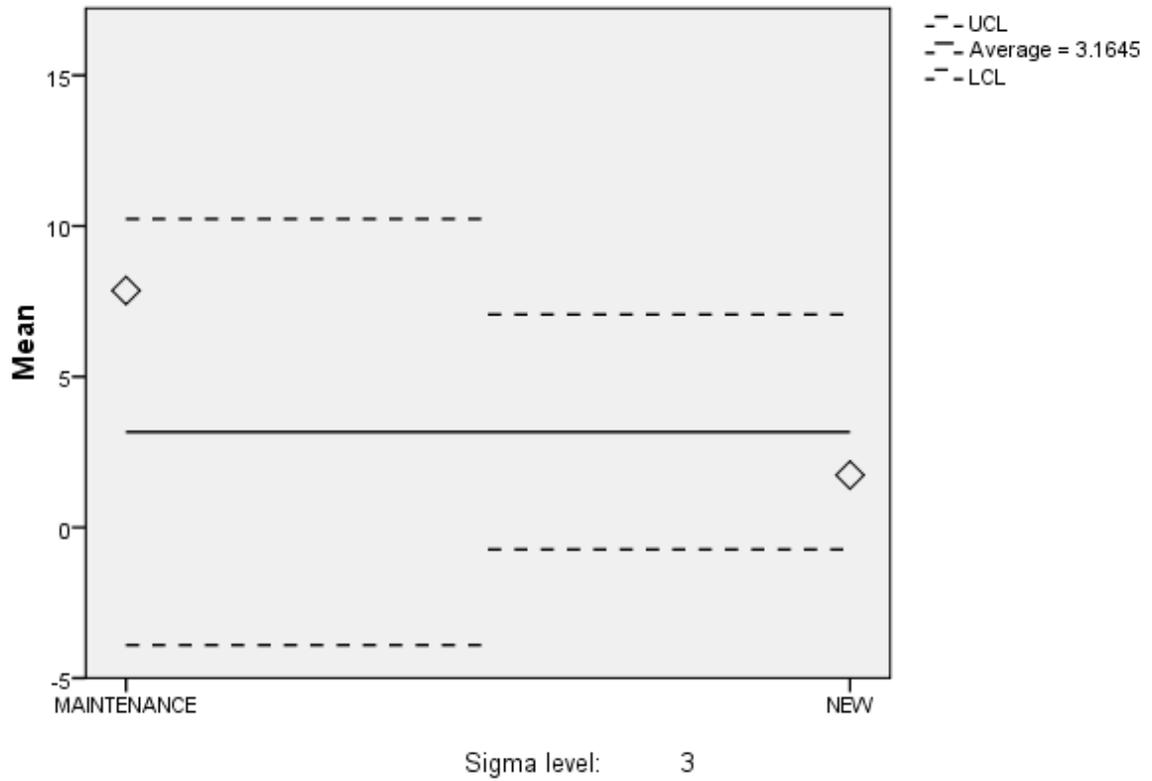


Figure E. 8 Sub - Code 5 Percent Change from Original Contract Amount by New/Maintenance

### Control Chart: Code5Change

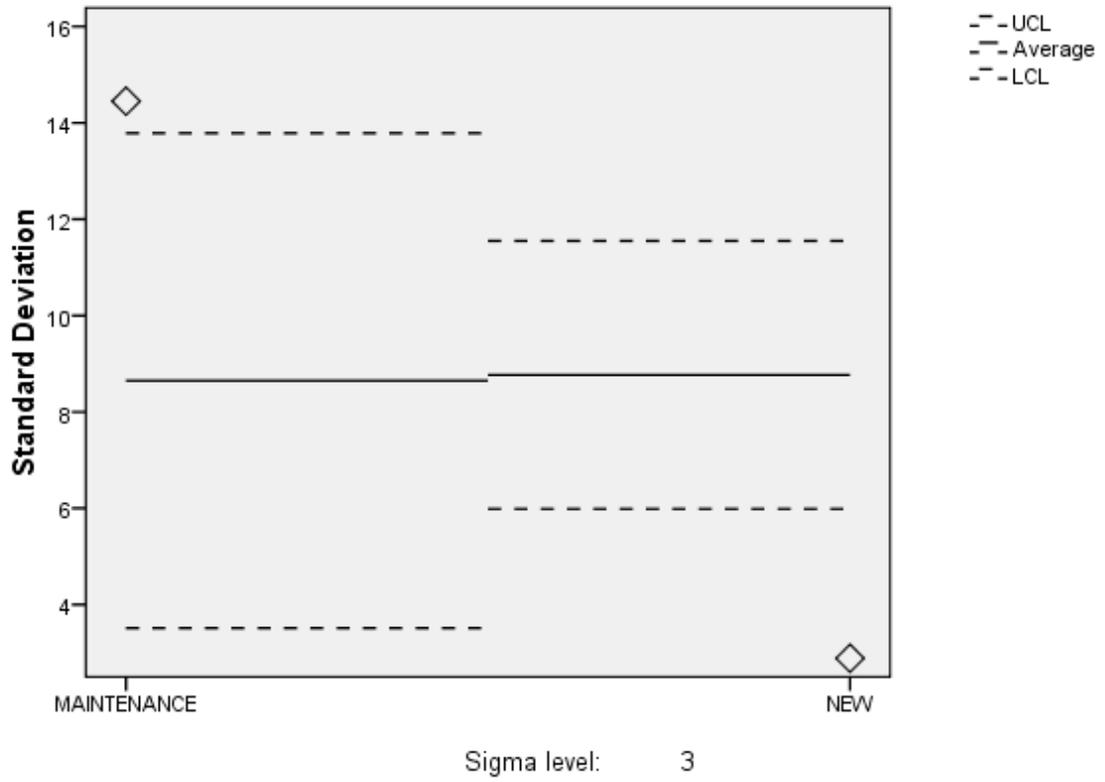


Figure E. 9 Sub - Code 5 Percent Change from Original Contract Amount by New/Maintenance – Standard Deviation

### Control Chart: Code6Change

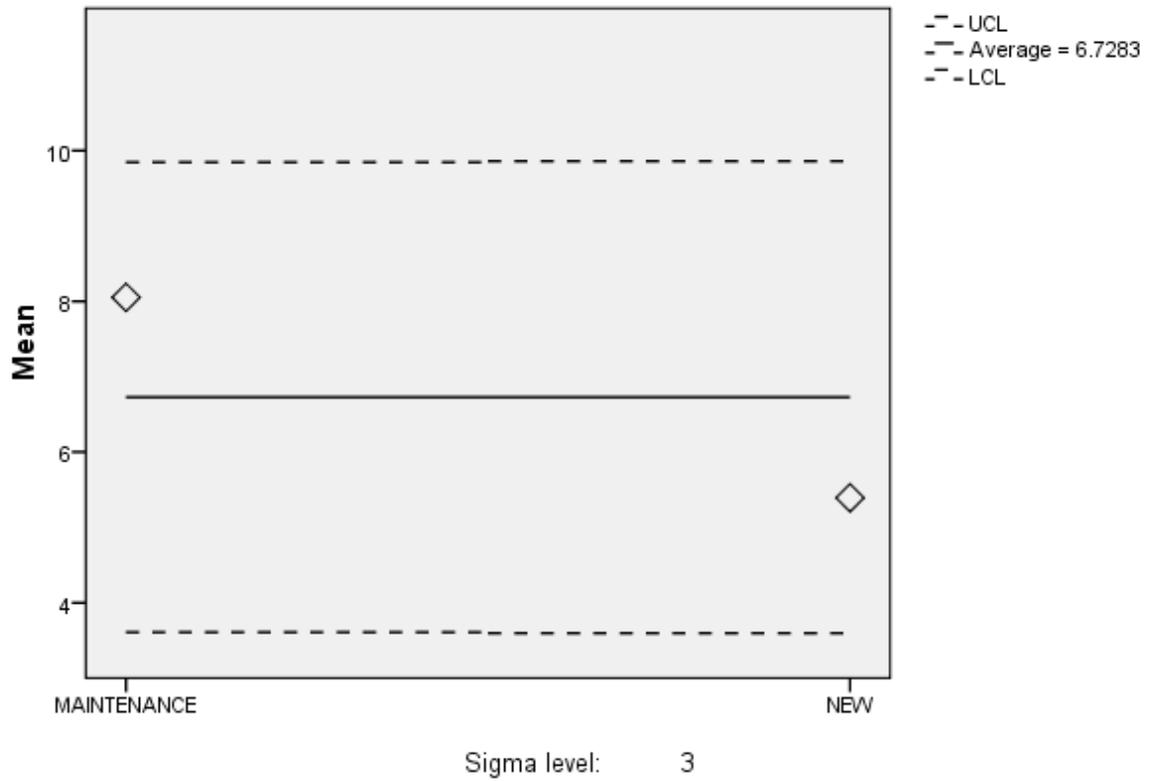


Figure E. 10 Sub - Code 6 Percent Change from Original Contract Amount by New/Maintenance

Control Chart: Code6Change

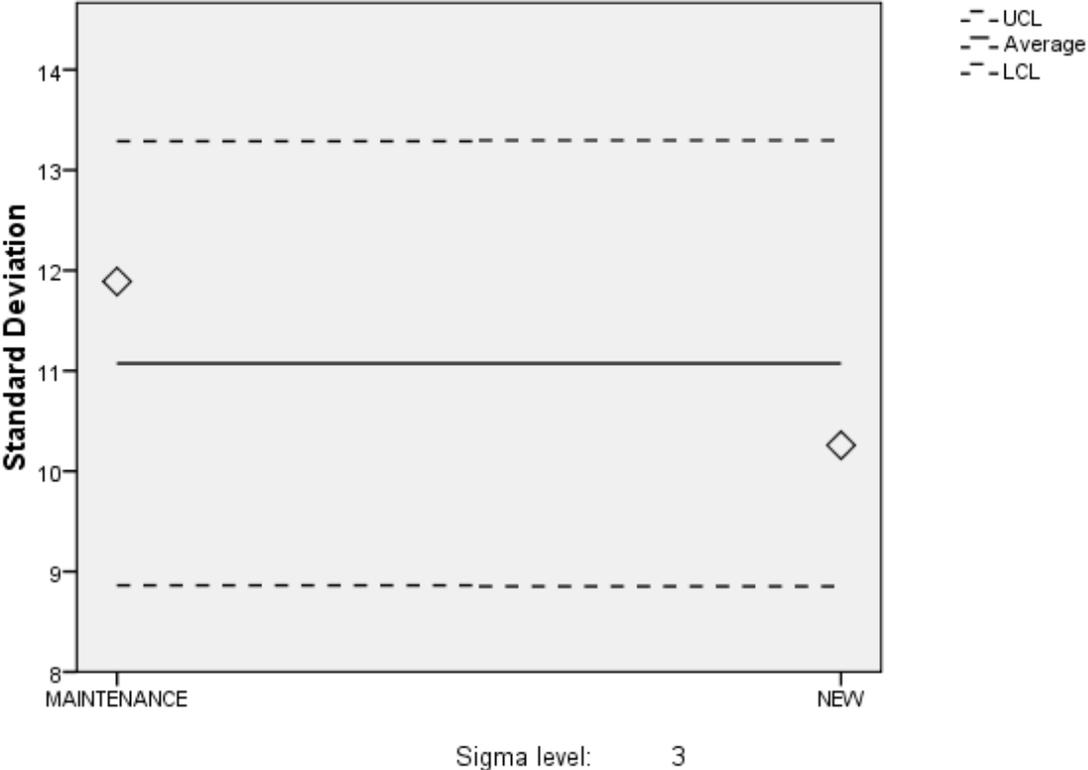


Figure E. 11 Sub - Code 6 Percent Change from Original Contract Amount by New/Maintenance – Standard Deviation

### Control Chart: Code7Change

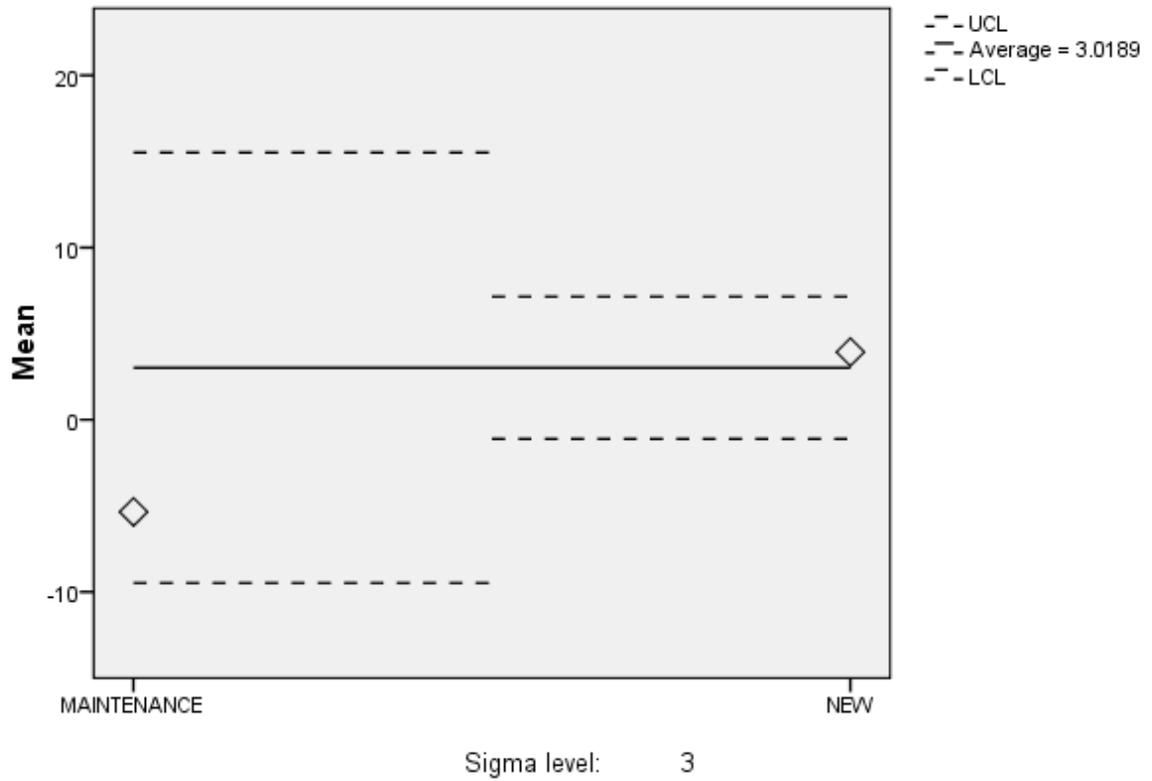
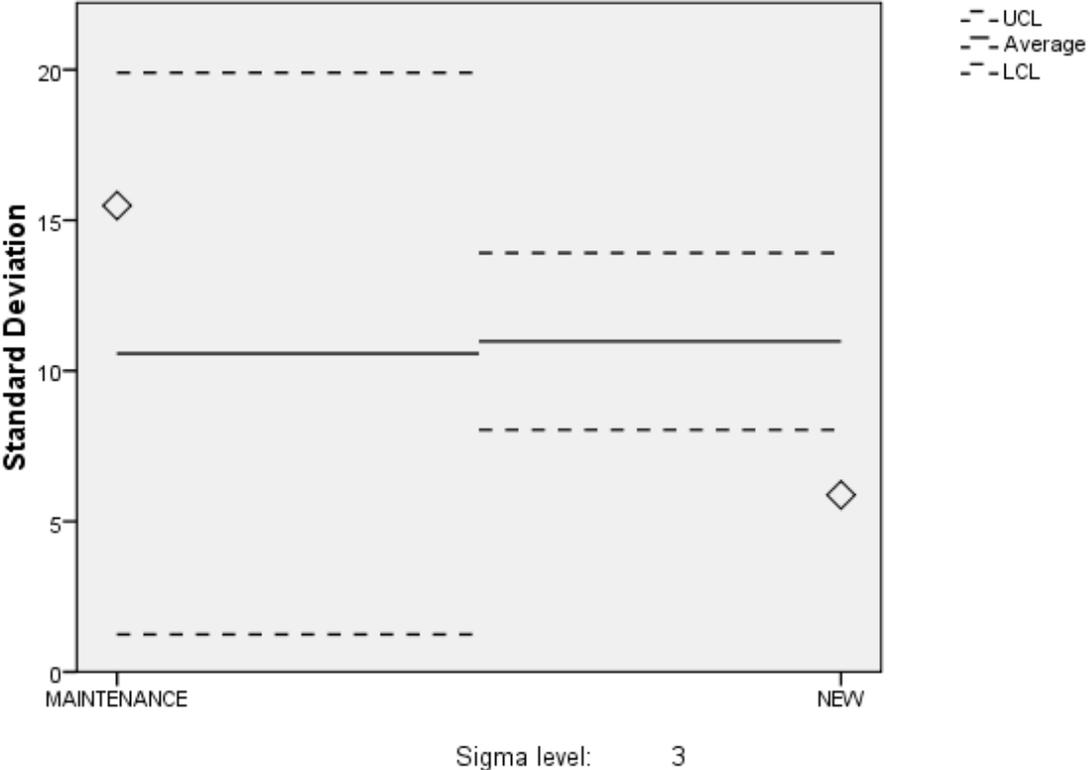


Figure E. 12 Sub - Code 7 Percent Change from Original Contract Amount by New/Maintenance

**Control Chart: Code7Change**



**Figure E. 13 Sub - Code 7 Percent Change from Original Contract Amount by New/Maintenance – Standard Deviation**

### Control Chart: Code8Change

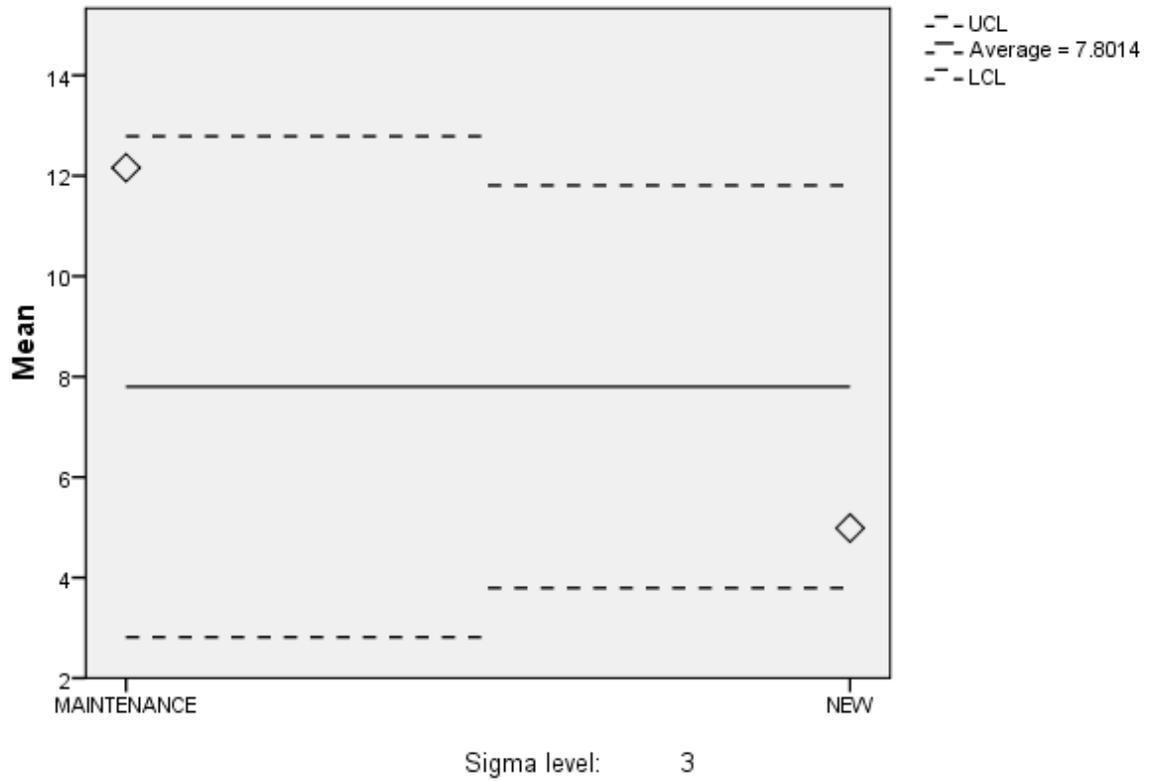


Figure E. 14 Sub - Code 8 Percent Change from Original Contract Amount by New/Maintenance

### Control Chart: Code8Change

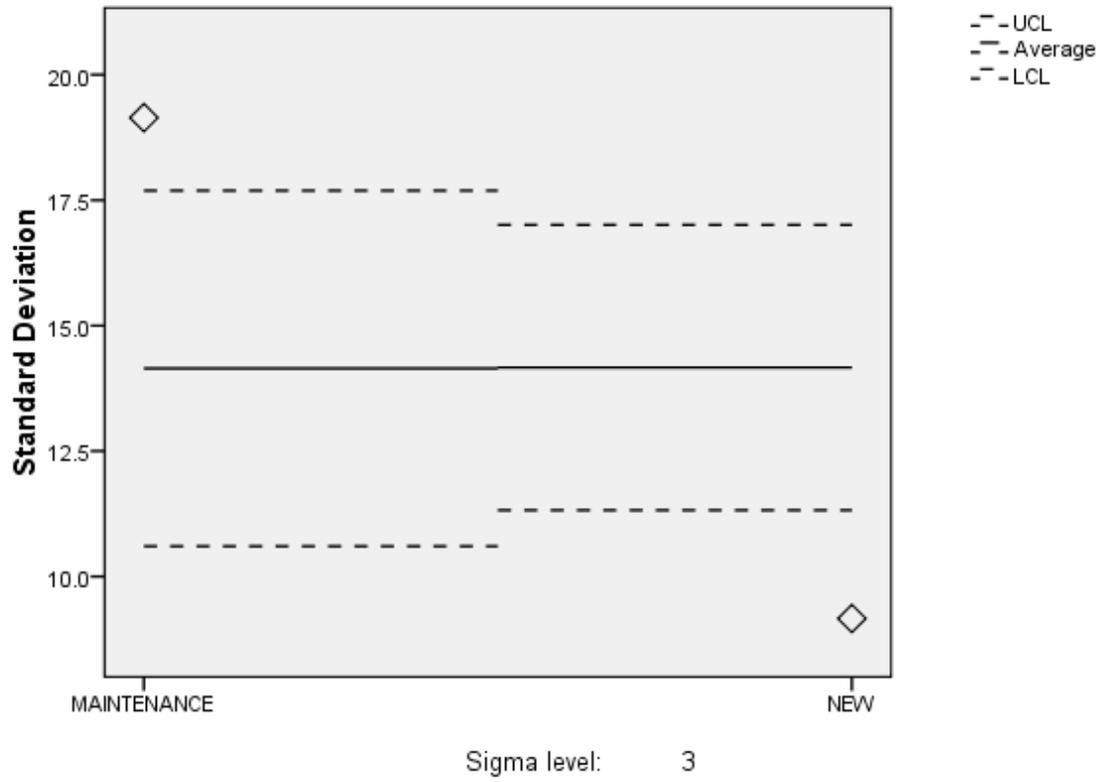


Figure E. 15 Sub - Code 8 Percent Change from Original Contract Amount by New/Maintenance – Standard Deviation

### Control Chart: Code9Change

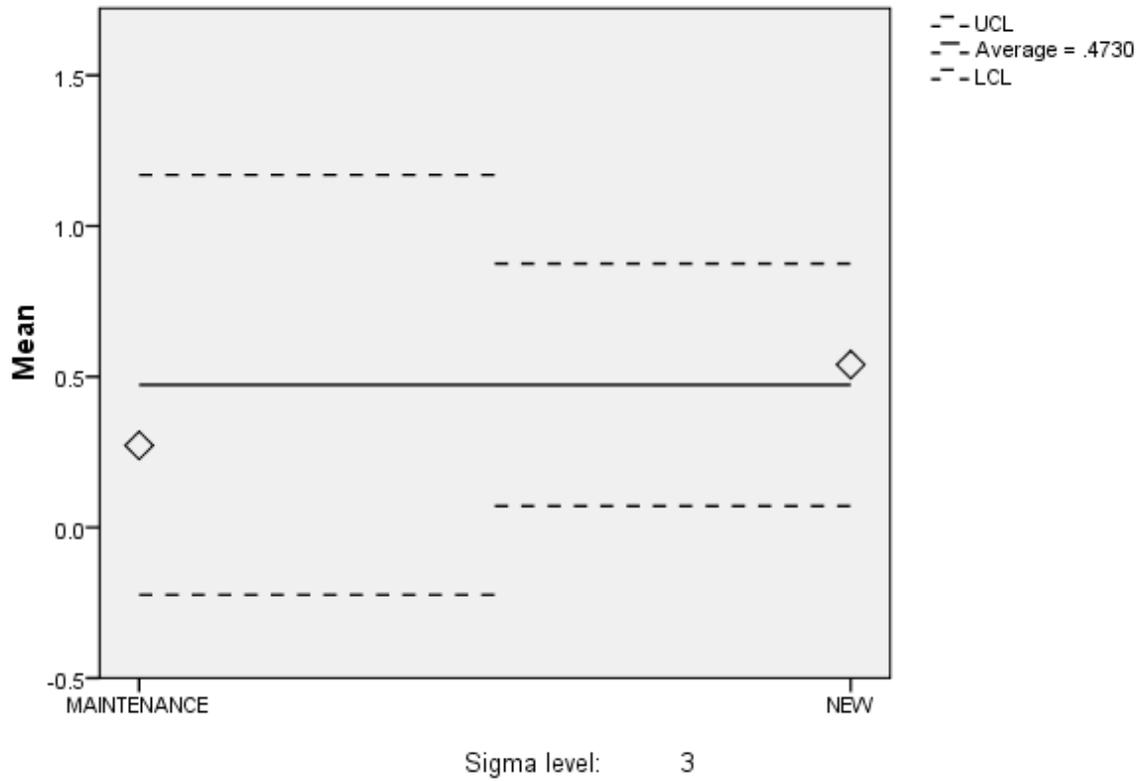


Figure E. 16 Sub - Code 9 Percent Change from Original Contract Amount by New/Maintenance

### Control Chart: Code9Change

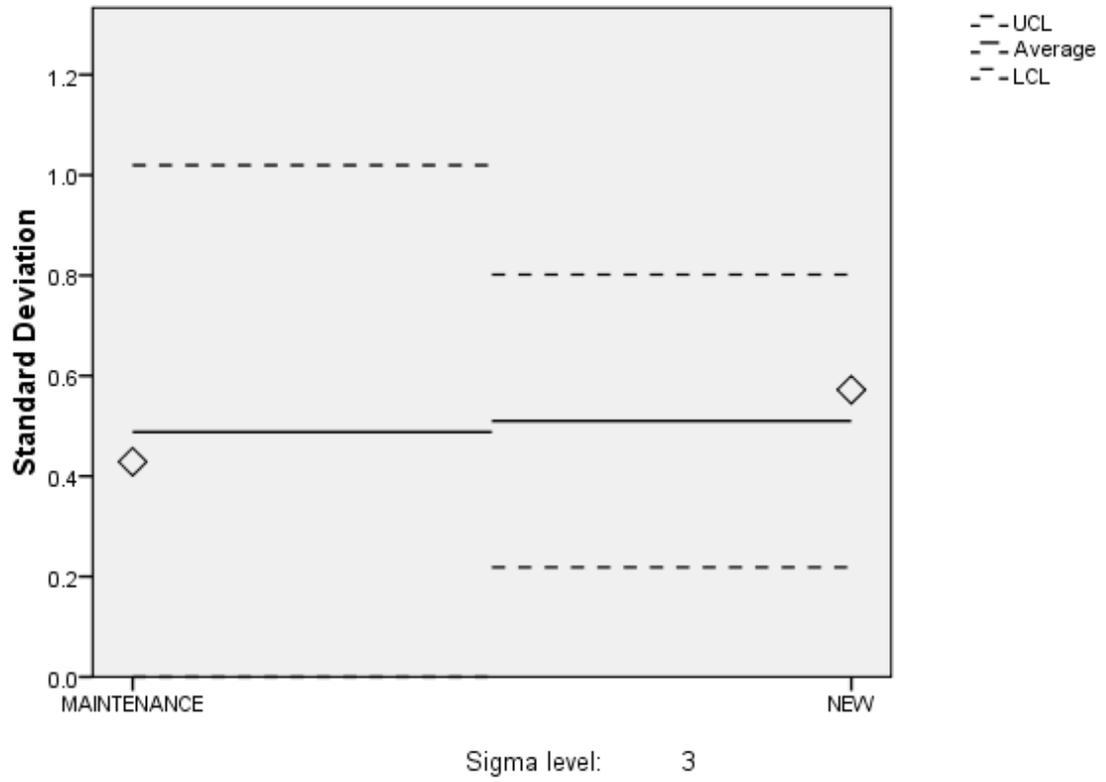


Figure E. 17 Sub - Code 9 Percent Change from Original Contract Amount by New/Maintenance – Standard Deviation

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Control Chart: Change\_1through9

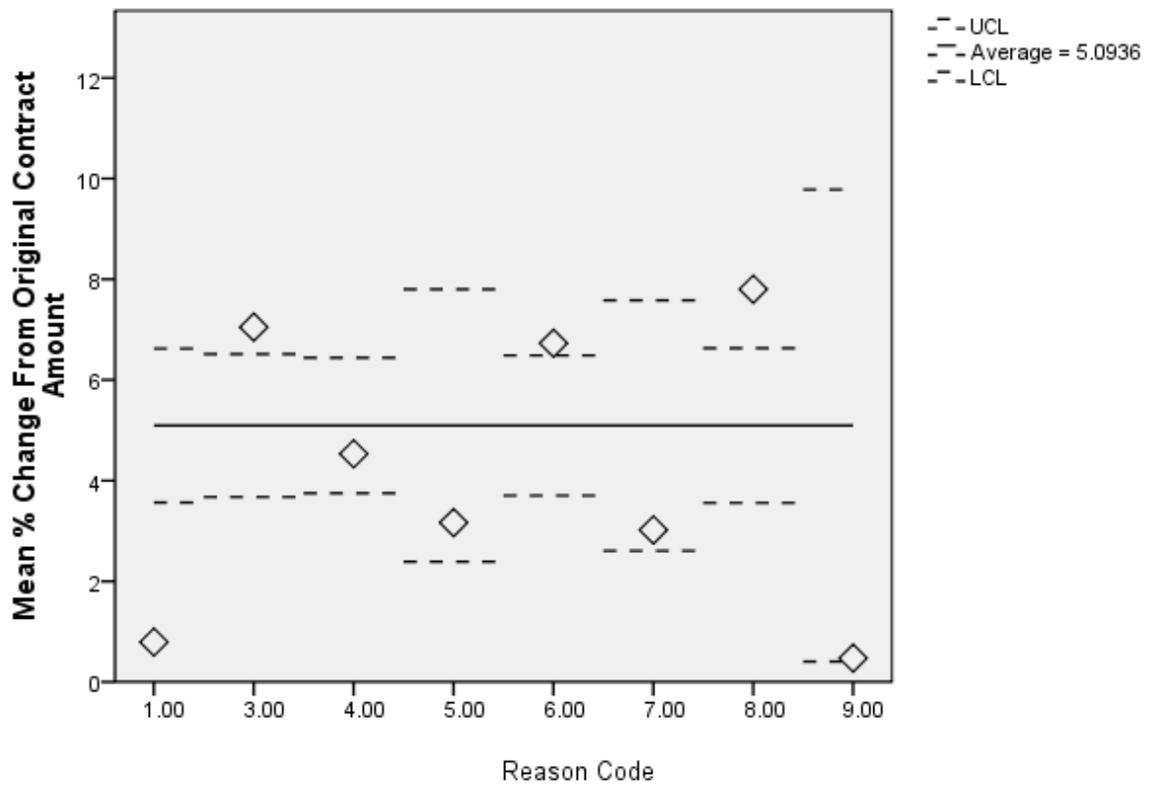


Figure F. 1 Overall Percent Change from Original Contract Amount

### Control Chart: Code1Change

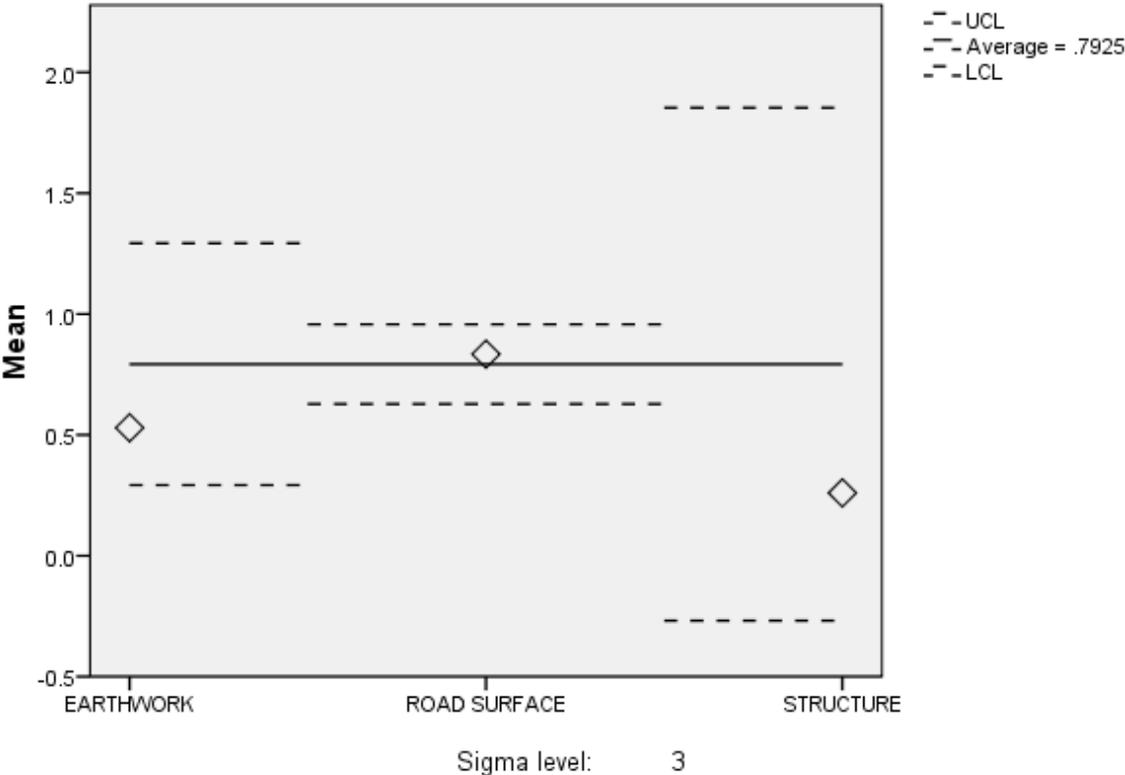
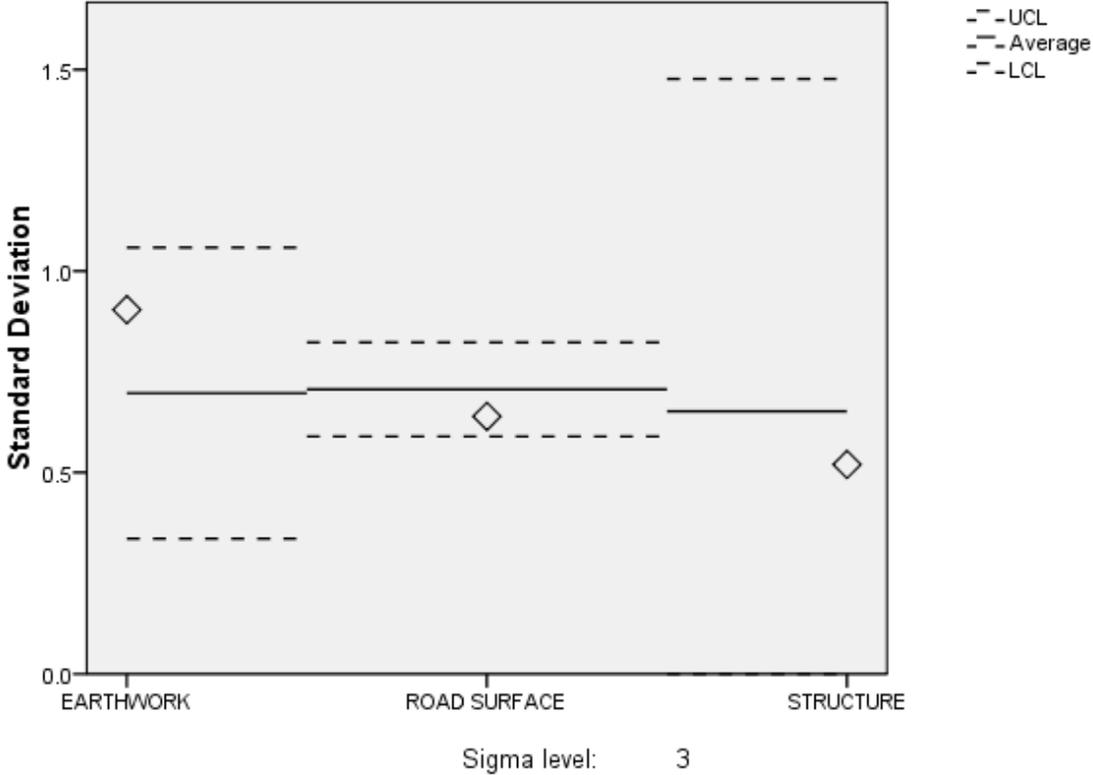


Figure F. 2 Sub - Code 1 Percent Change from Original Contract Amount by Construction Type

**Control Chart: Code1Change**



**Figure F.3 Sub - Code 1 Percent Change from Original Contract Amount by Construction Type – Standard Deviation**

### Control Chart: Code3Change

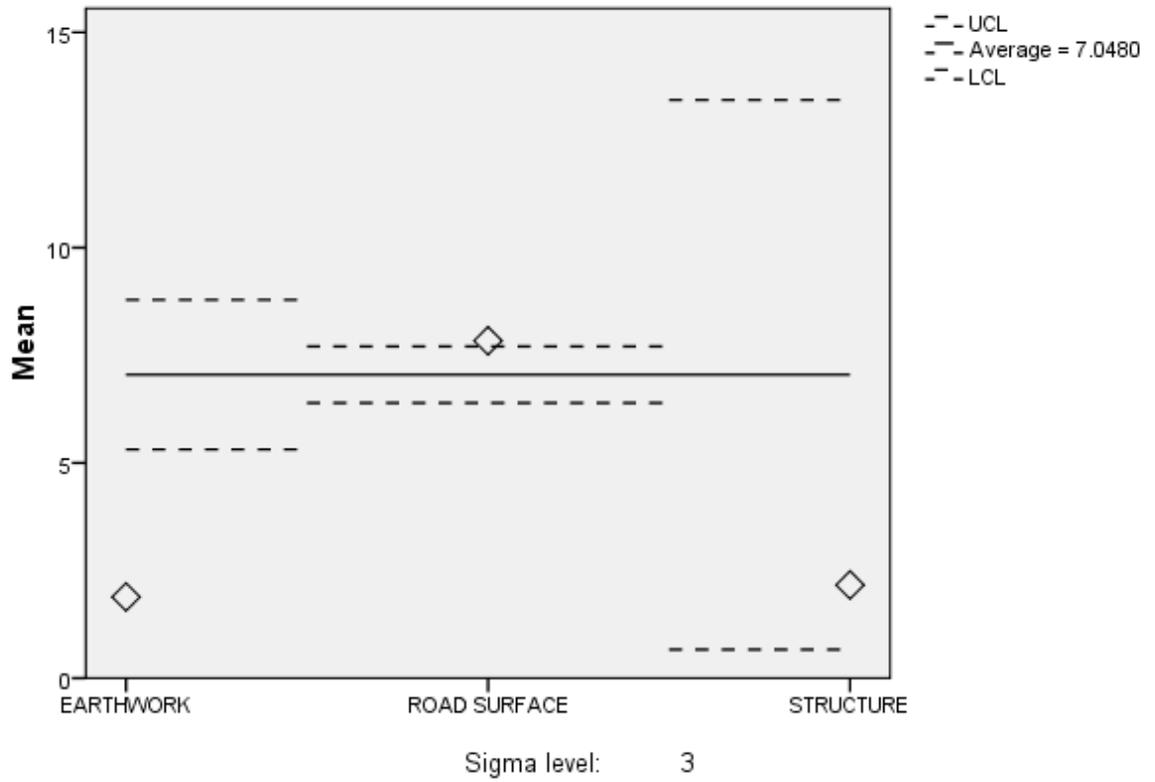


Figure F. 4 Sub - Code 3 Percent Change from Original Contract Amount by Construction Type

### Control Chart: Code3Change

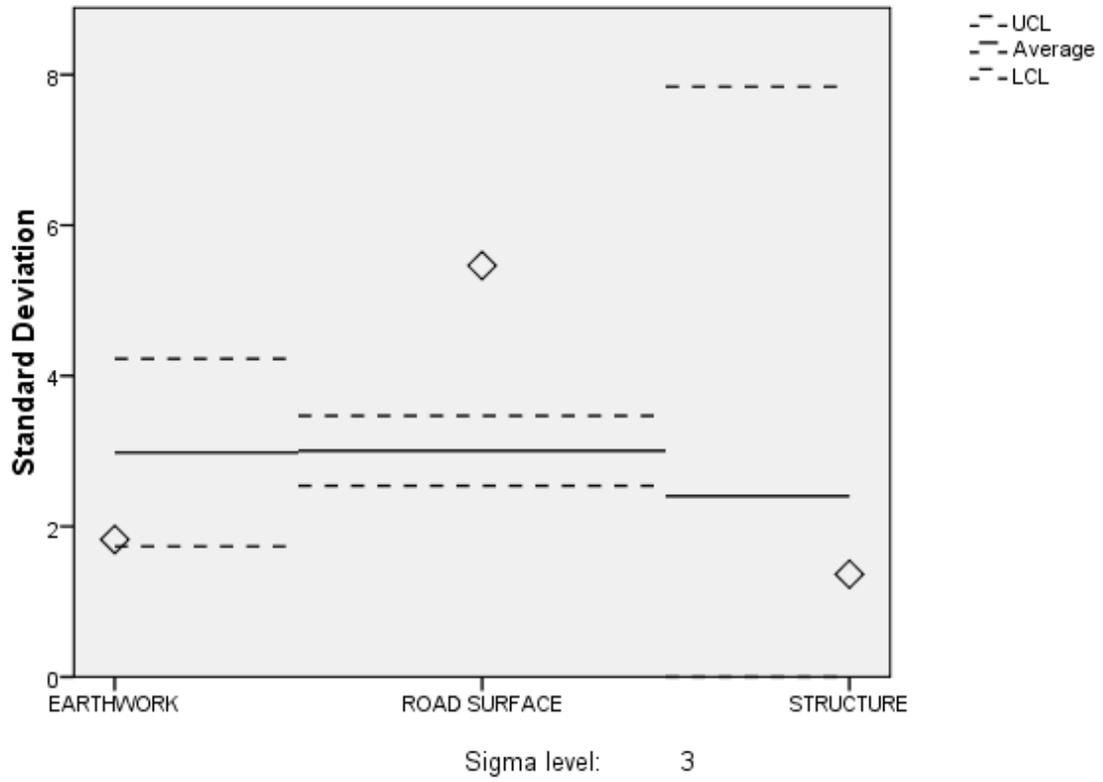


Figure F. 5 Sub - Code 3 Percent Change from Original Contract Amount by Construction Type – Standard Deviation

### Control Chart: Code4Change

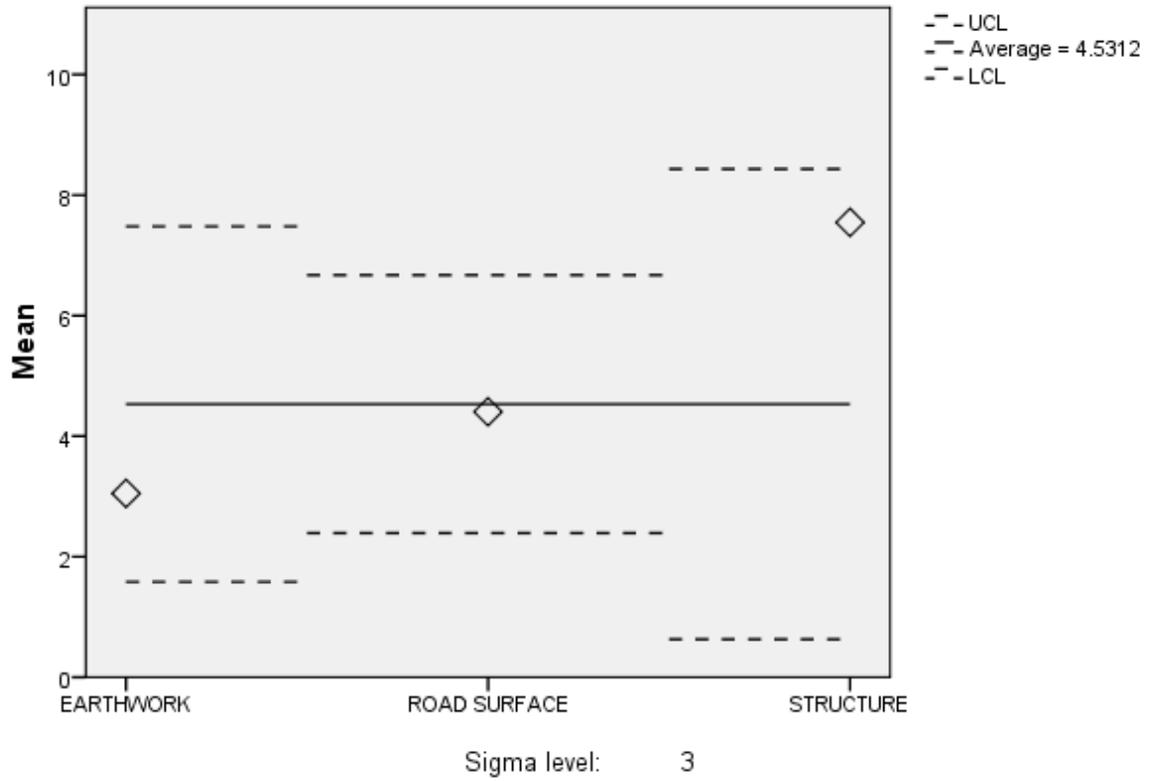


Figure F. 6 Sub - Code 4 Percent Change from Original Contract Amount by Construction Type

### Control Chart: Code4Change

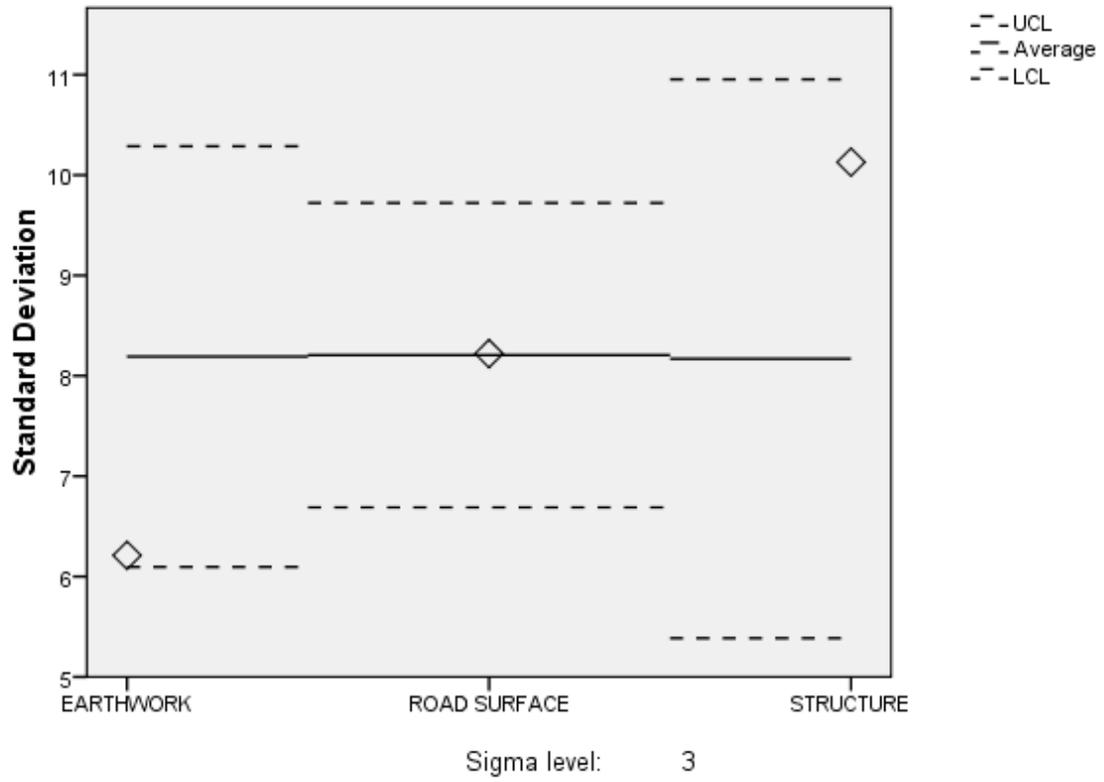


Figure F. 7 Sub - Code 4 Percent Change from Original Contract Amount by Construction Type – Standard Deviation

### Control Chart: Code5Change

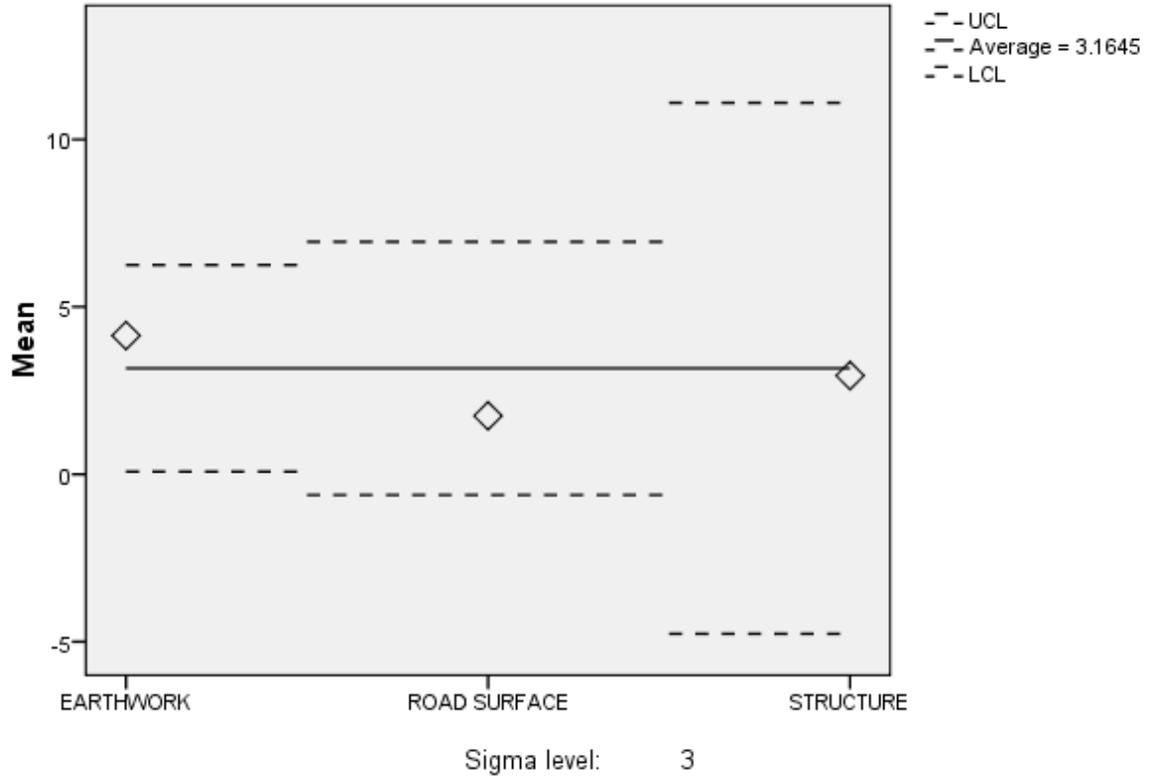


Figure F. 8 Sub - Code 5 Percent Change from Original Contract Amount by Construction Type

Control Chart: Code5Change

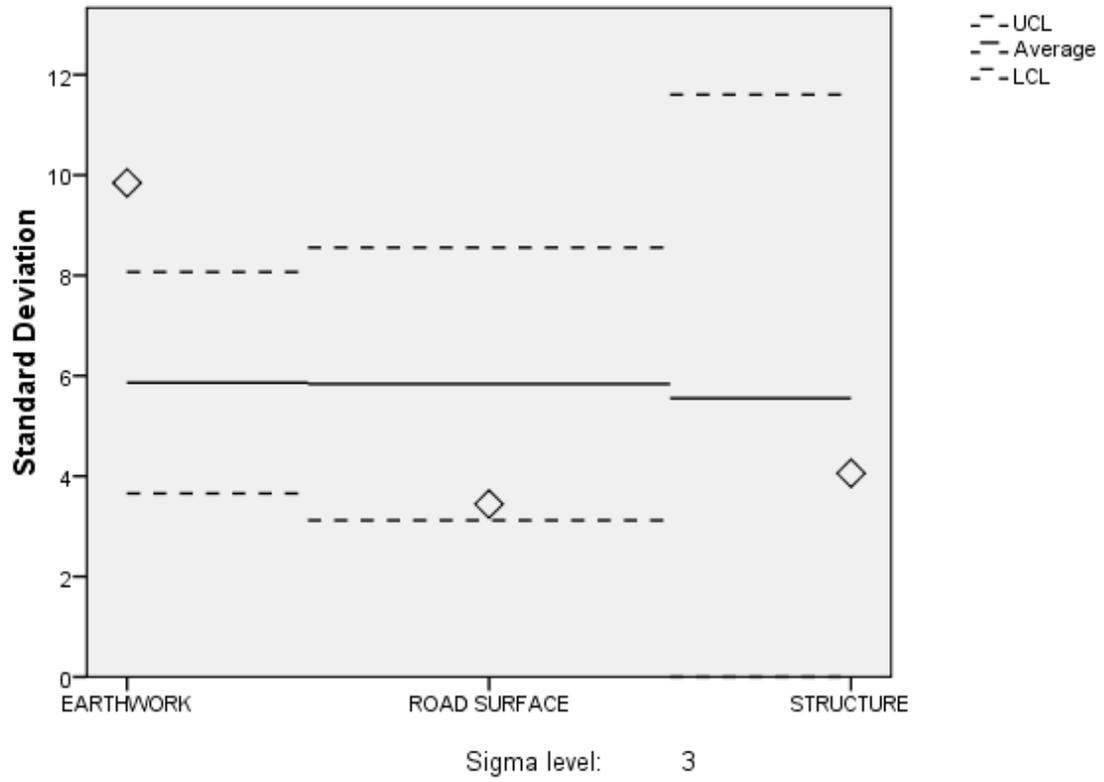


Figure F. 9 Sub - Code 5 Percent Change from Original Contract Amount by Construction Type – Standard Deviation

### Control Chart: Code6Change

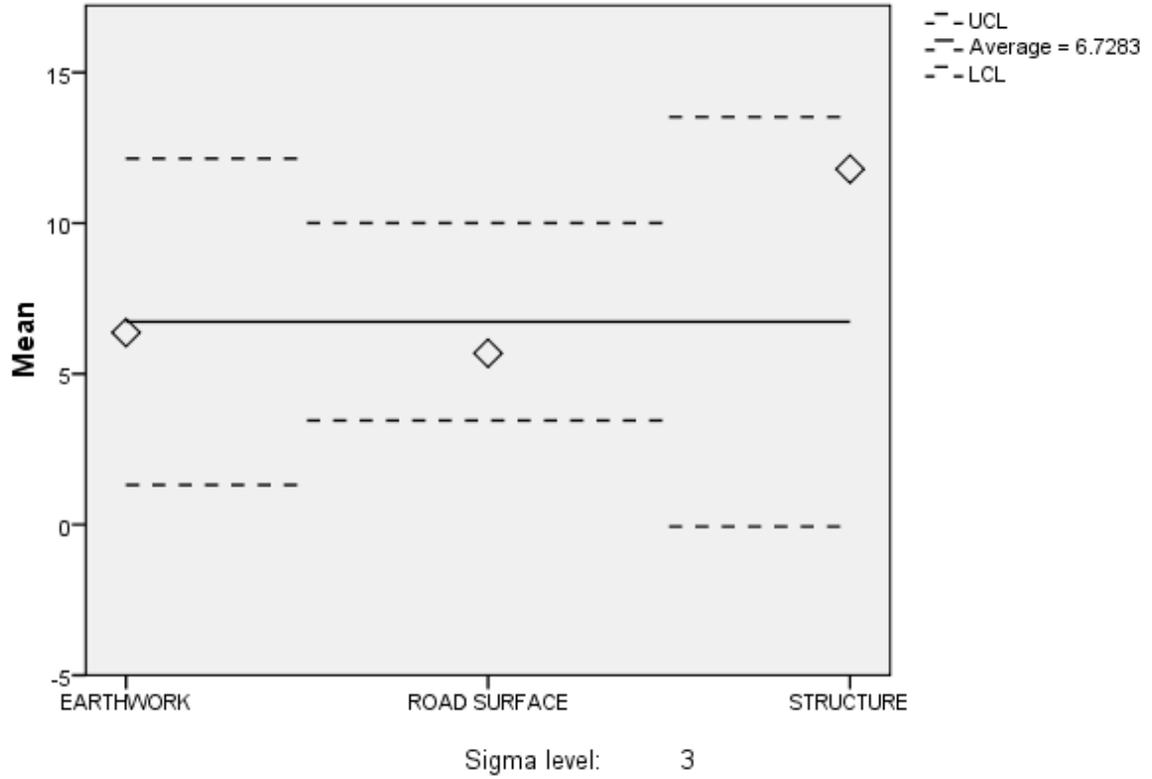


Figure F. 10 Sub - Code 6 Percent Change from Original Contract Amount by Construction Type

### Control Chart: Code6Change

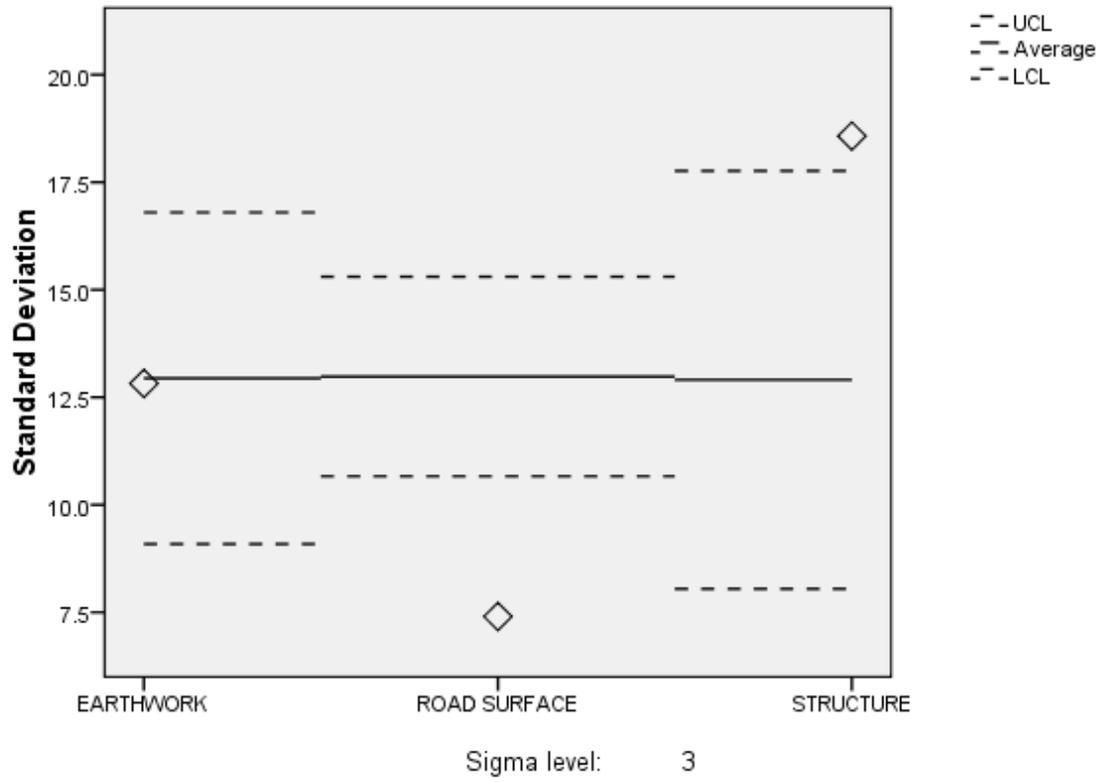


Figure F. 11 Sub - Code 6 Percent Change from Original Contract Amount by Construction Type – Standard Deviation

### Control Chart: Code7Change

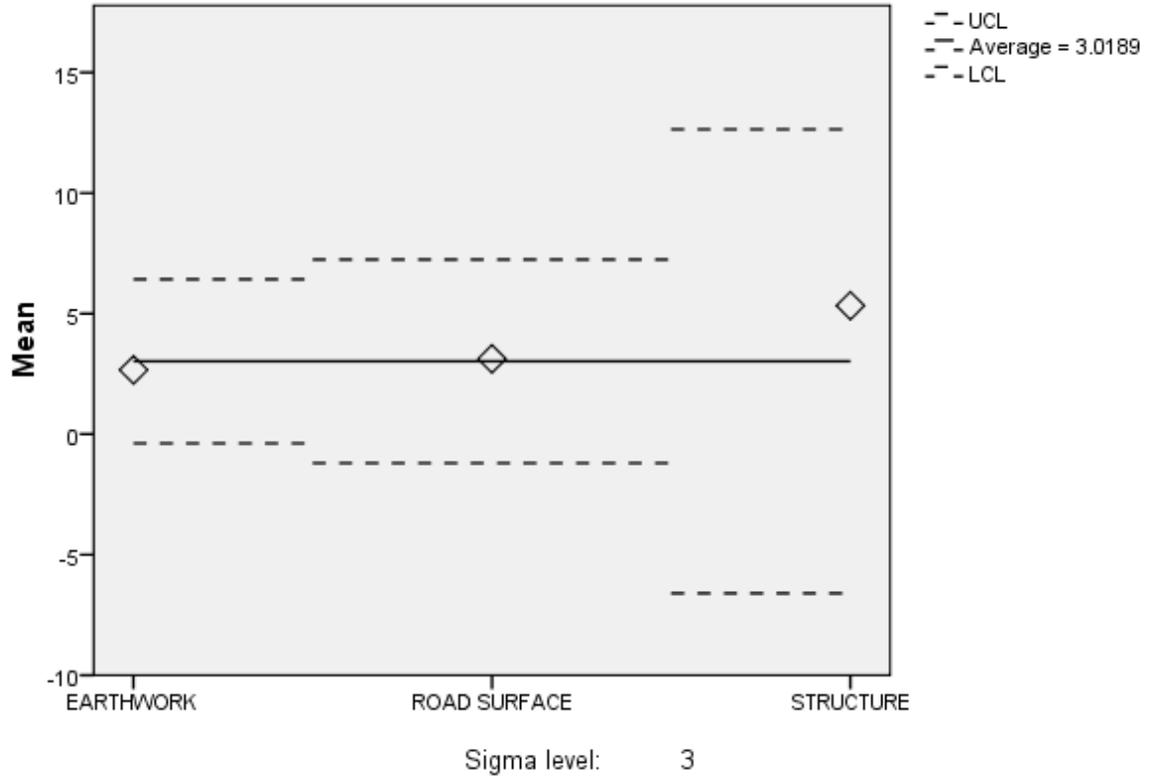


Figure F. 12 Sub - Code 7 Percent Change from Original Contract Amount by Construction Type

Control Chart: Code7Change

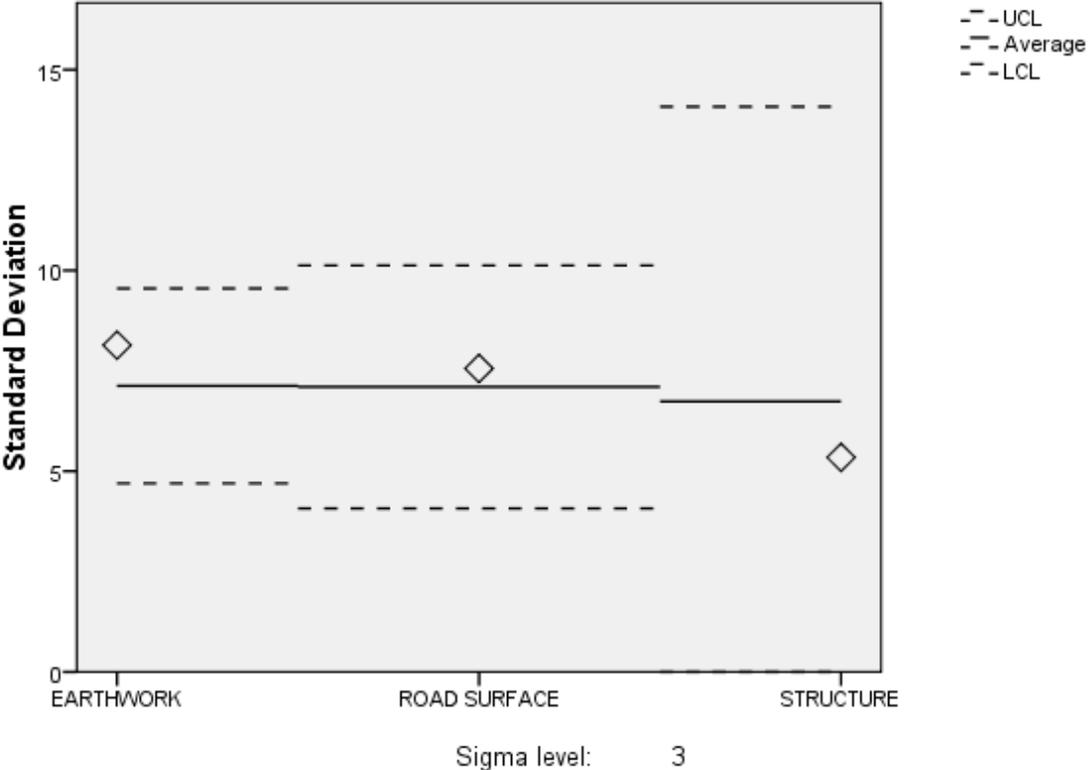


Figure F. 13 Sub - Code 7 Percent Change from Original Contract Amount by Construction Type – Standard Deviation

### Control Chart: Code8Change

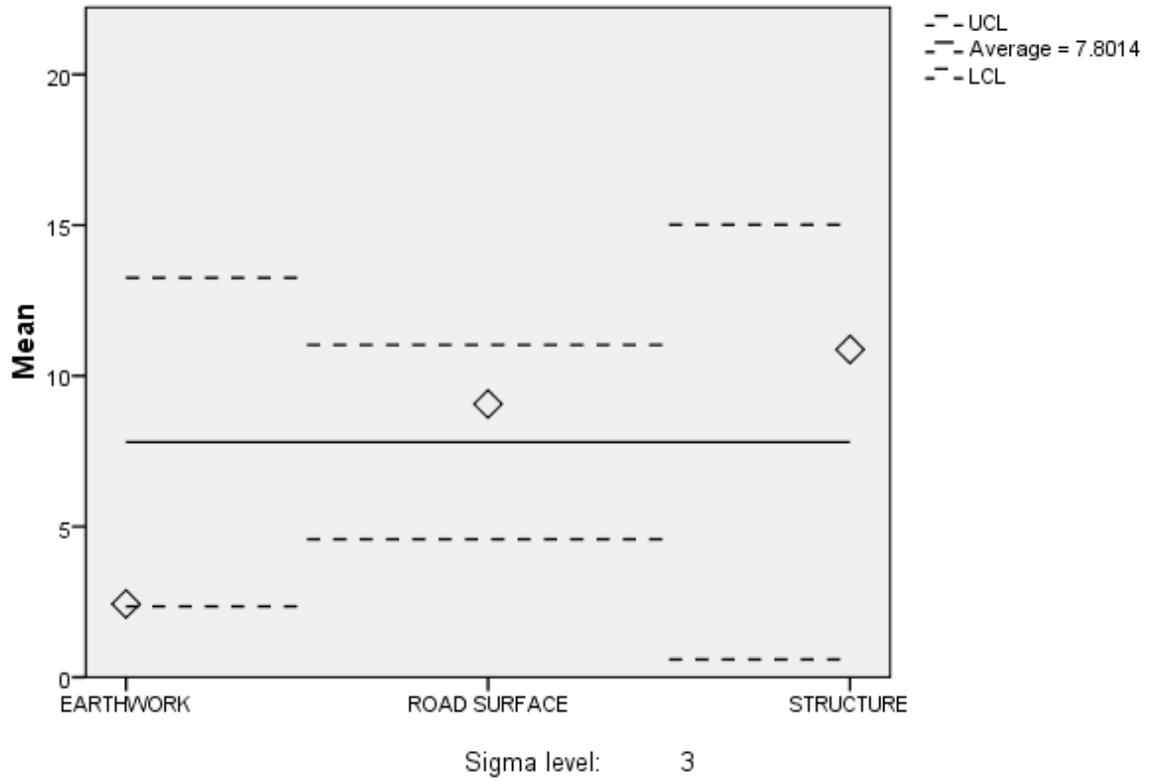


Figure F. 14 Sub - Code 8 Percent Change from Original Contract Amount by Construction Type

Control Chart: Code8Change

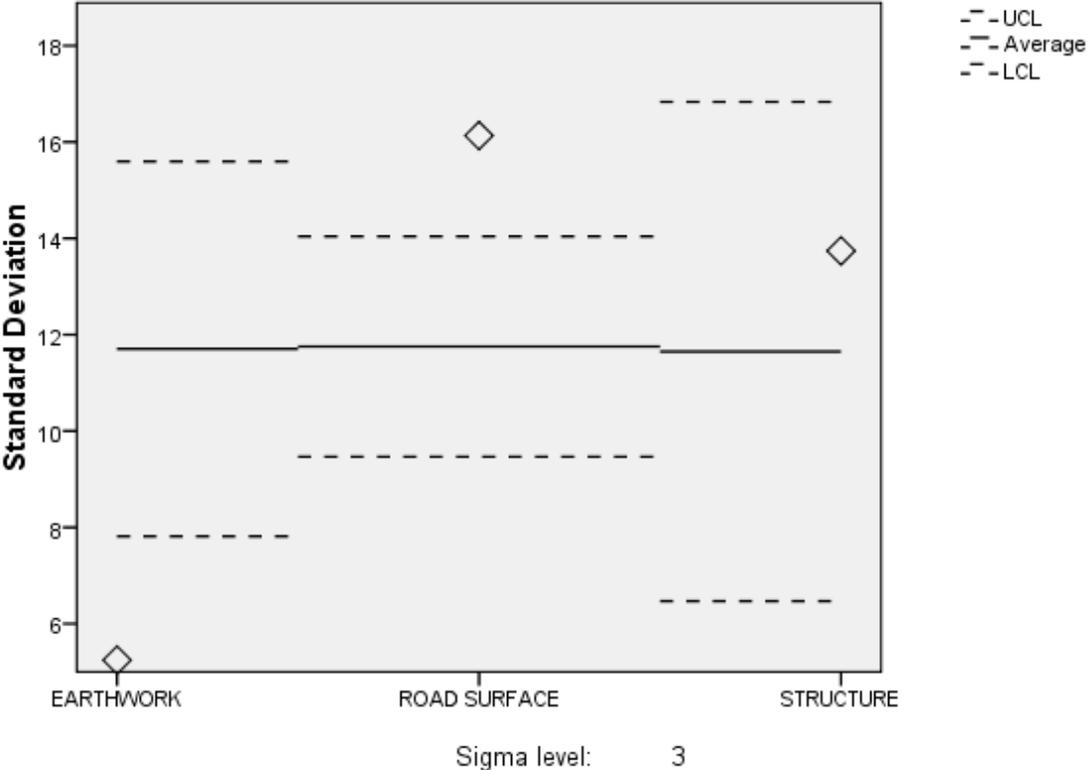


Figure F. 15 Sub - Code 8 Percent Change from Original Contract Amount by Construction Type – Standard Deviation

### Control Chart: Code9Change

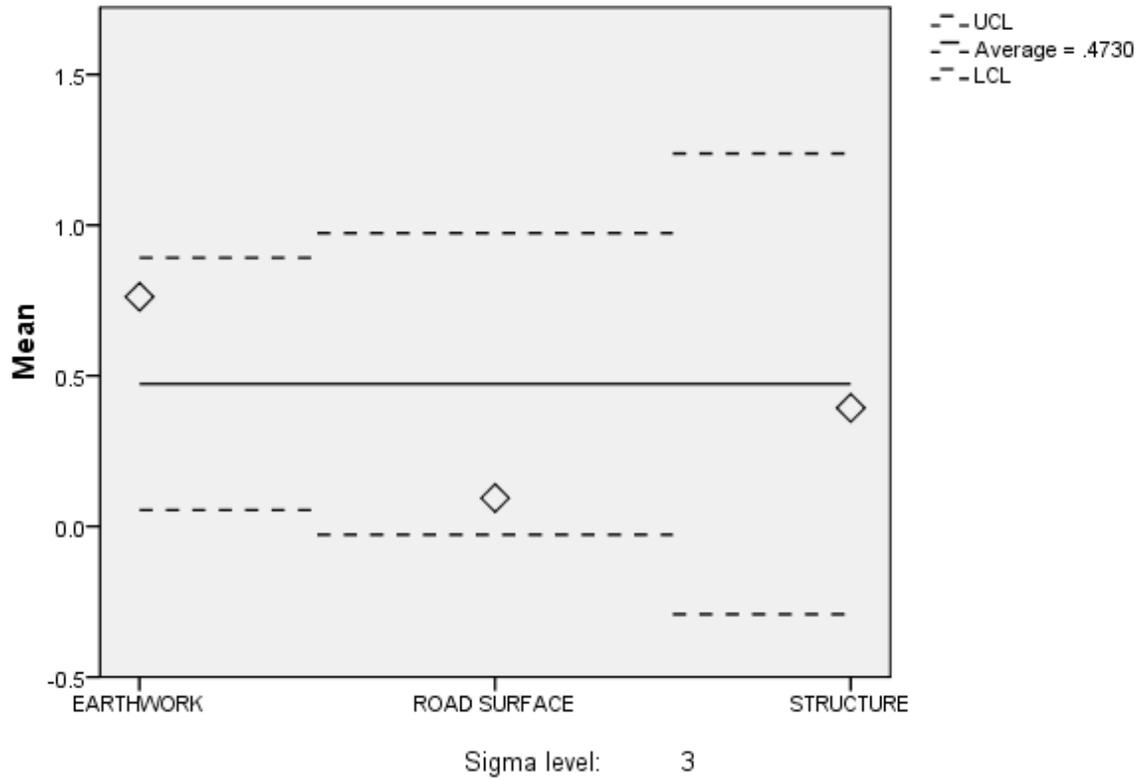


Figure F. 16 Sub - Code 9 Percent Change from Original Contract Amount by Construction Type

### Control Chart: Code9Change

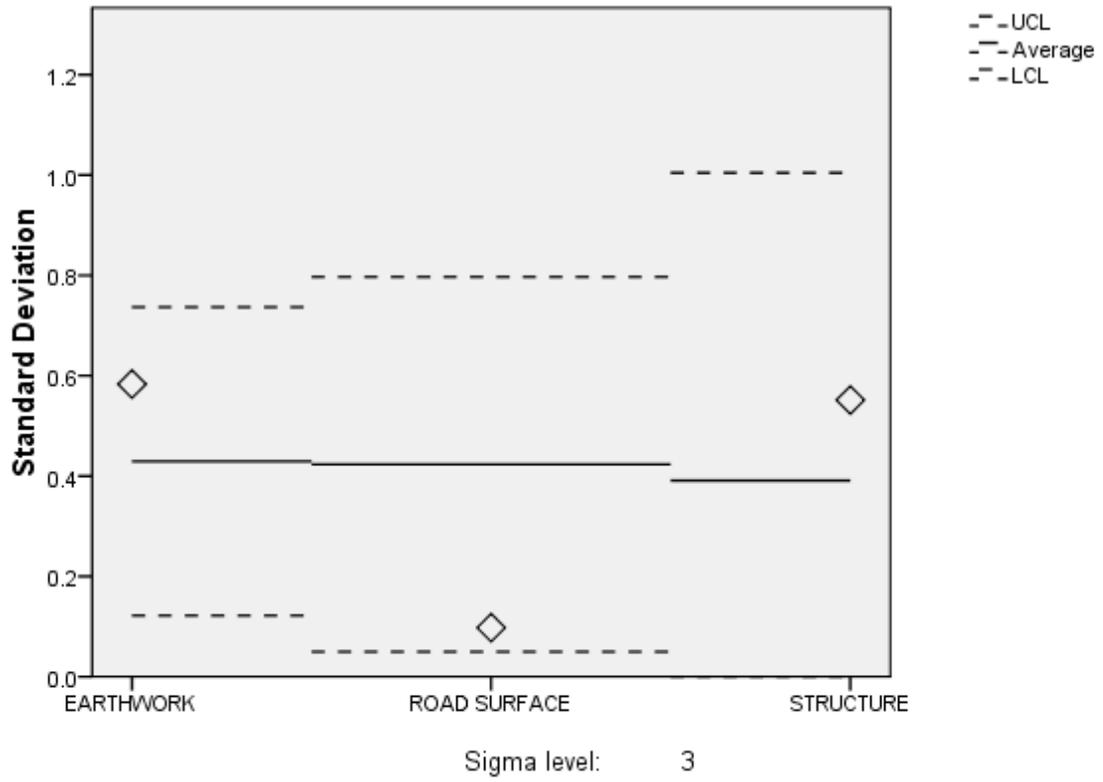


Figure F. 17 Sub - Code 9 Percent Change from Original Contract Amount by Construction Type – Standard Deviation

## **14.0 Appendix G: Control Charts - Impact by Road Type**

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Control Chart: Impact\_1through9

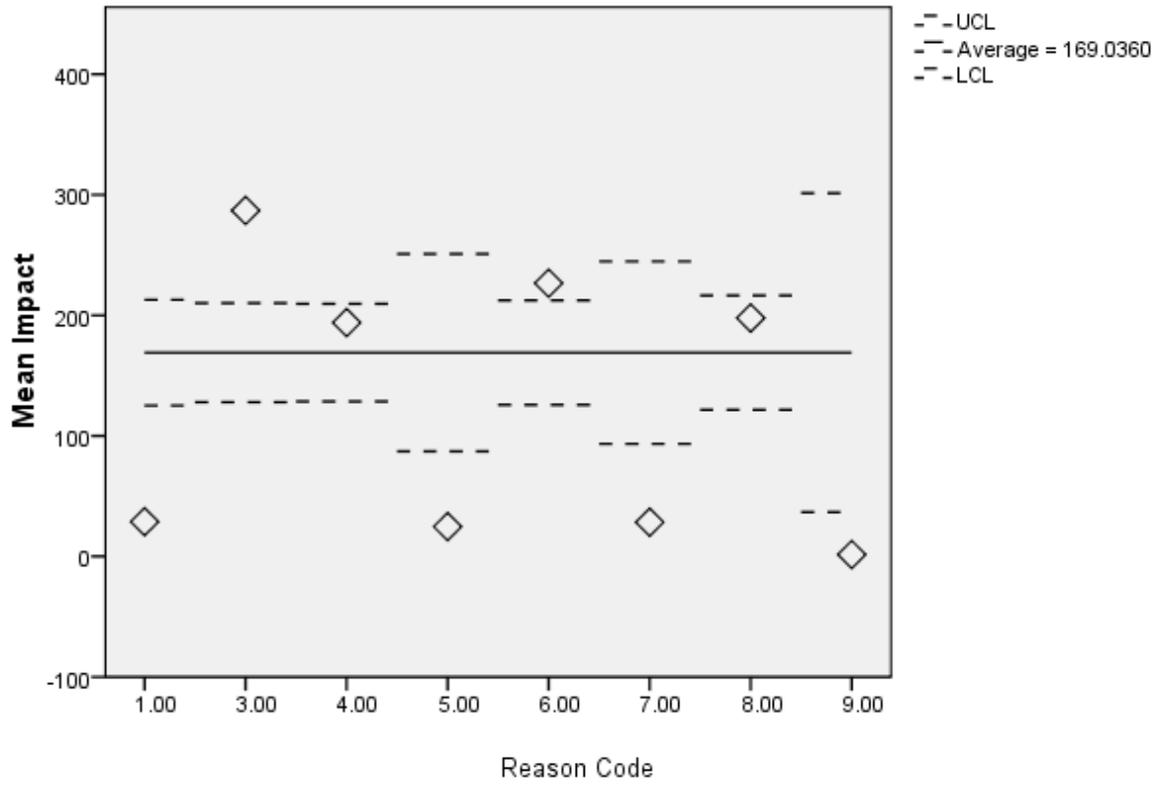


Figure G. 1 Overall Impact

### Control Chart: Impact\_1

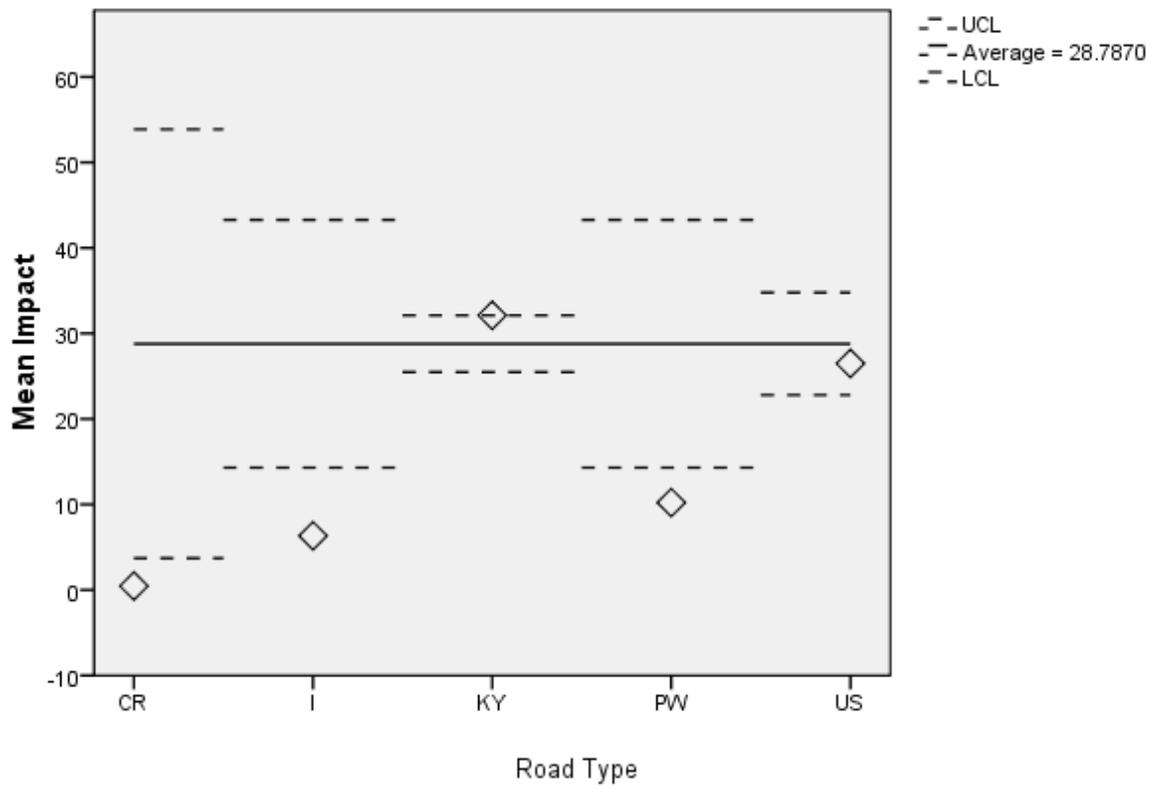


Figure G.2 Sub - Code 1 Impact by Road Type

Control Chart: Impact\_1

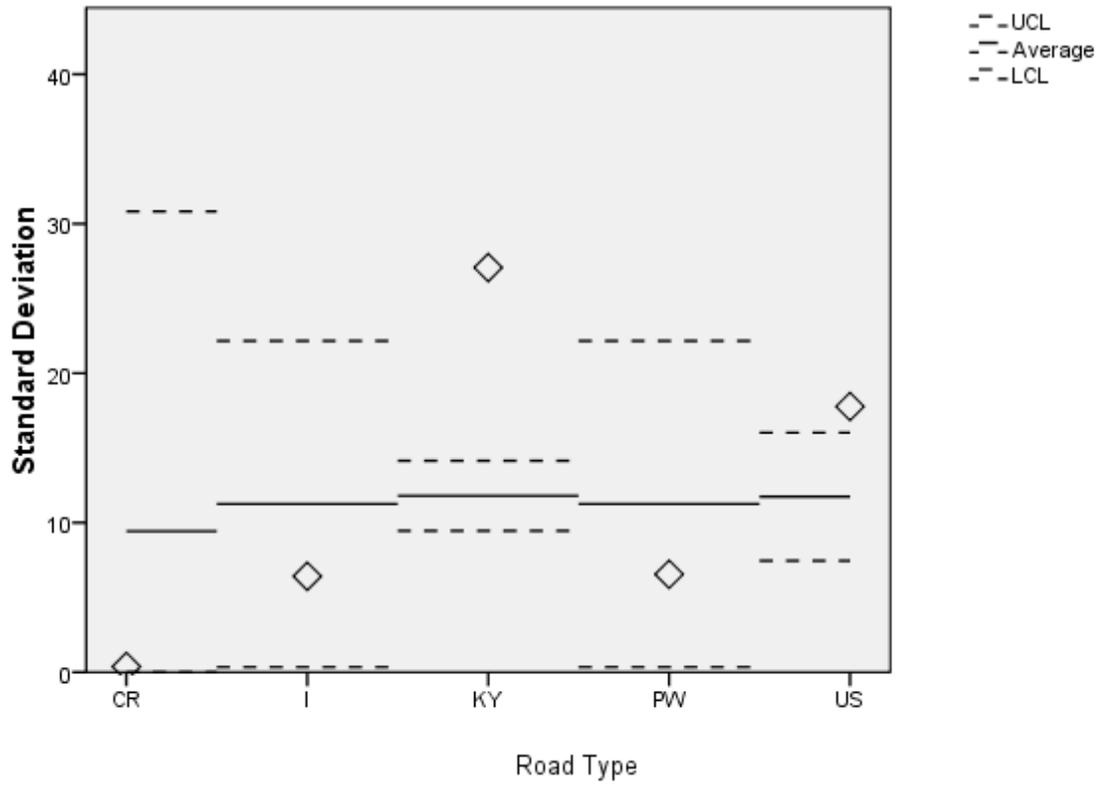


Figure G.3 Sub - Code 1 Impact by Road Type – Standard Deviation

### Control Chart: Impact\_3

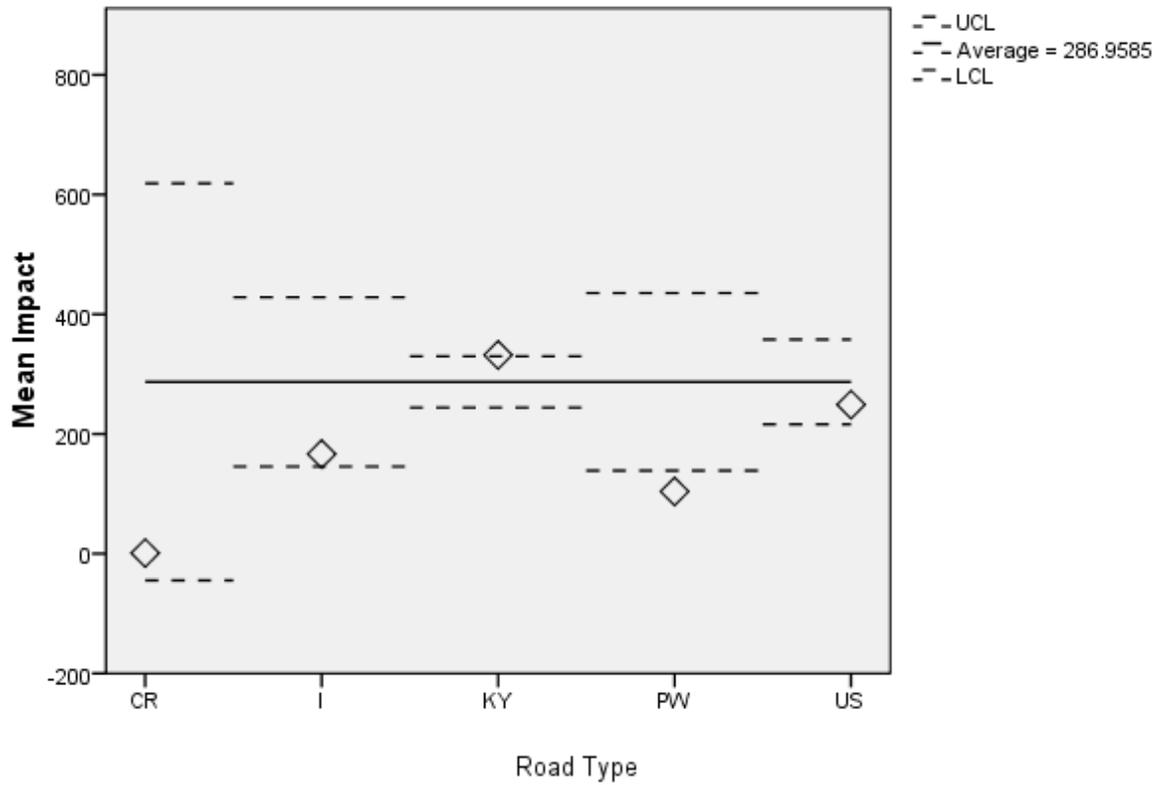


Figure G. 4 Sub - Code 3 Impact by Road Type

Control Chart: Impact\_3

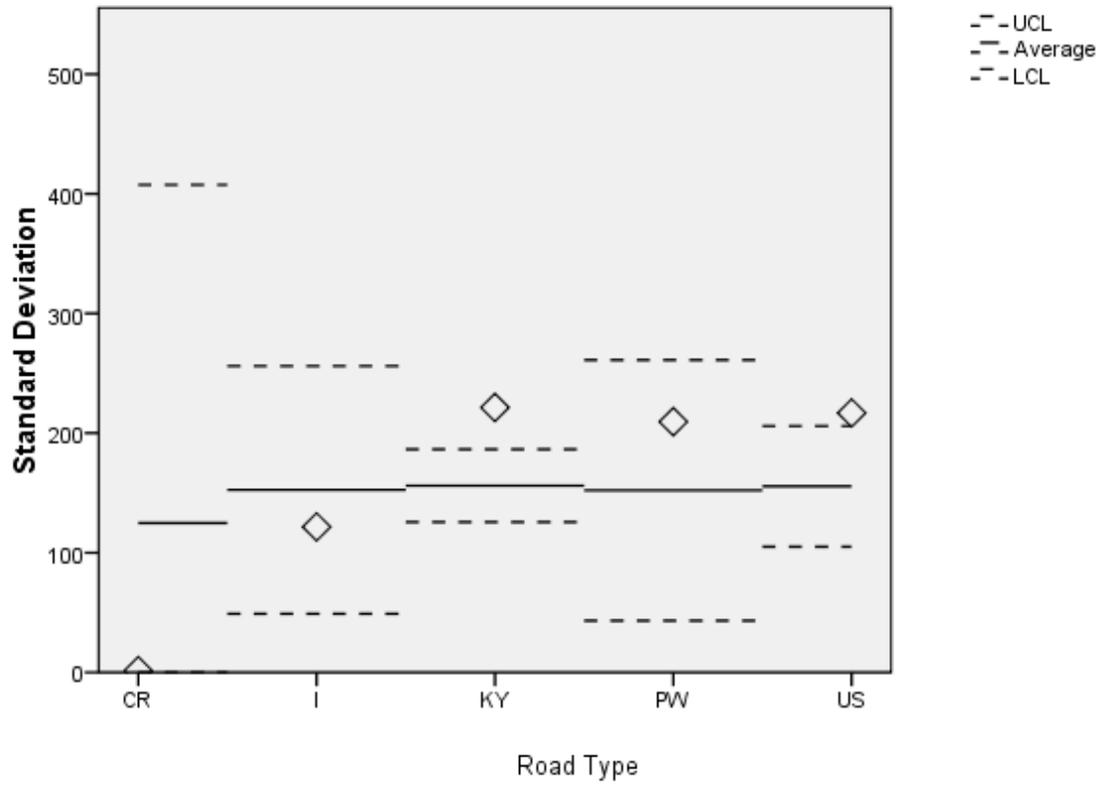


Figure G. 5 Sub - Code 3 Impact by Road Type – Standard Deviation

Control Chart: Impact\_4

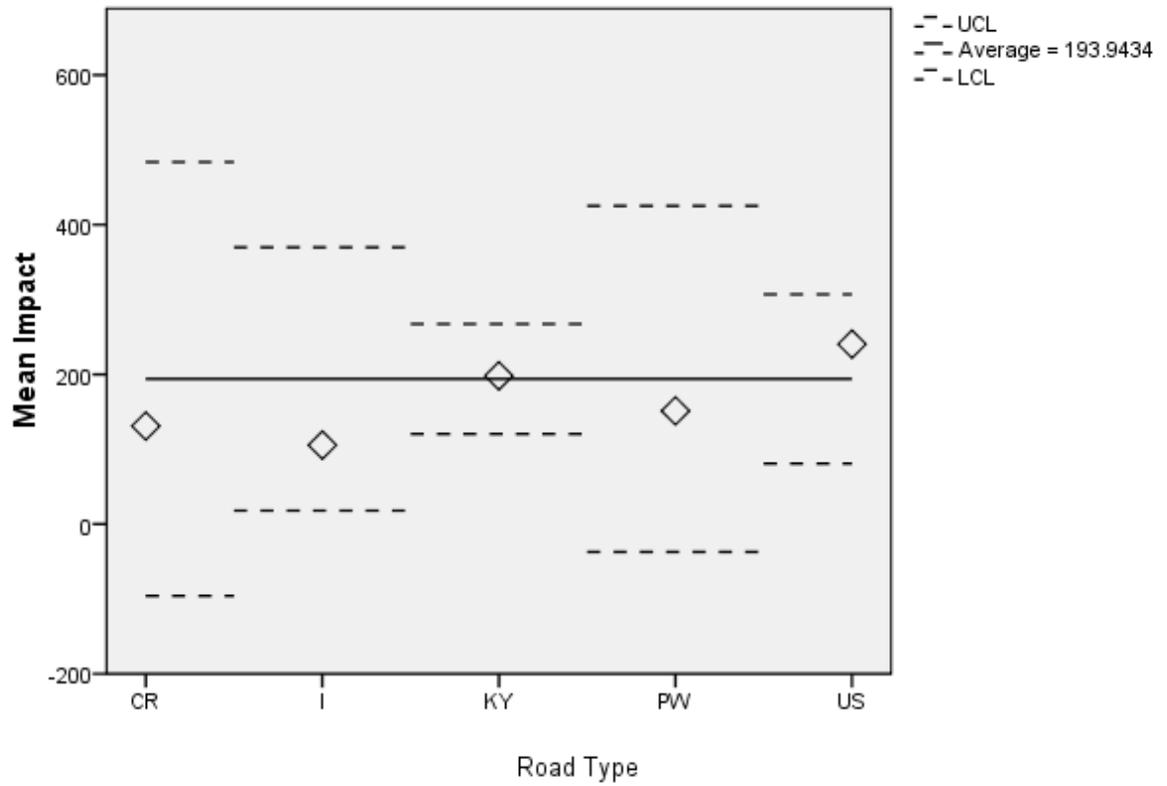


Figure G. 6 Sub - Code 4 Impact by Road Type

Control Chart: Impact\_4

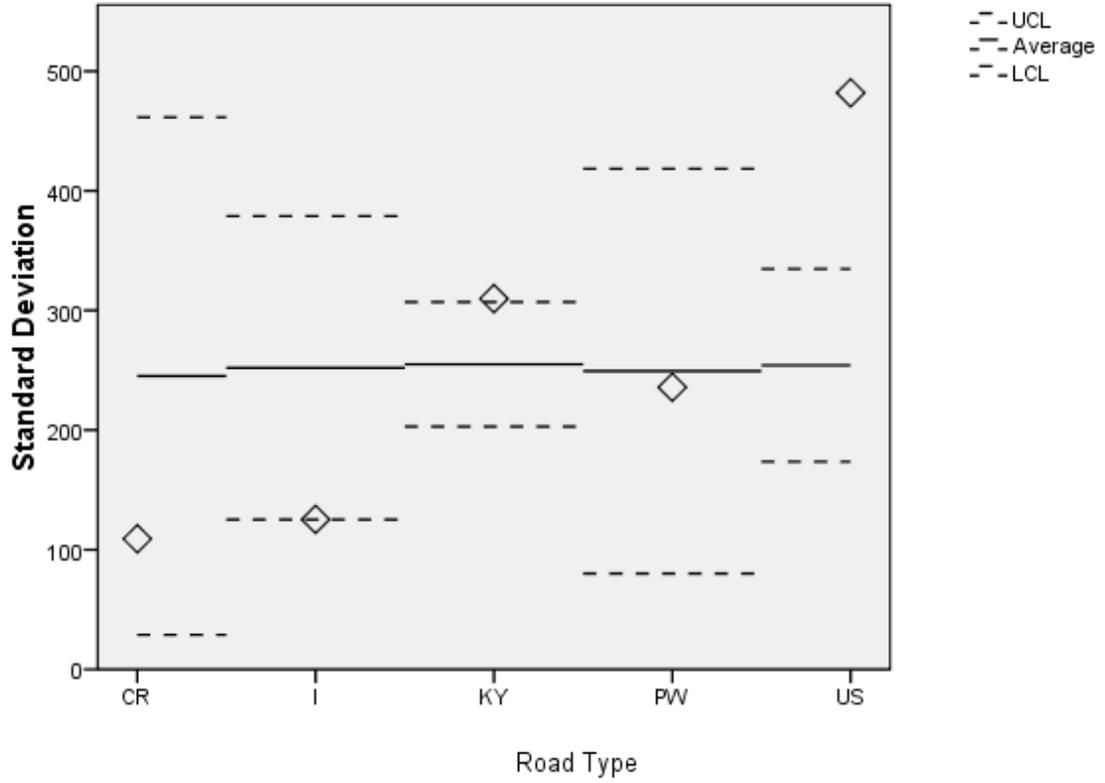


Figure G. 7 Sub - Code 4 Impact by Road Type – Standard Deviation

### Warnings

One or more subgroups do not contain the minimum sample size required and have been excluded from the analysis.

### Control Chart: Impact\_5

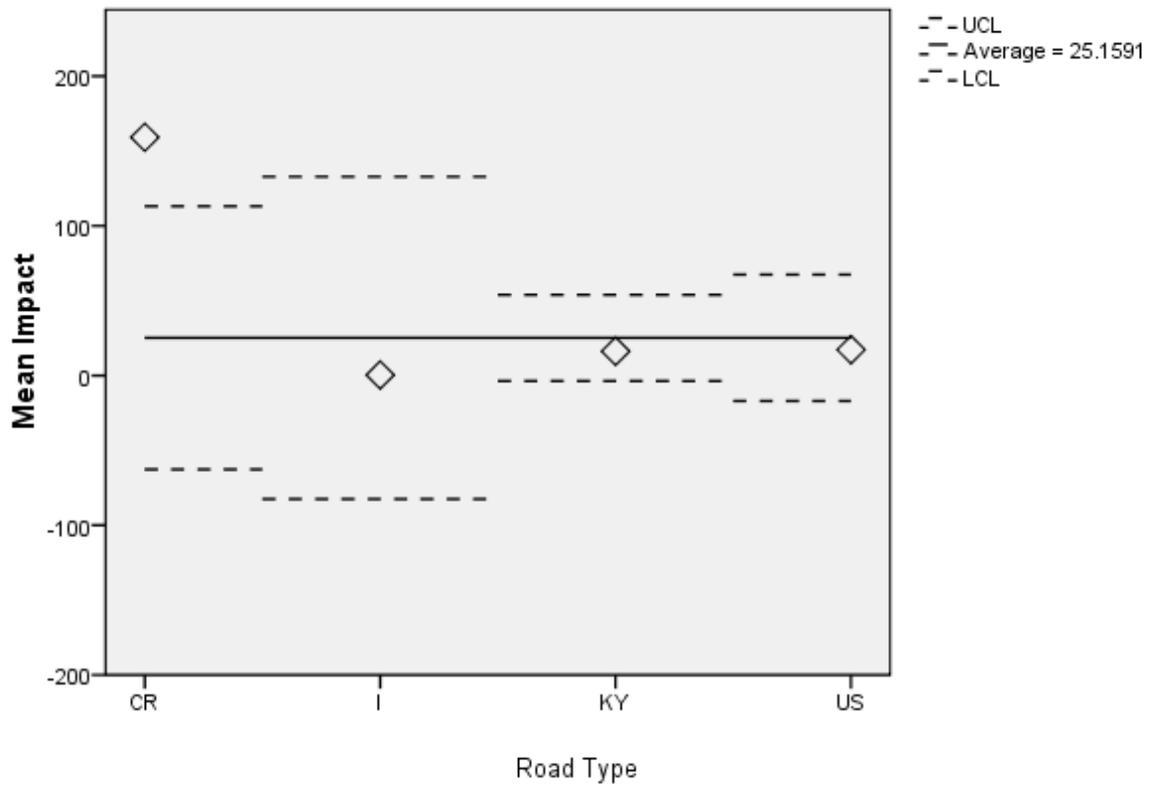


Figure G. 8 Sub - Code 5 Impact by Road Type

Control Chart: Impact\_5

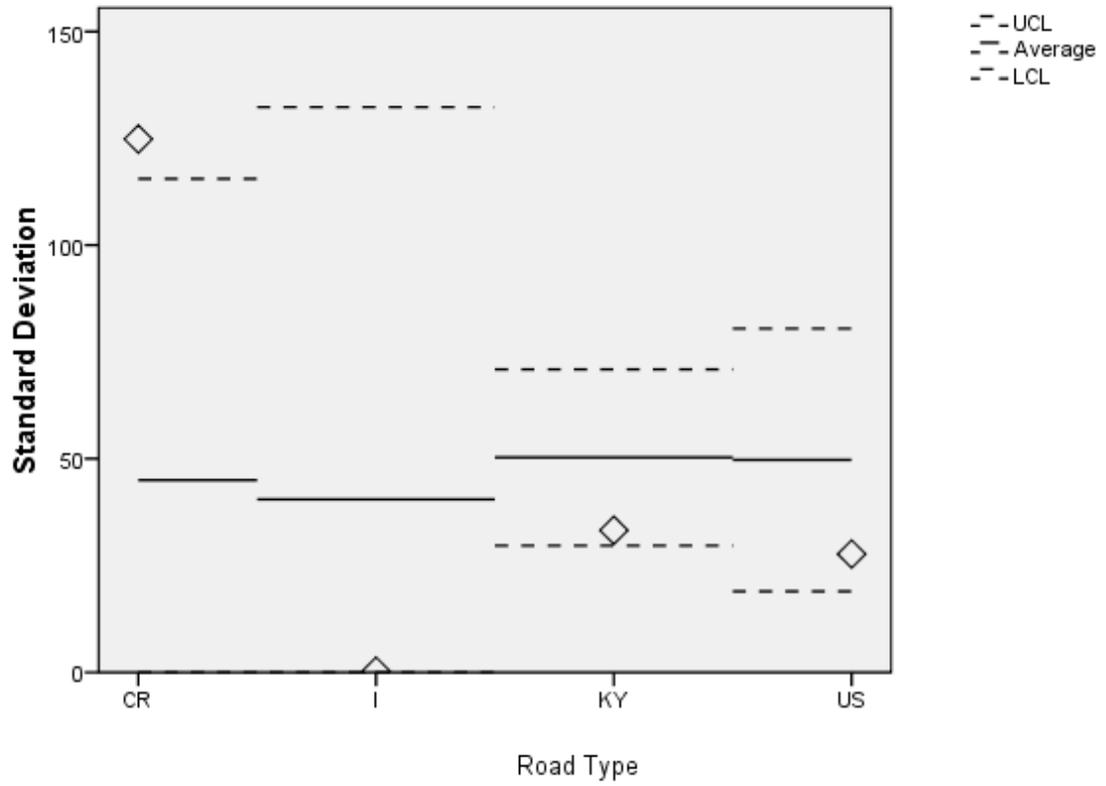


Figure G. 9 Sub - Code 5 Impact by Road Type – Standard Deviation

Control Chart: Impact\_6

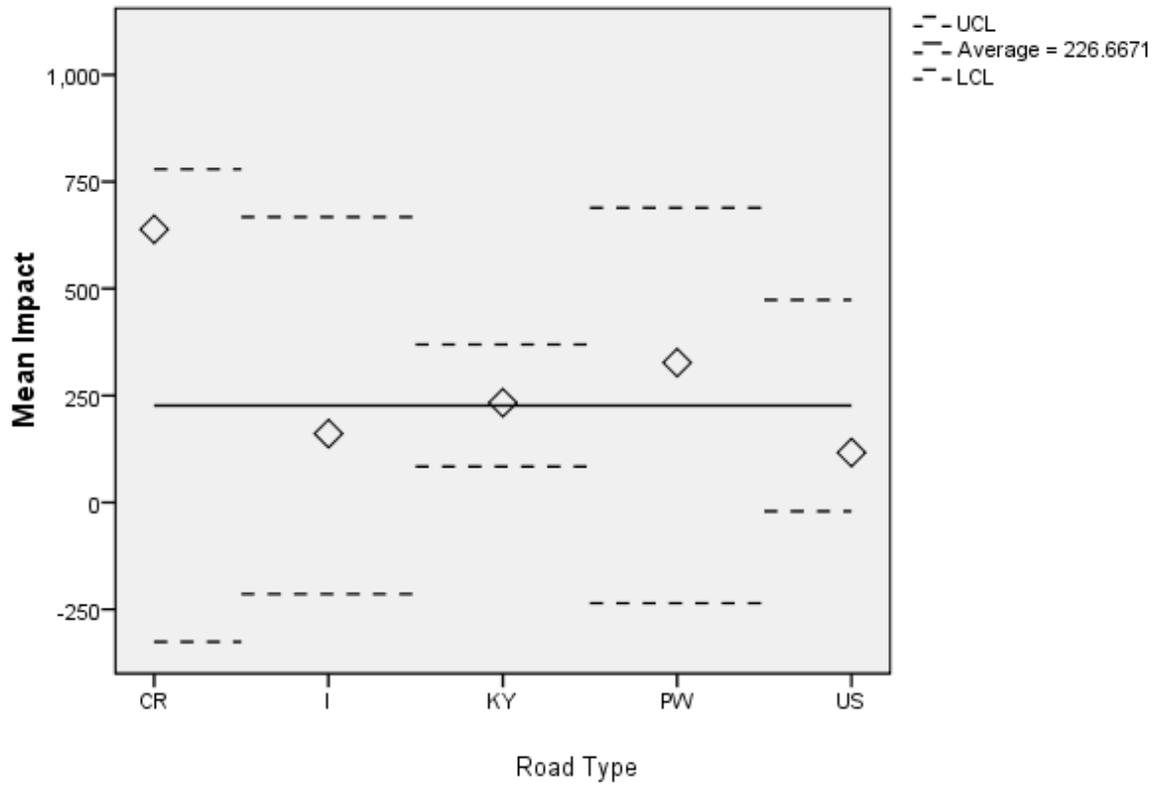


Figure G. 10 Sub - Code 6 Impact by Road Type

Control Chart: Impact\_6

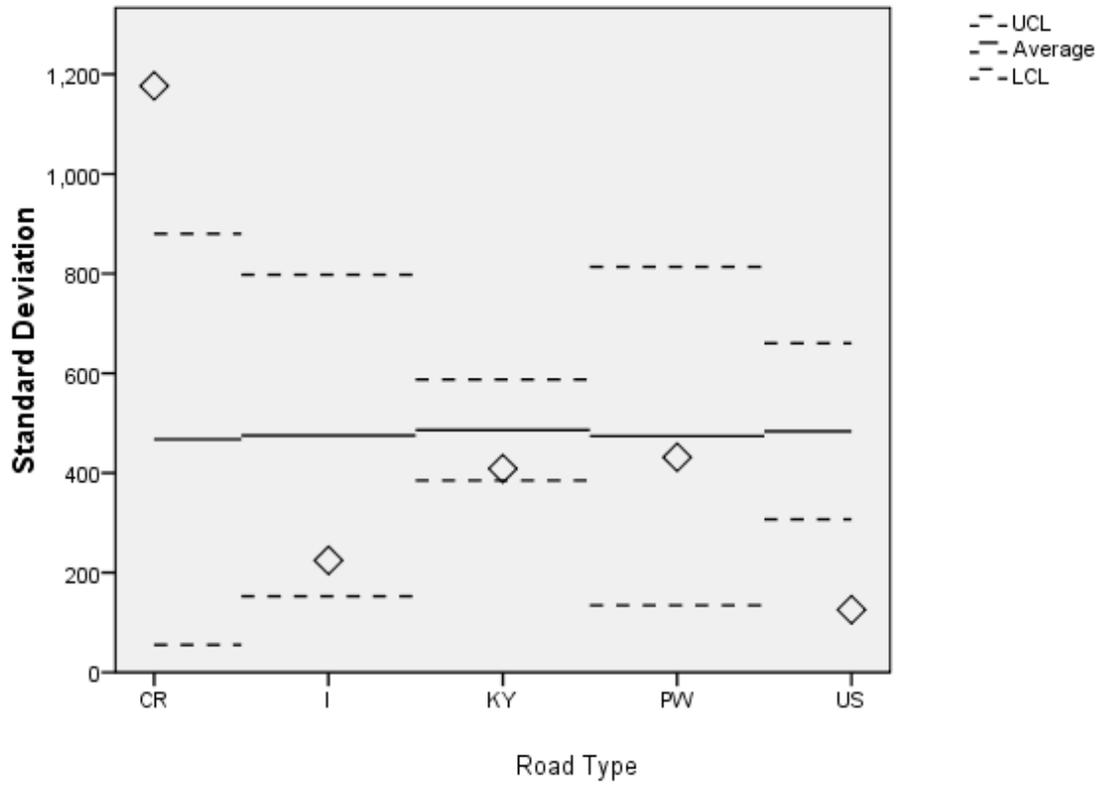


Figure G. 11 Sub - Code 6 Impact by Road Type – Standard Deviation

### Warnings

One or more subgroups do not contain the minimum sample size required and have been excluded from the analysis.

### Control Chart: Impact\_7

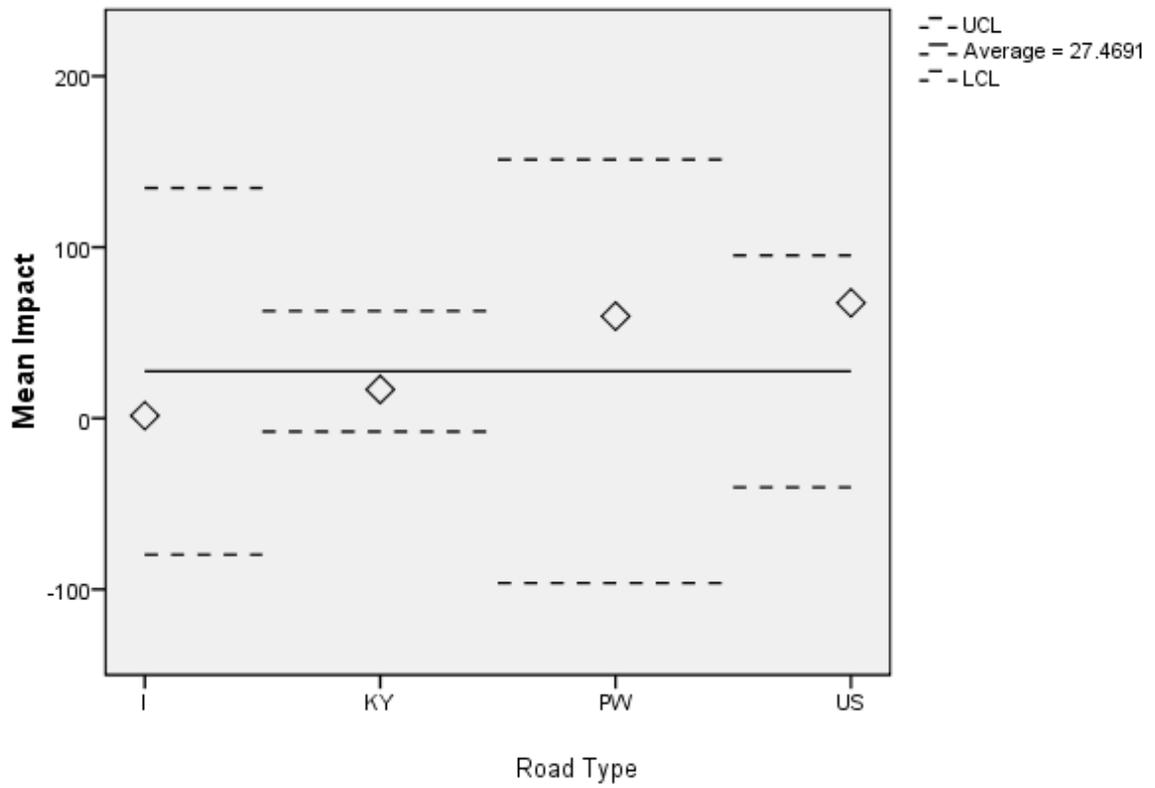


Figure G. 12 Sub - Code 7 Impact by Road Type

Control Chart: Impact\_7

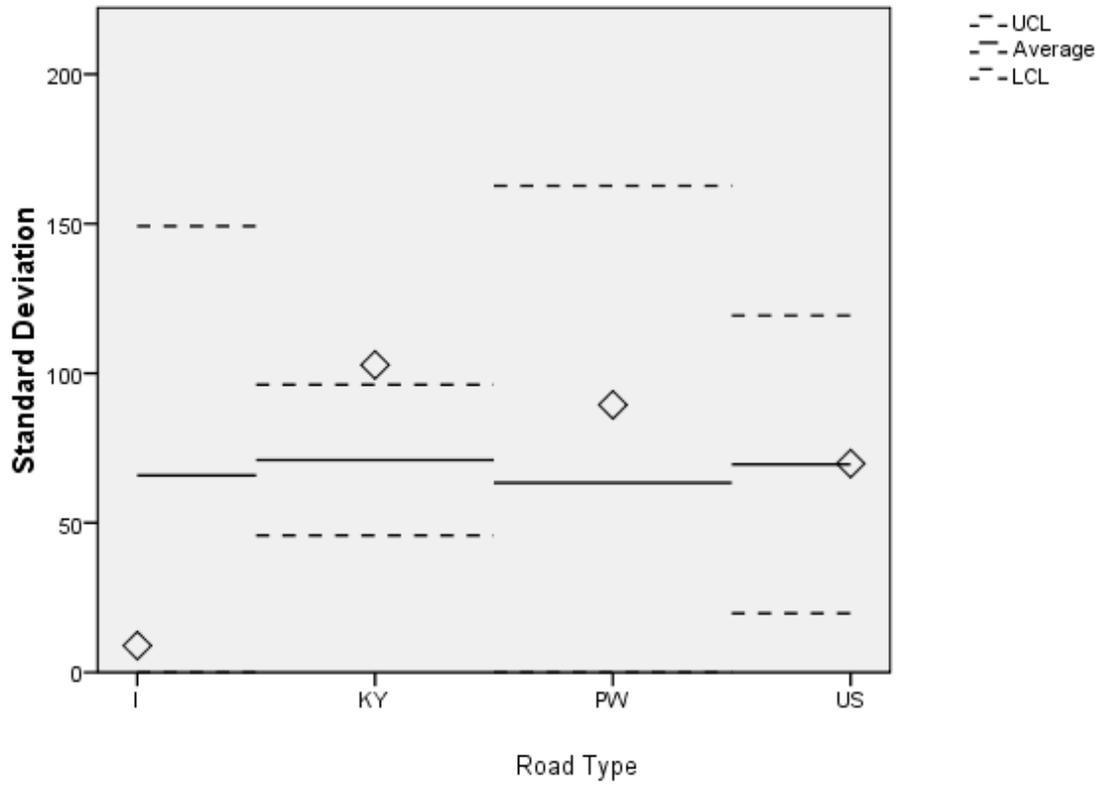


Figure G. 13 Sub - Code 7 Impact by Road Type – Standard Deviation

Control Chart: Impact\_8

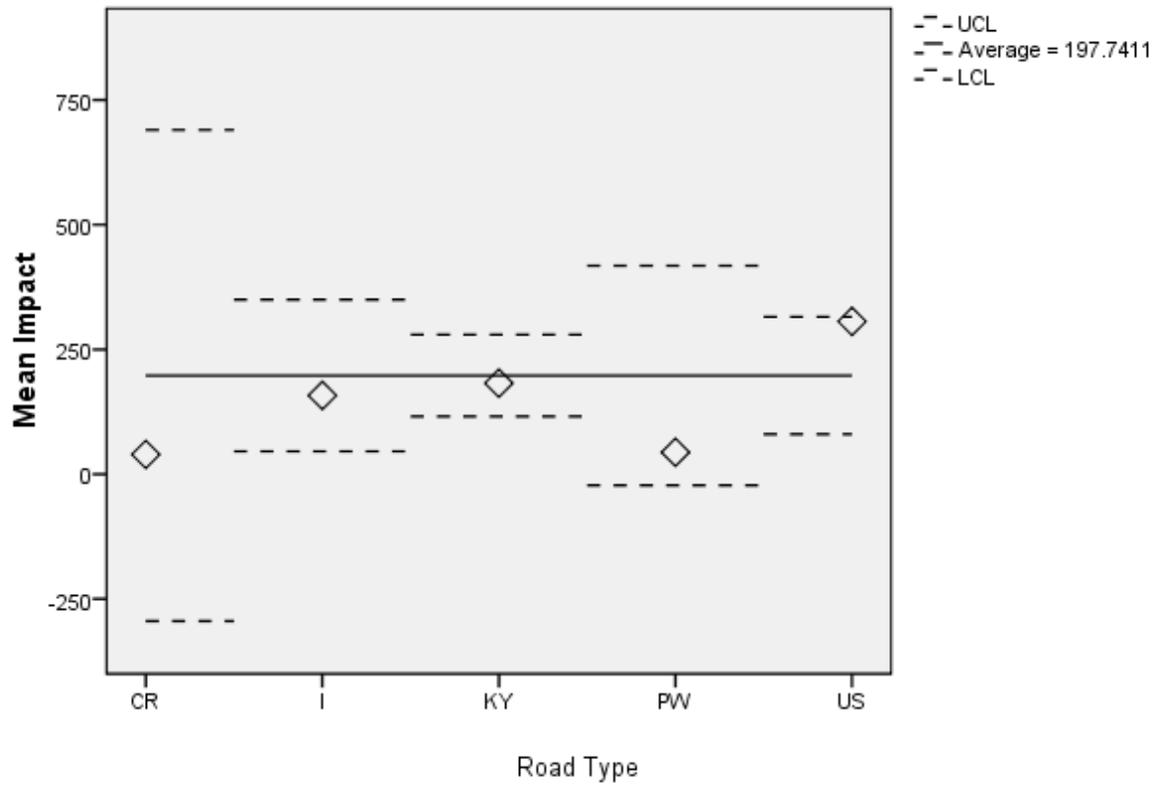


Figure G. 14 Sub - Code 8 Impact by Road Type

Control Chart: Impact\_8

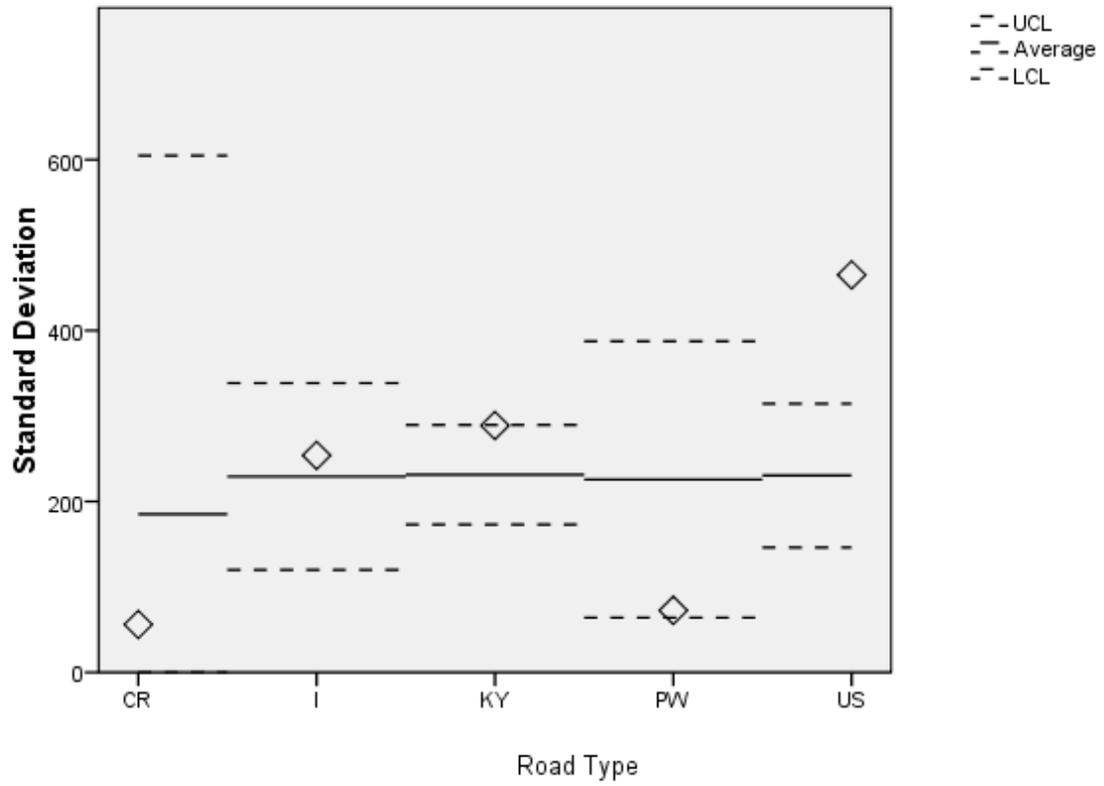


Figure G. 15 Sub - Code 8 Impact by Road Type – Standard Deviation

### Warnings

One or more subgroups do not contain the minimum sample size required and have been excluded from the analysis.

### Control Chart: Impact\_9

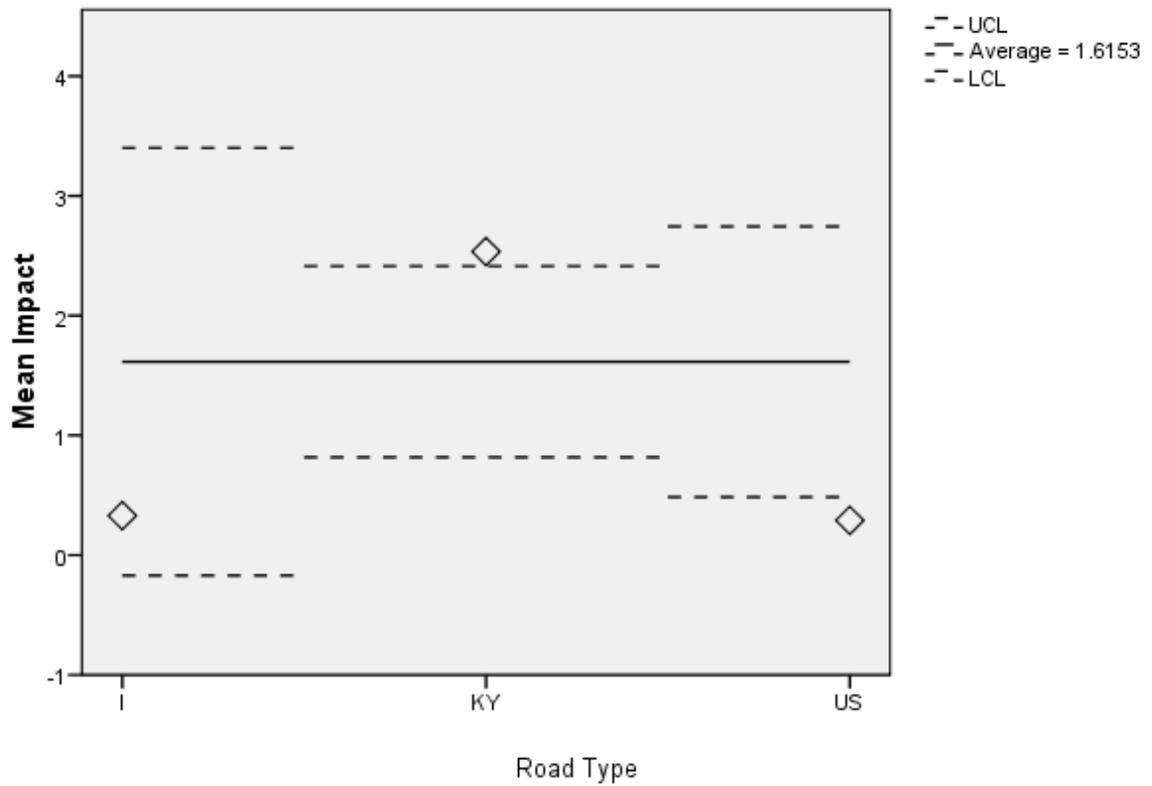


Figure G. 16 Sub - Code 9 Impact by Road Type

Control Chart: Impact\_9

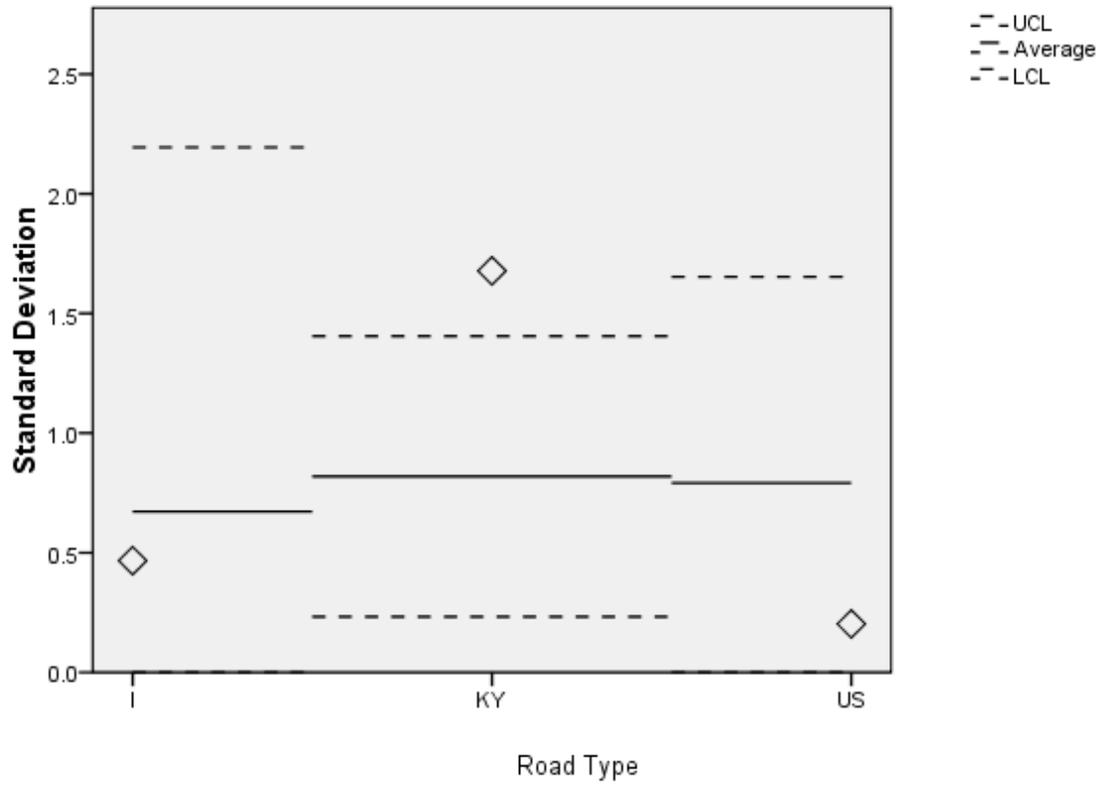


Figure G. 17 Sub - Code 9 Impact by Road Type – Standard Deviation

**15.0 Appendix H: Control Charts – Impact by District**

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Control Chart: Impact\_1through9

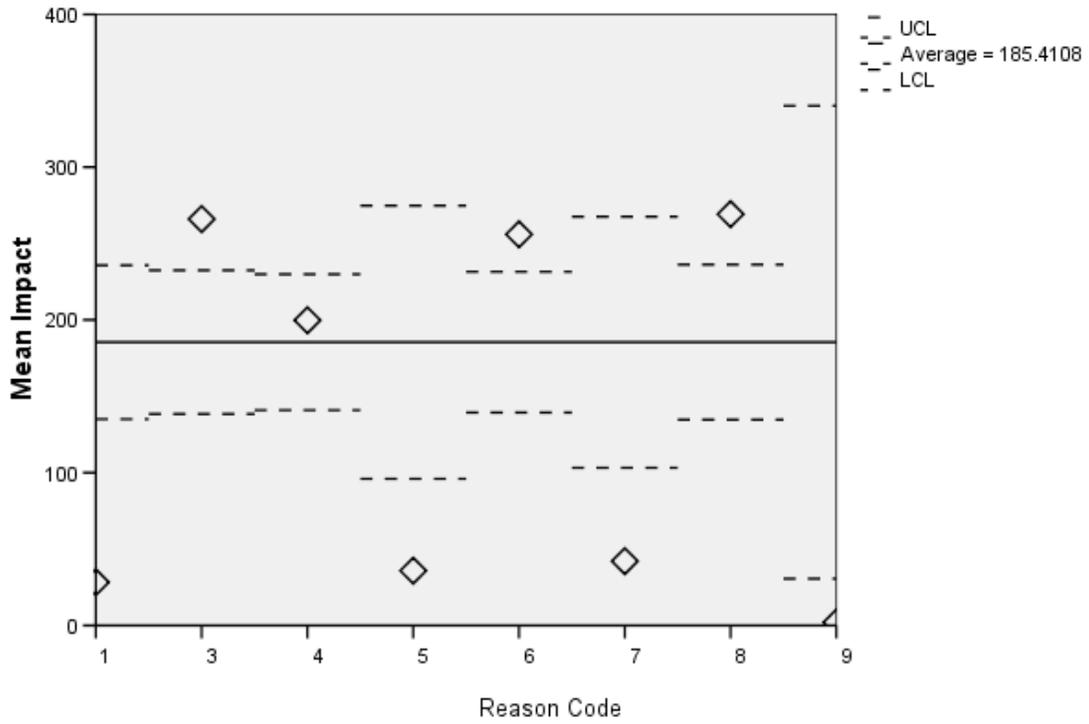


Figure H. 1 Overall Impact

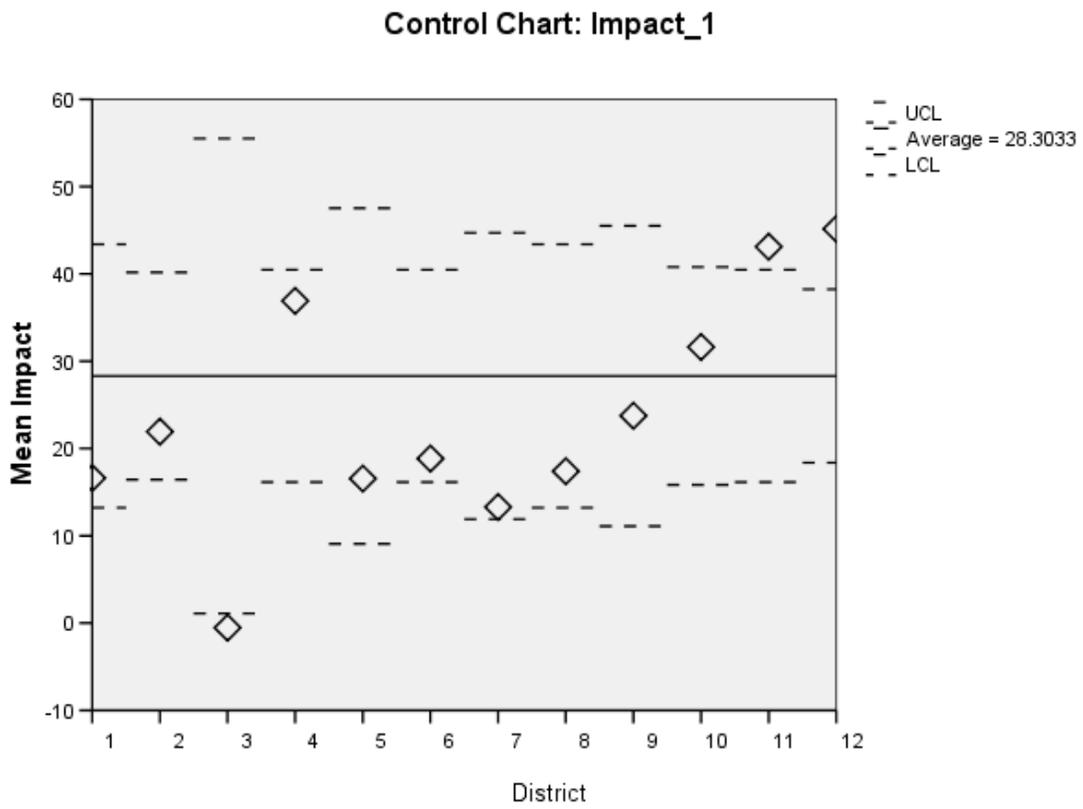


Figure H.2 Sub - Code 1 Impact

Control Chart: Impact\_1

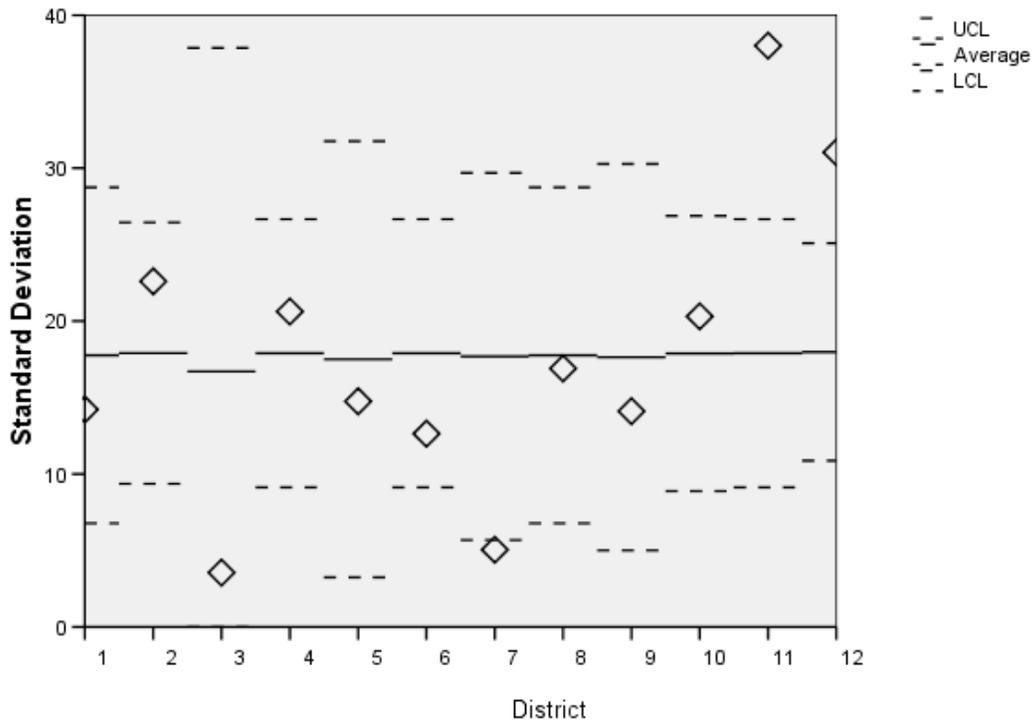


Figure H.3 Sub - Code 1 Impact – Standard Deviation

Control Chart: Impact\_3

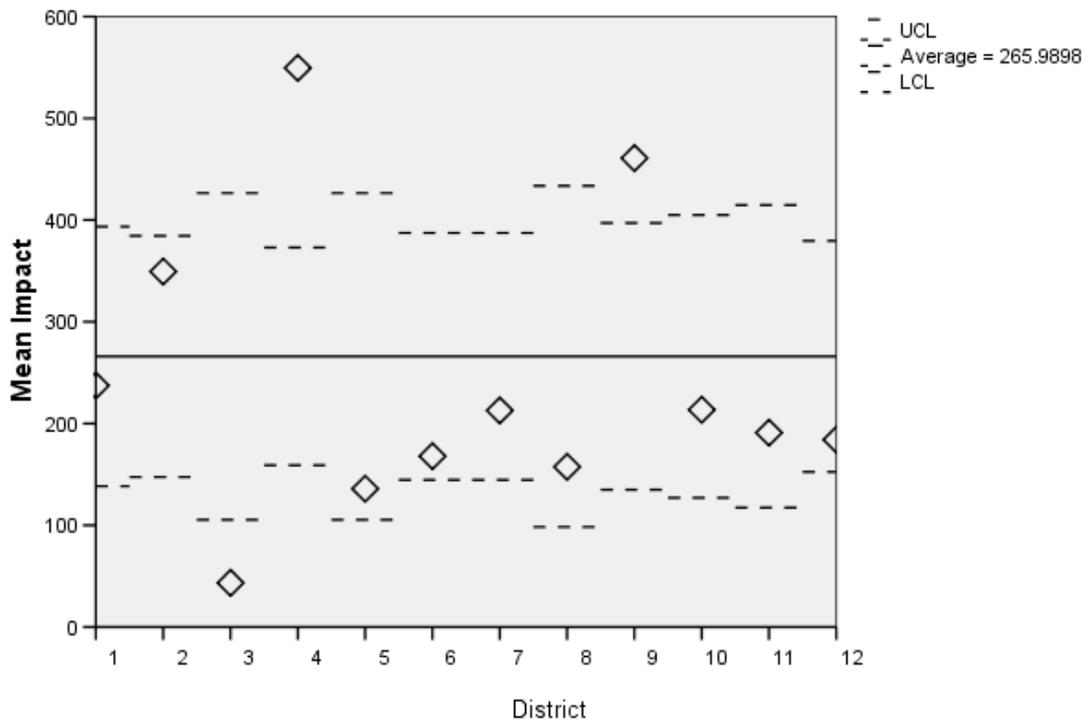


Figure H. 4 Sub - Code 3 Impact

Control Chart: Impact\_3

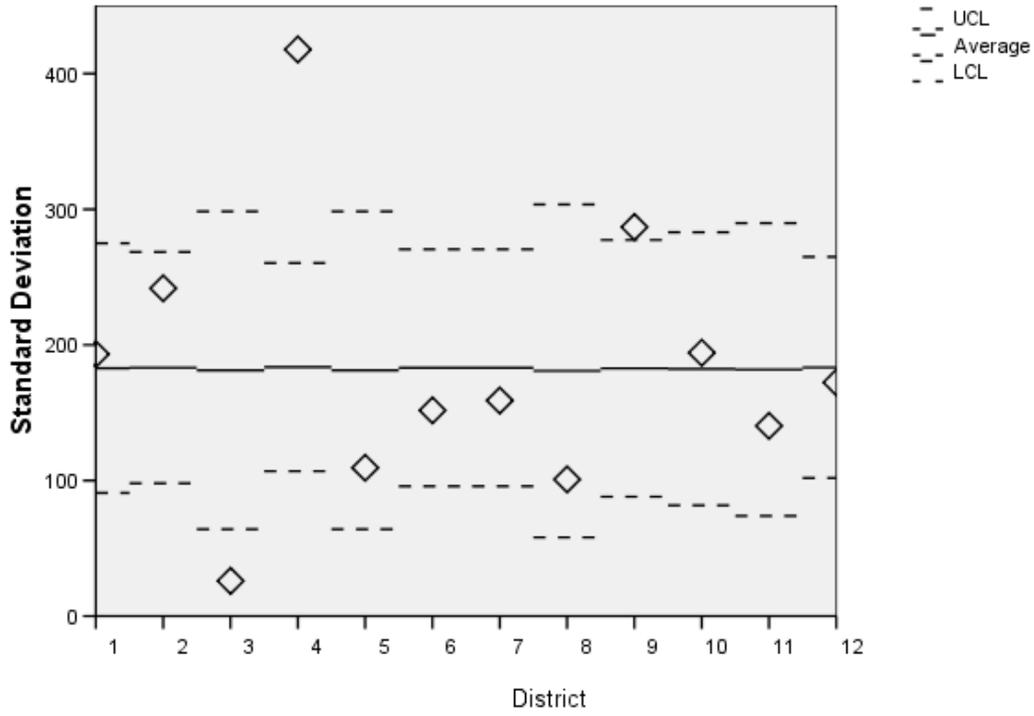


Figure H. 5 Sub - Code 3 Impact – Standard Deviation

Control Chart: Impact\_4

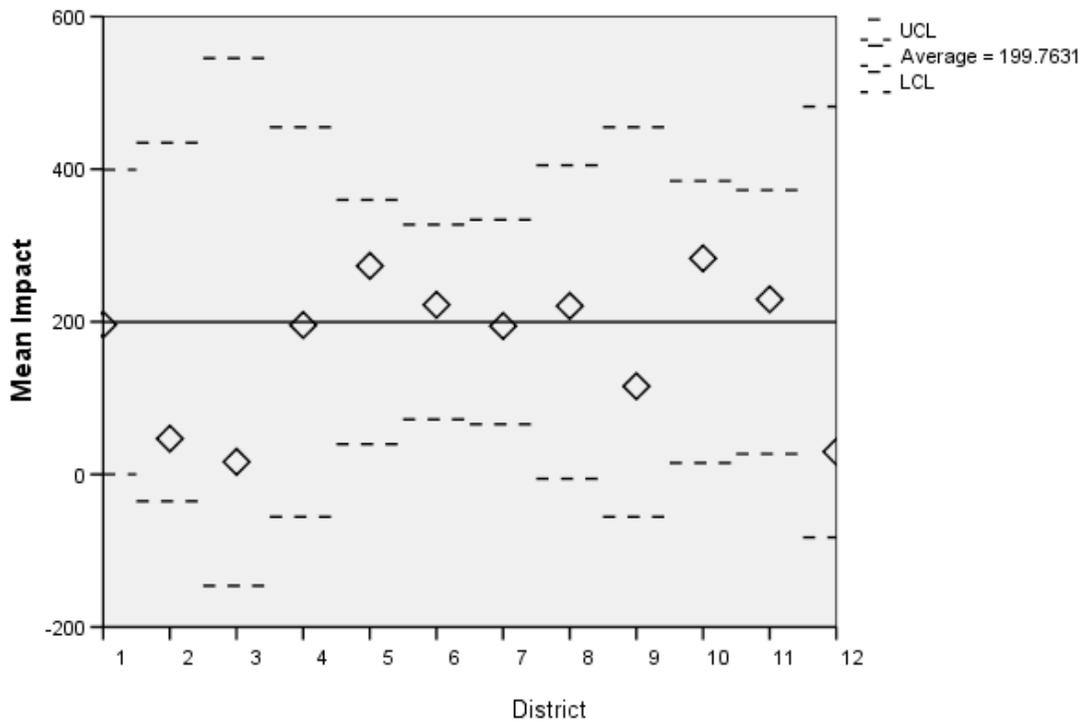


Figure H. 6 Sub - Code 4 Impact

Control Chart: Impact\_4

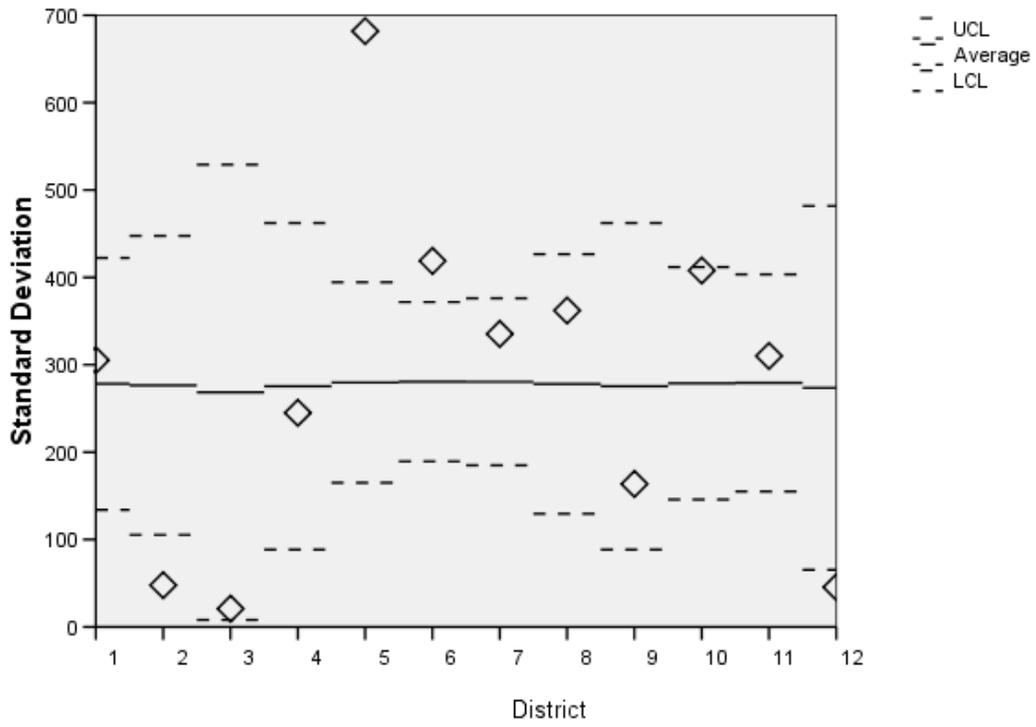


Figure H. 7 Sub - Code 4 Impact – Standard Deviation

### Warnings

One or more subgroups do not contain the minimum sample size required and have been excluded from the analysis.

### Control Chart: Impact\_5

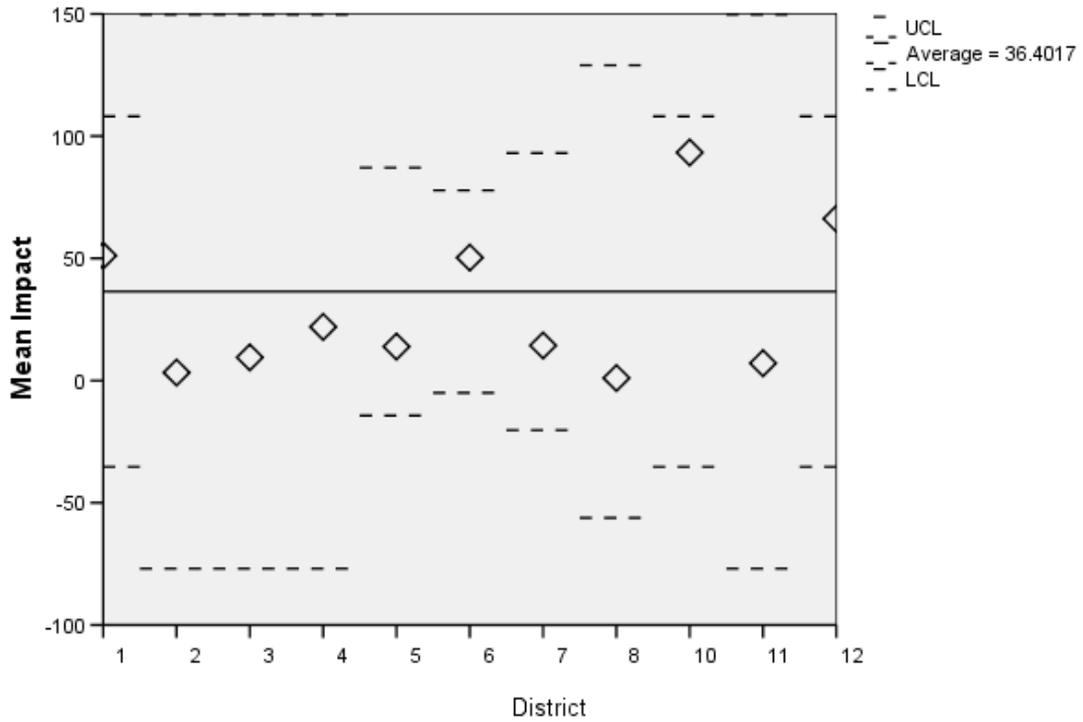


Figure H. 8 Sub - Code 5 Impact

Control Chart: Impact\_5

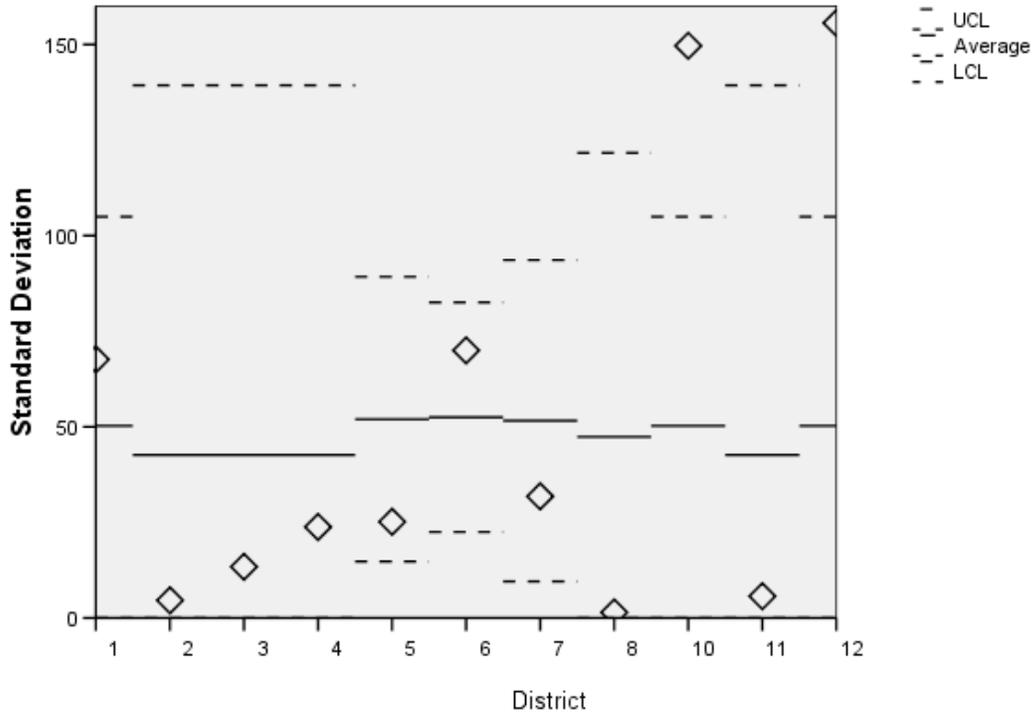


Figure H.9 Sub - Code 5 Impact – Standard Deviation

Control Chart: Impact\_6

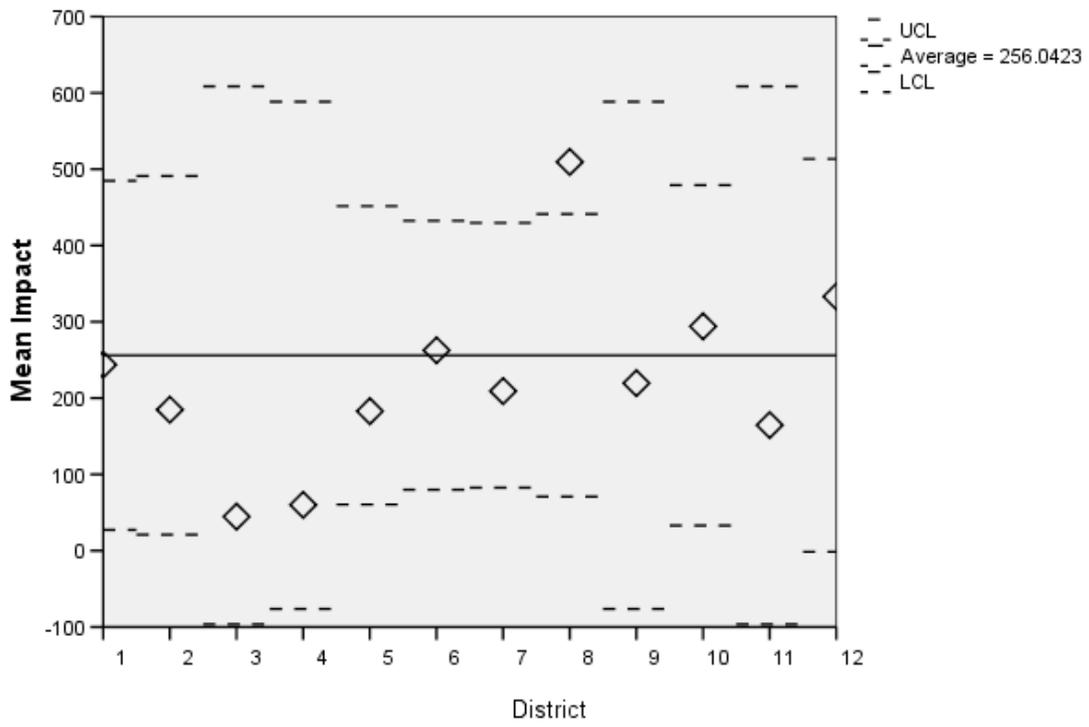


Figure H. 10 Sub - Code 6 Impact

Control Chart: Impact\_6

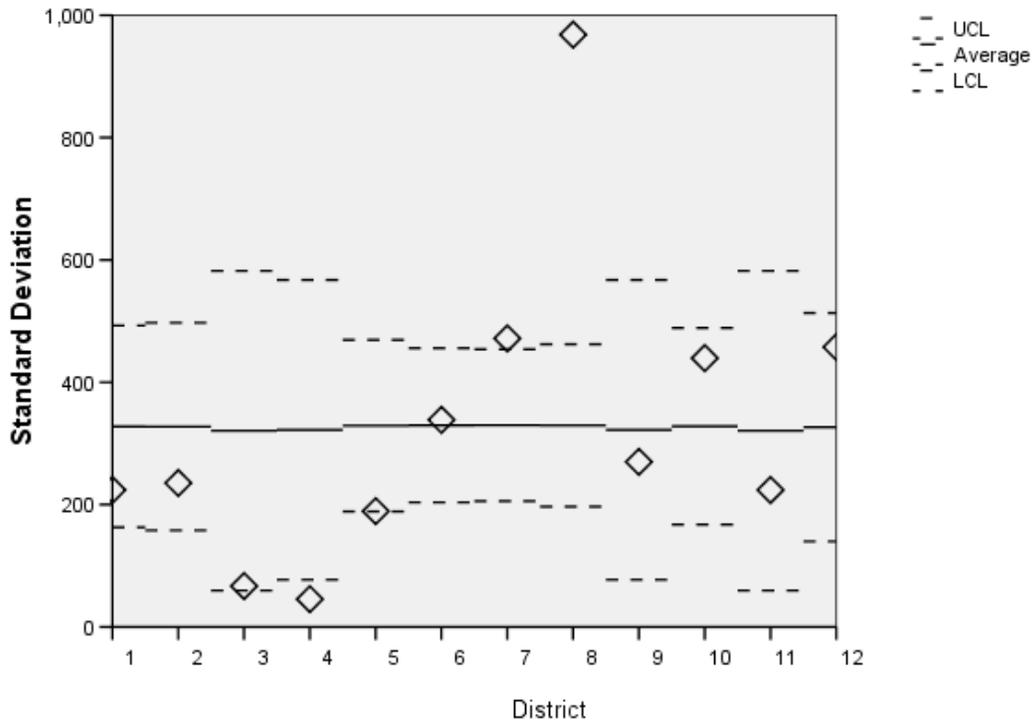


Figure H. 11 Sub - Code 6 Impact – Standard Deviation

### Warnings

One or more subgroups do not contain the minimum sample size required and have been excluded from the analysis.

### Control Chart: Impact\_7

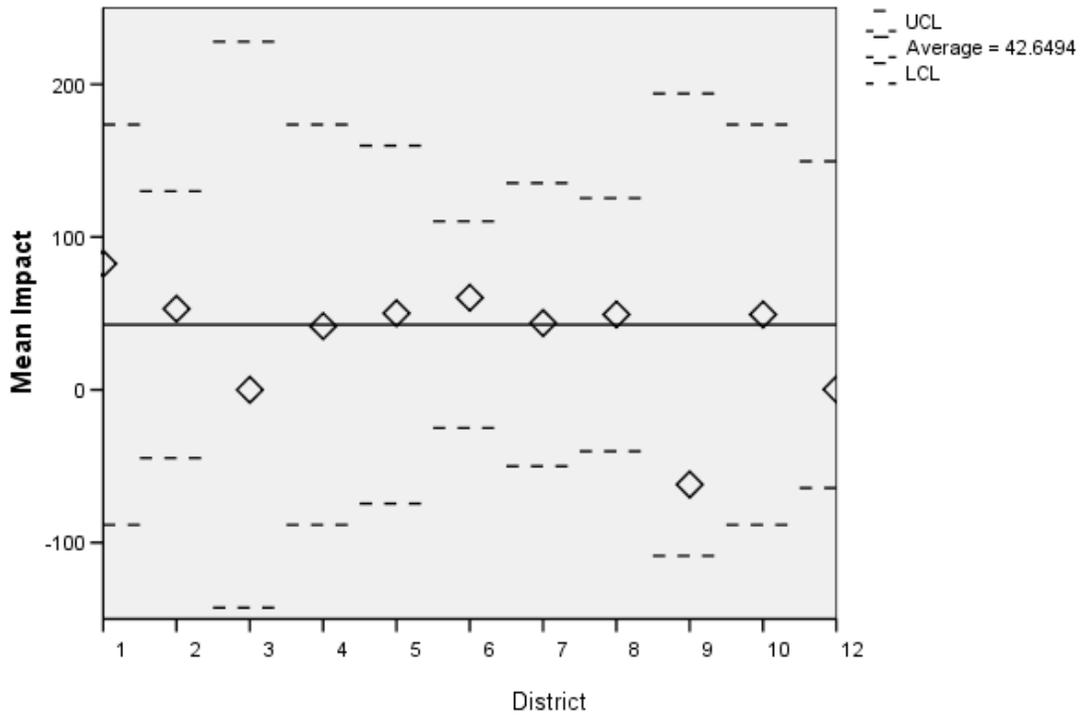


Figure H. 12 Sub - Code 7 Impact

Control Chart: Impact\_7

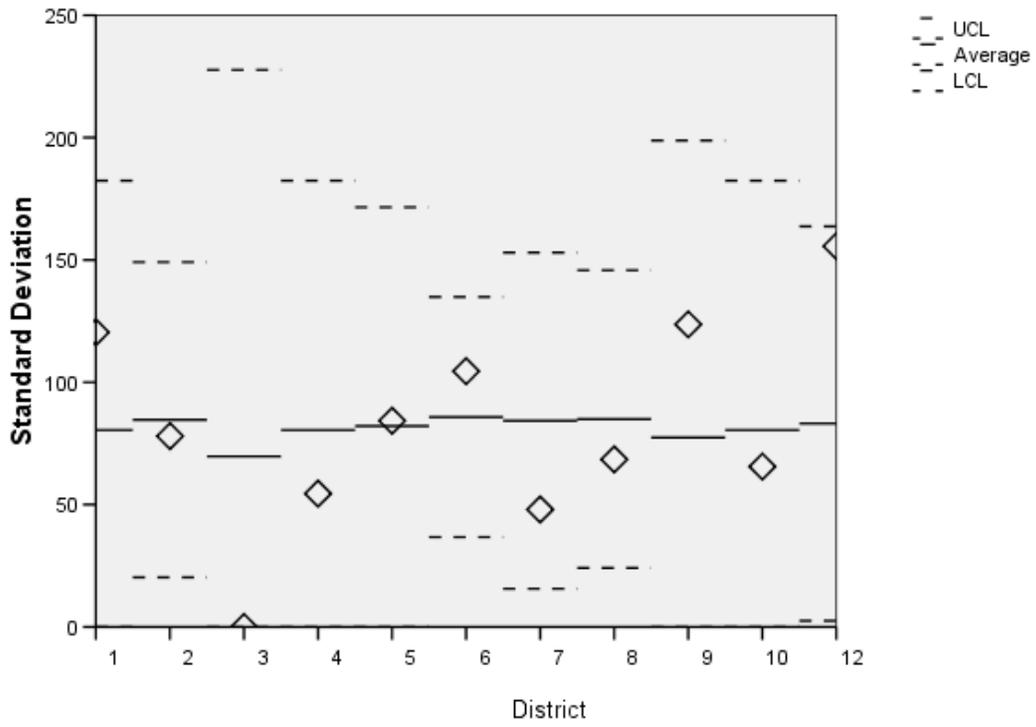


Figure H. 13 Sub - Code 7 Impact – Standard Deviation

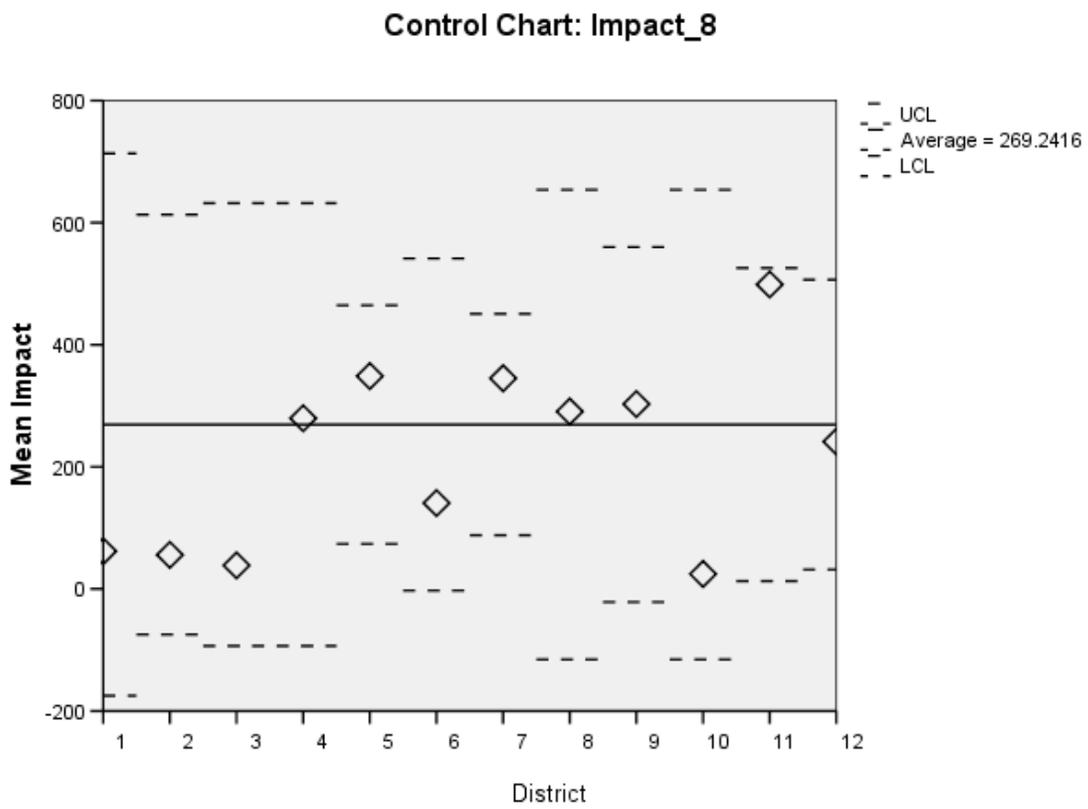


Figure H. 14 Sub - Code 8 Impact

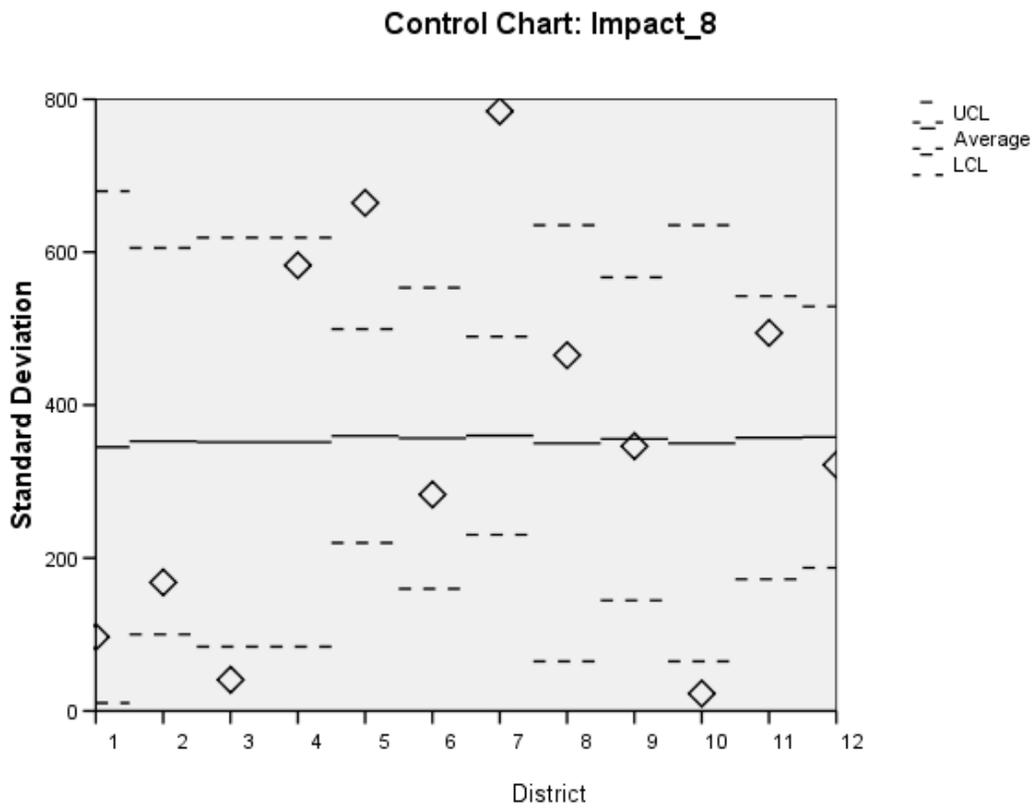


Figure H. 15 Sub - Code 8 Impact – Standard Deviation

### Warnings

One or more subgroups do not contain the minimum sample size required and have been excluded from the analysis.

### Control Chart: Impact\_9

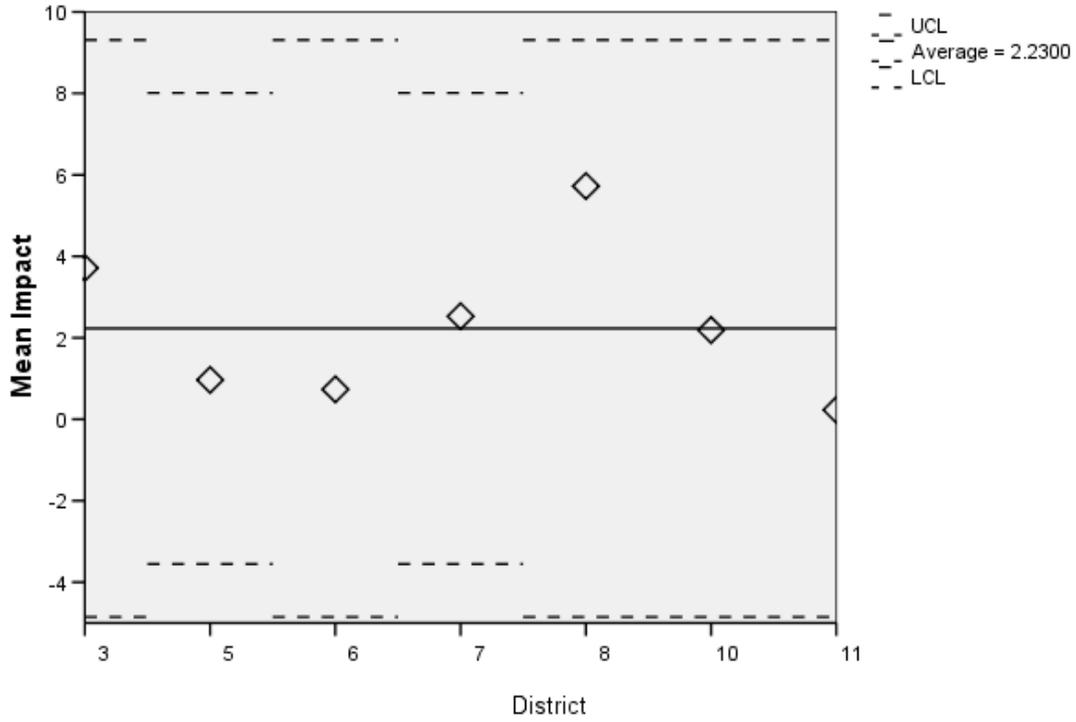


Figure H. 16 Sub - Code 9 Impact

## **16.0 Appendix I: Control Charts – Impact by New/Maintenance Projects**

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Control Chart: New\_Maint\_Impact

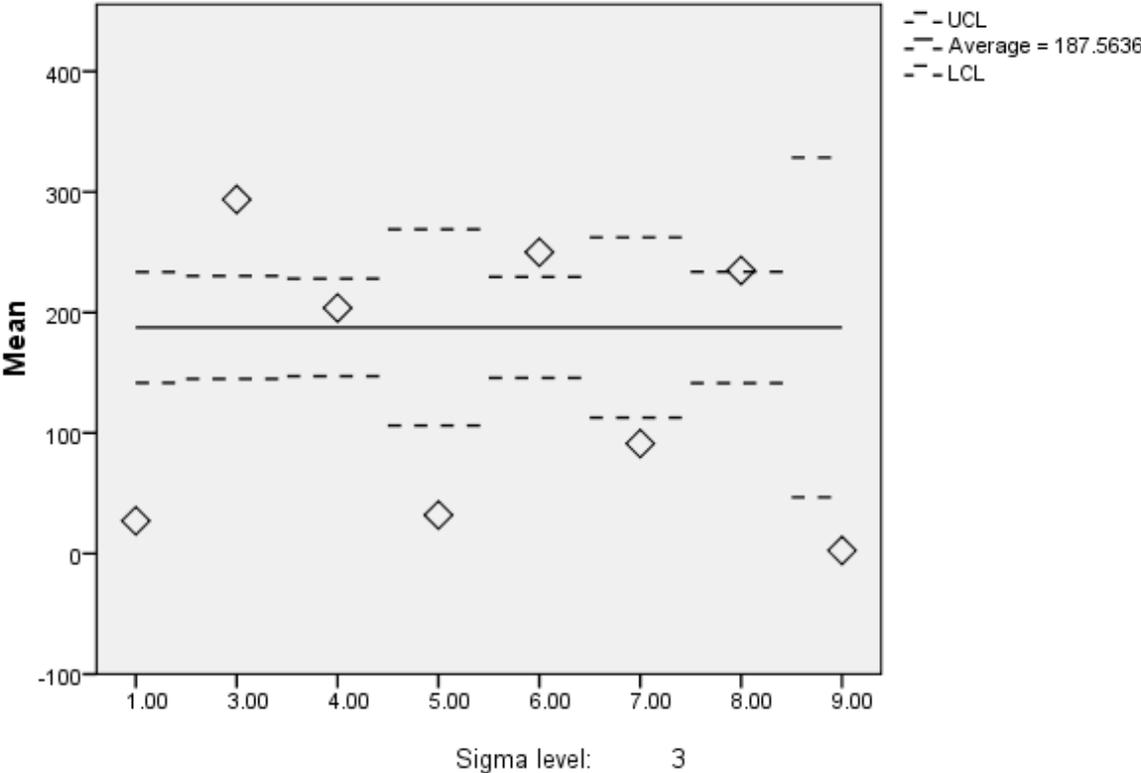


Figure I. 1 Overall New/Maintenance Impact

### Control Chart: New\_Maint\_Impact

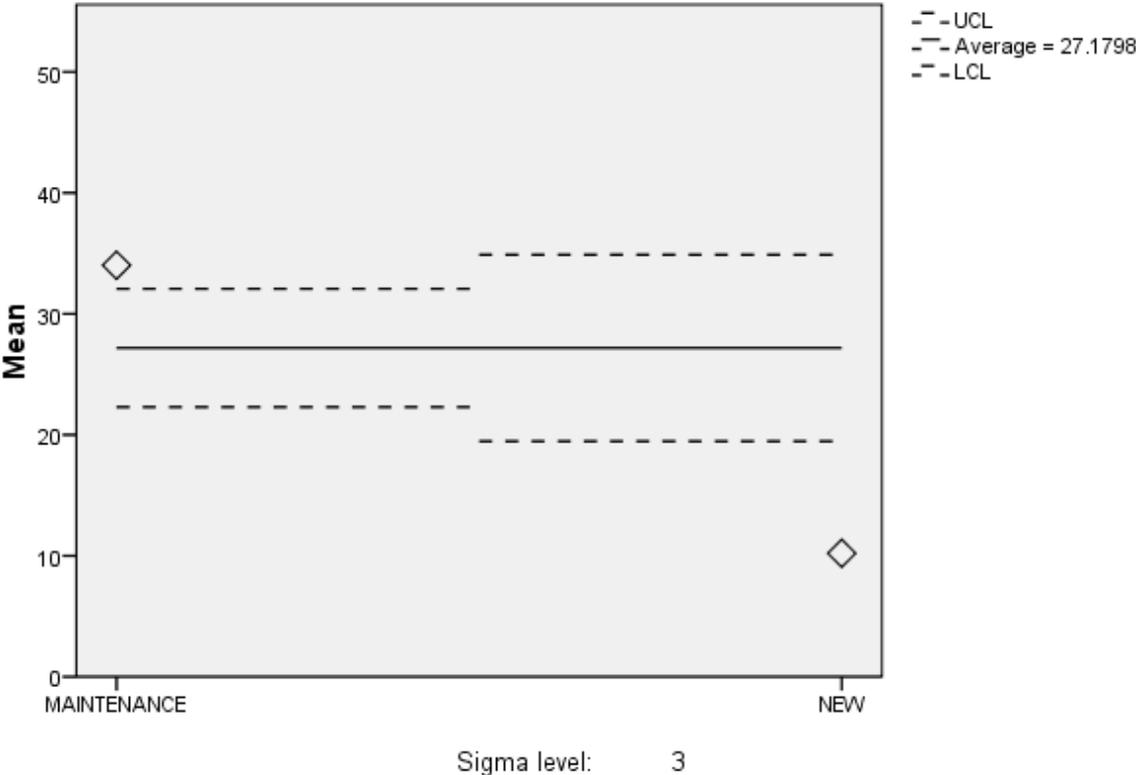


Figure I. 2 Sub - Code 1 New/Maintenance Impact

### Control Chart: New\_Maint\_Impact

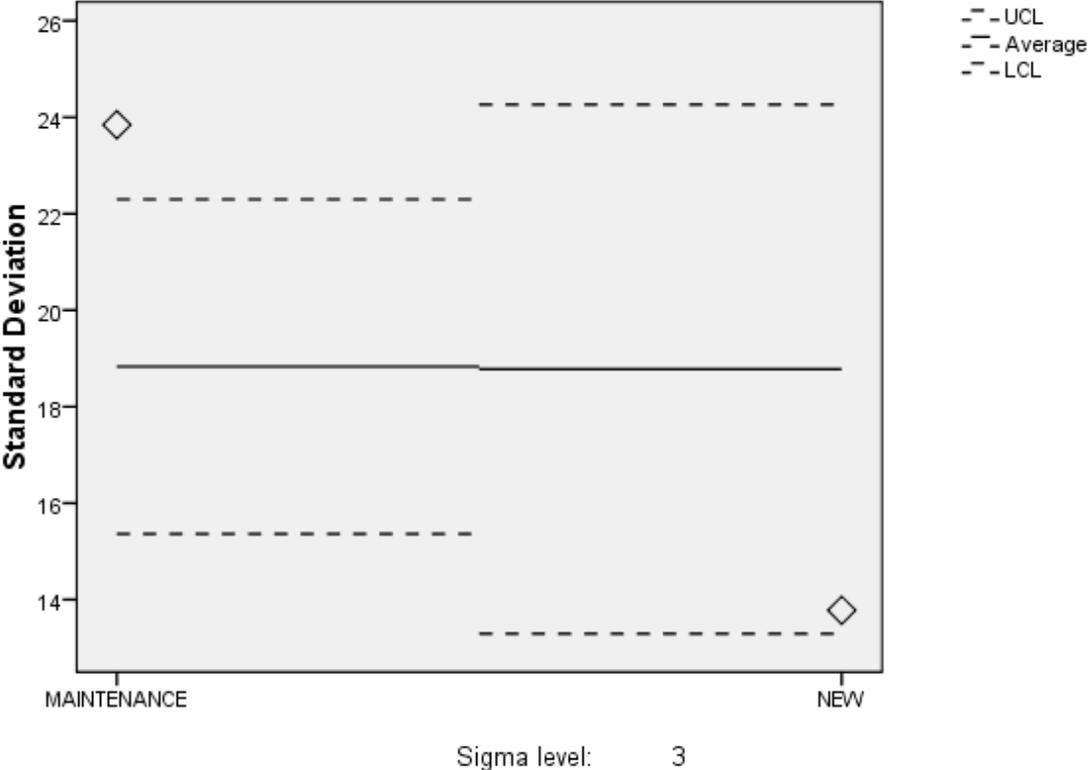


Figure I. 3 Sub - Code 1 New/Maintenance Impact – Standard Deviation

### Control Chart: New\_Maint\_Impact

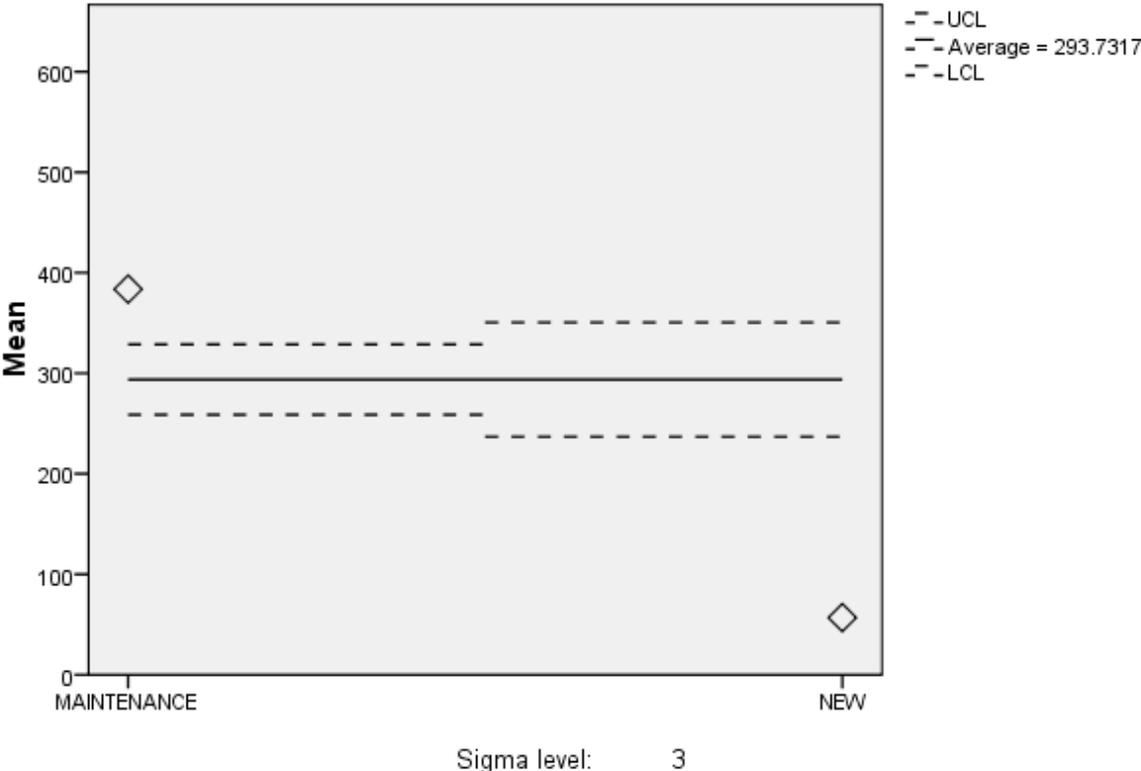


Figure I. 4 Sub - Code 3 New/Maintenance Impact

### Control Chart: New\_Maint\_Impact

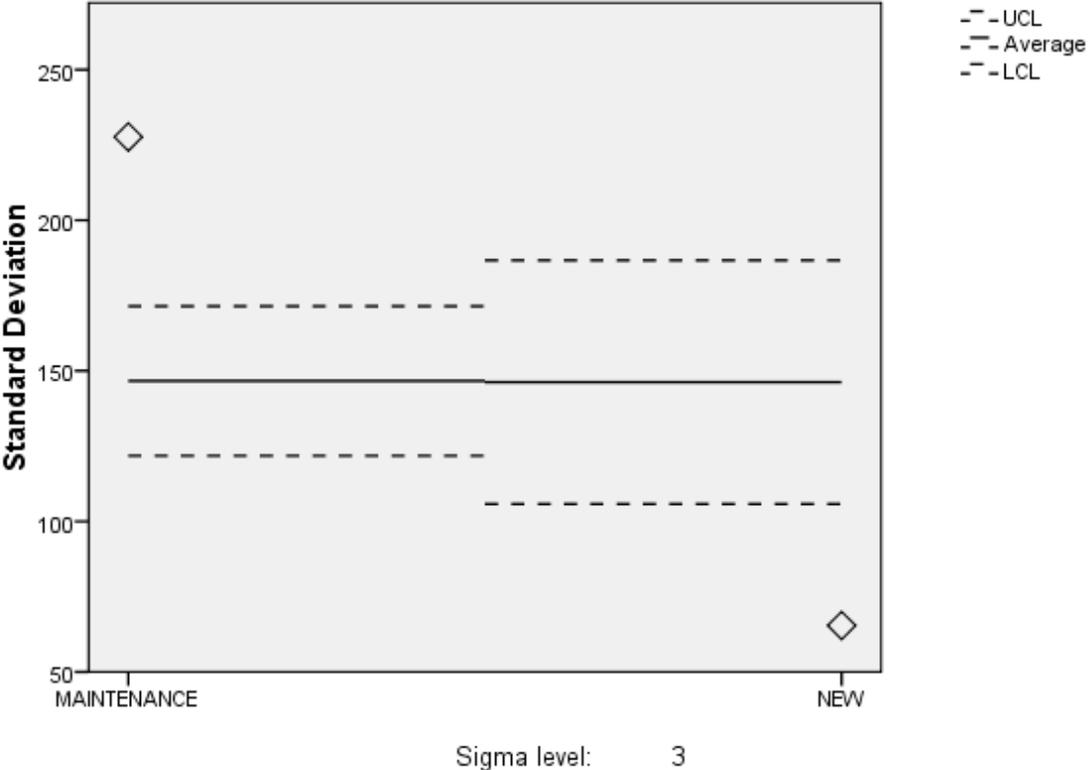


Figure I. 5 Sub - Code 3 New/Maintenance Impact – Standard Deviation

### Control Chart: New\_Maint\_Impact

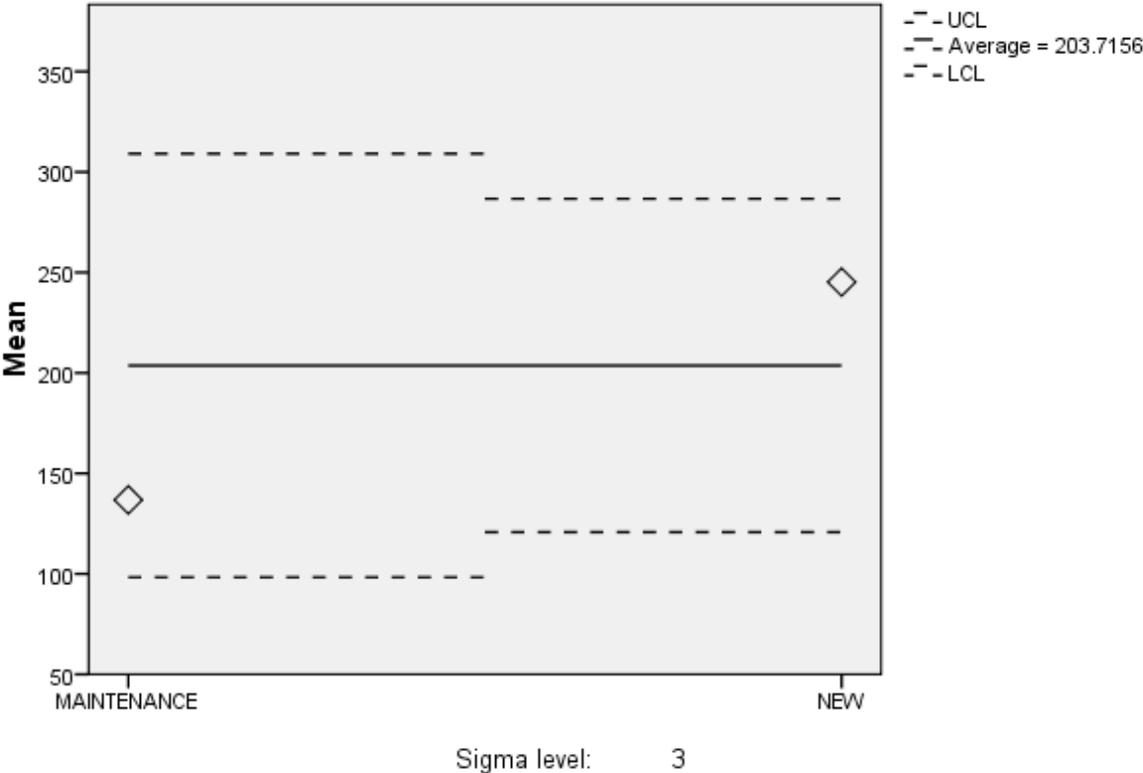


Figure I. 6 Sub - Code 4 New/Maintenance Impact

### Control Chart: New\_Maint\_Impact

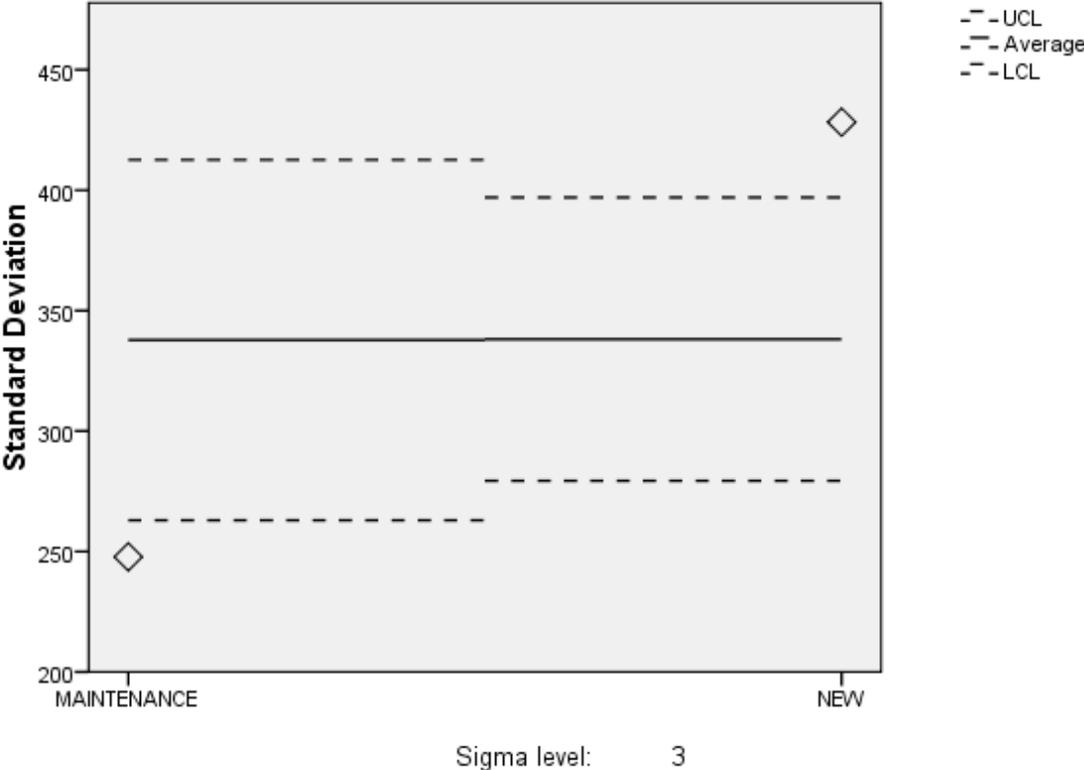


Figure I. 7 Sub - Code 4 New/Maintenance Impact – Standard Deviation

### Control Chart: New\_Maint\_Impact

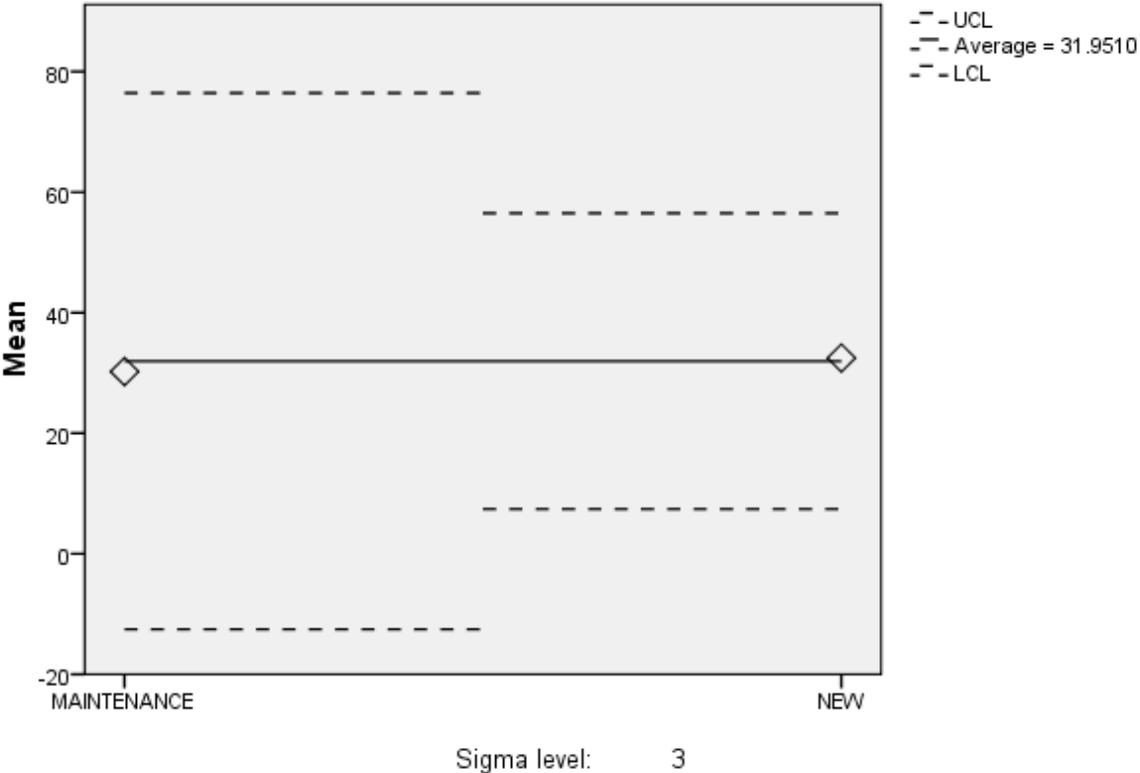


Figure I. 8 Sub - Code 5 New/Maintenance Impact

### Control Chart: New\_Maint\_Impact

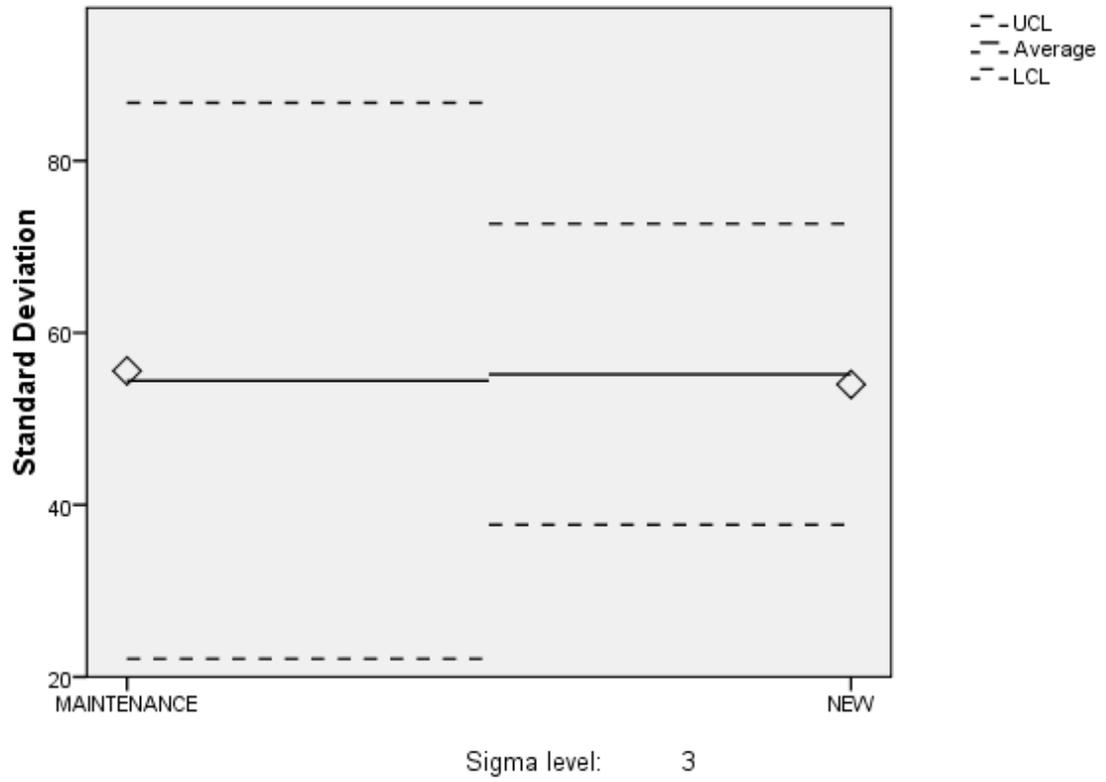


Figure I. 9 Sub - Code 5 New/Maintenance Impact – Standard Deviation

### Control Chart: New\_Maint\_Impact

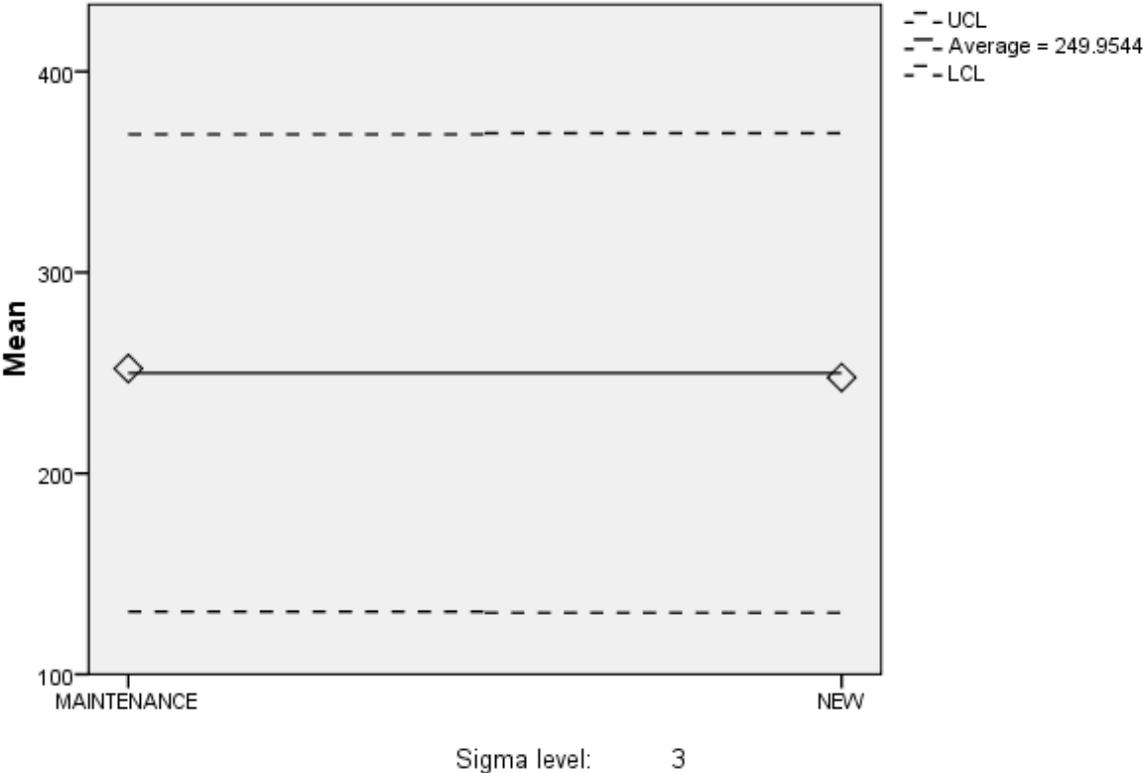


Figure I. 10 Sub - Code 6 New/Maintenance Impact

Control Chart: New\_Maint\_Impact

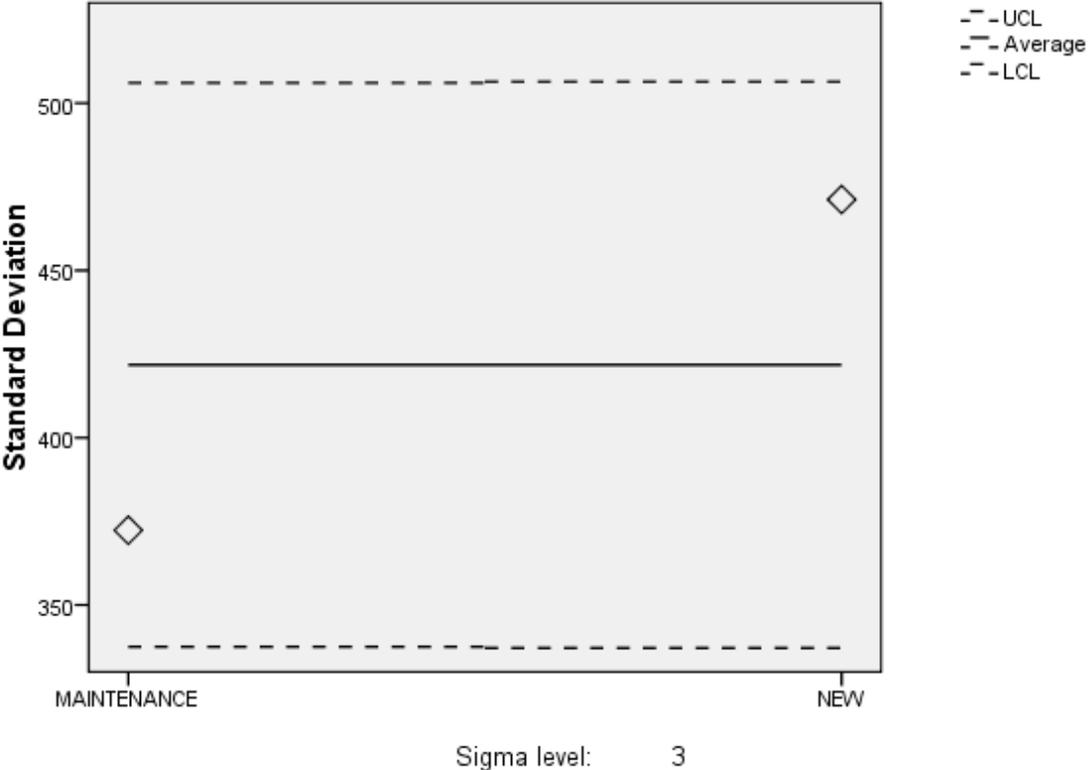


Figure I. 11 Sub - Code 6 New/Maintenance Impact – Standard Deviation

### Control Chart: New\_Maint\_Impact

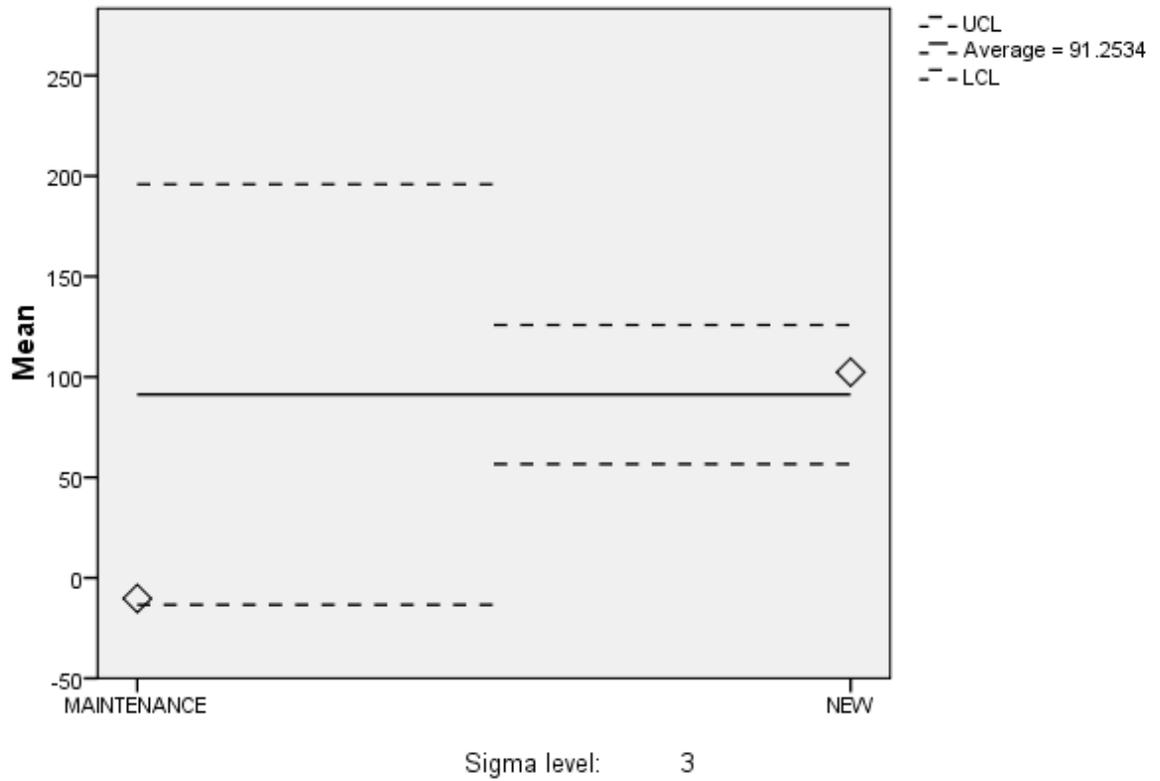


Figure I. 12 Sub - Code 7 New/Maintenance Impact

### Control Chart: New\_Maint\_Impact

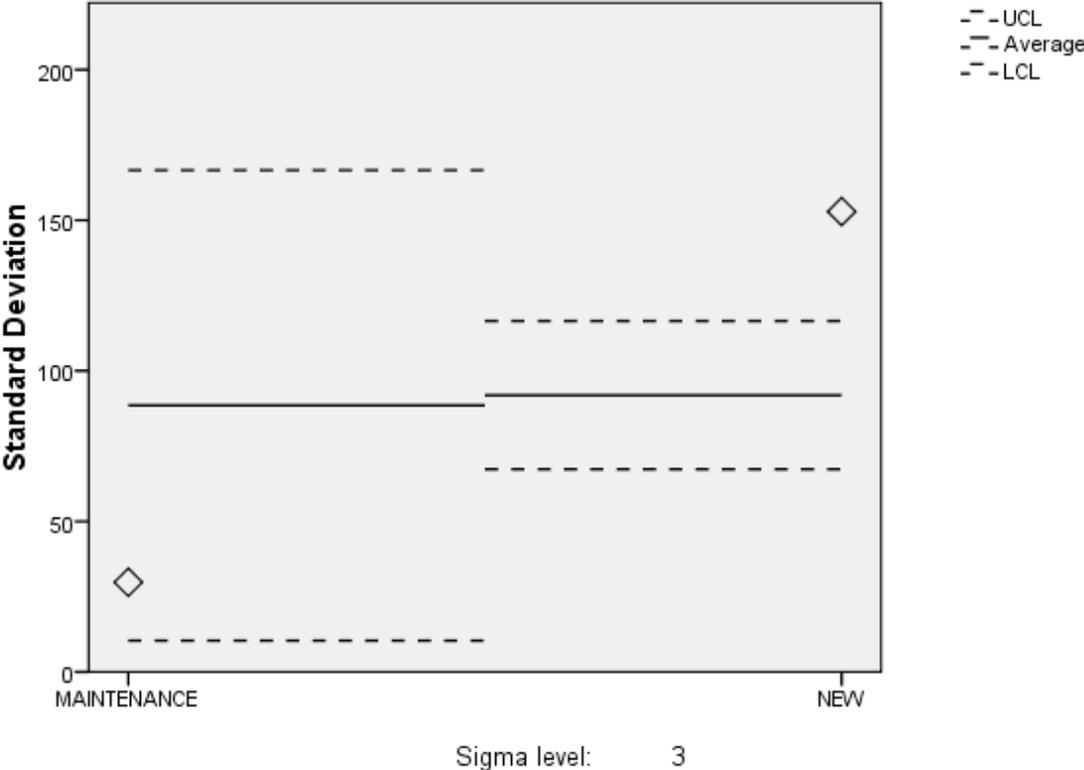


Figure I. 13 Sub - Code 7 New/Maintenance Impact – Standard Deviation

Control Chart: New\_Maint\_Impact

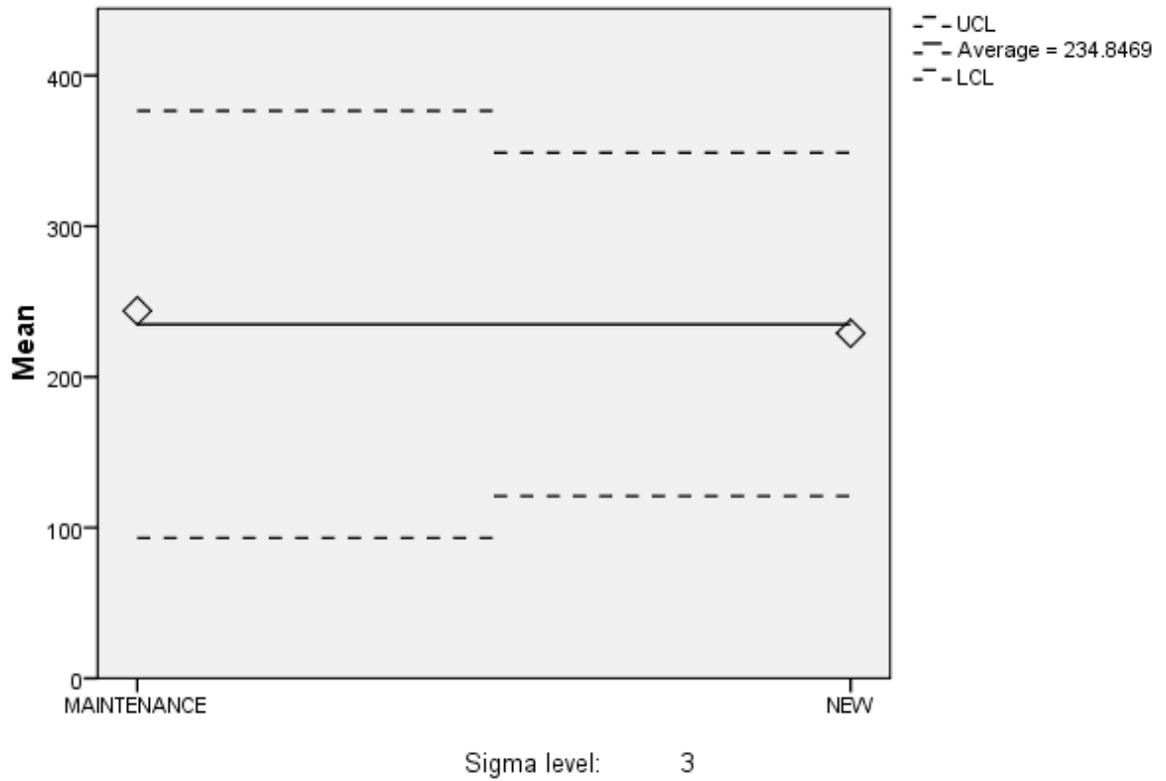


Figure I. 14 Sub - Code 8 New/Maintenance Impact

### Control Chart: New\_Maint\_Impact

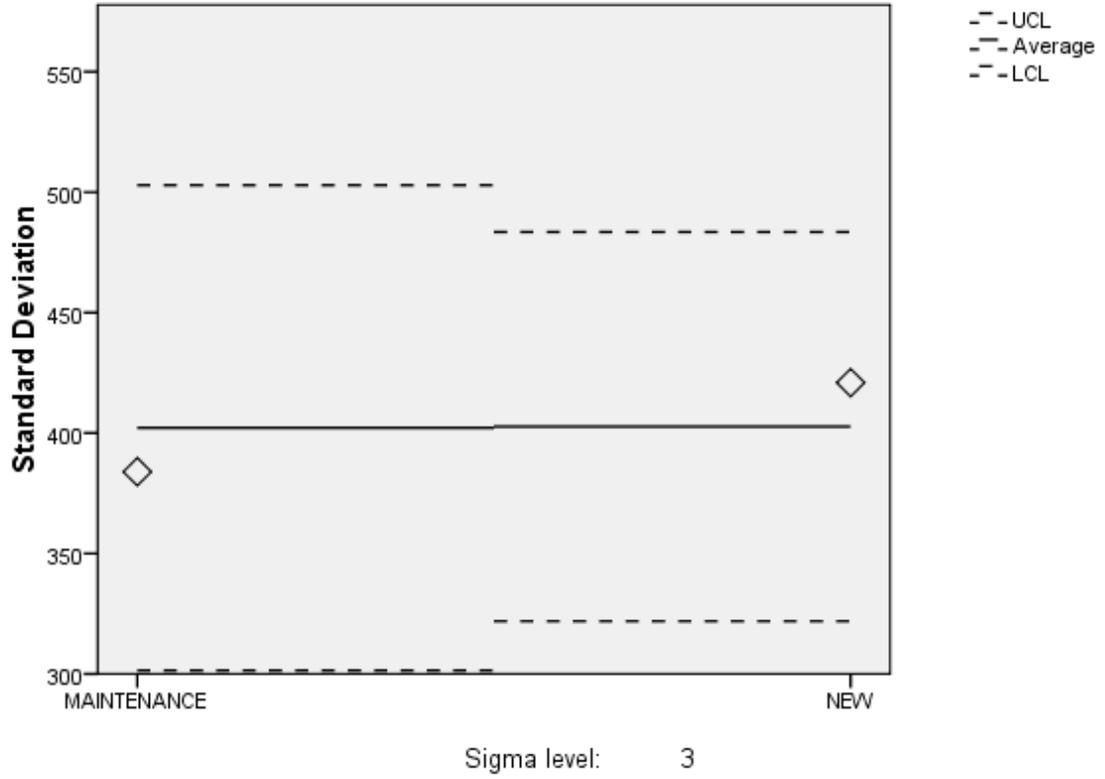


Figure I. 15 Sub - Code 8 New/Maintenance Impact – Standard Deviation

### Control Chart: New\_Maint\_Impact

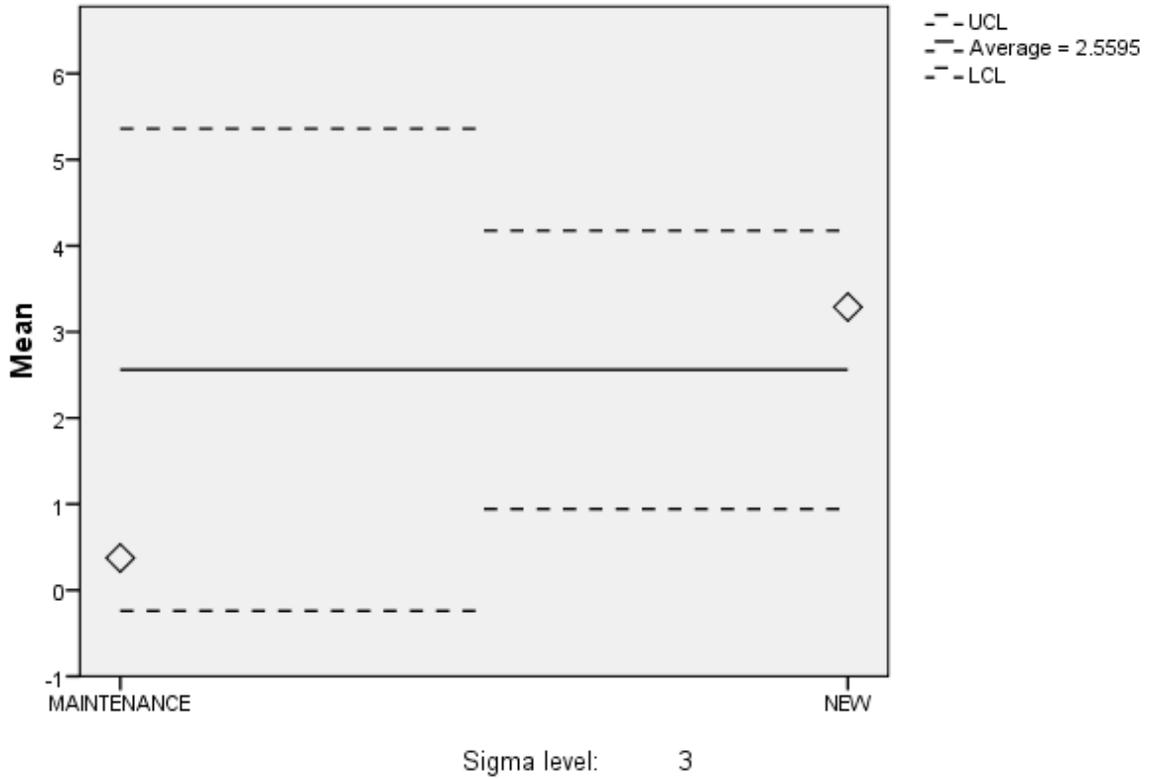


Figure I. 16 Sub - Code 9 New/Maintenance Impact

### Control Chart: New\_Maint\_Impact

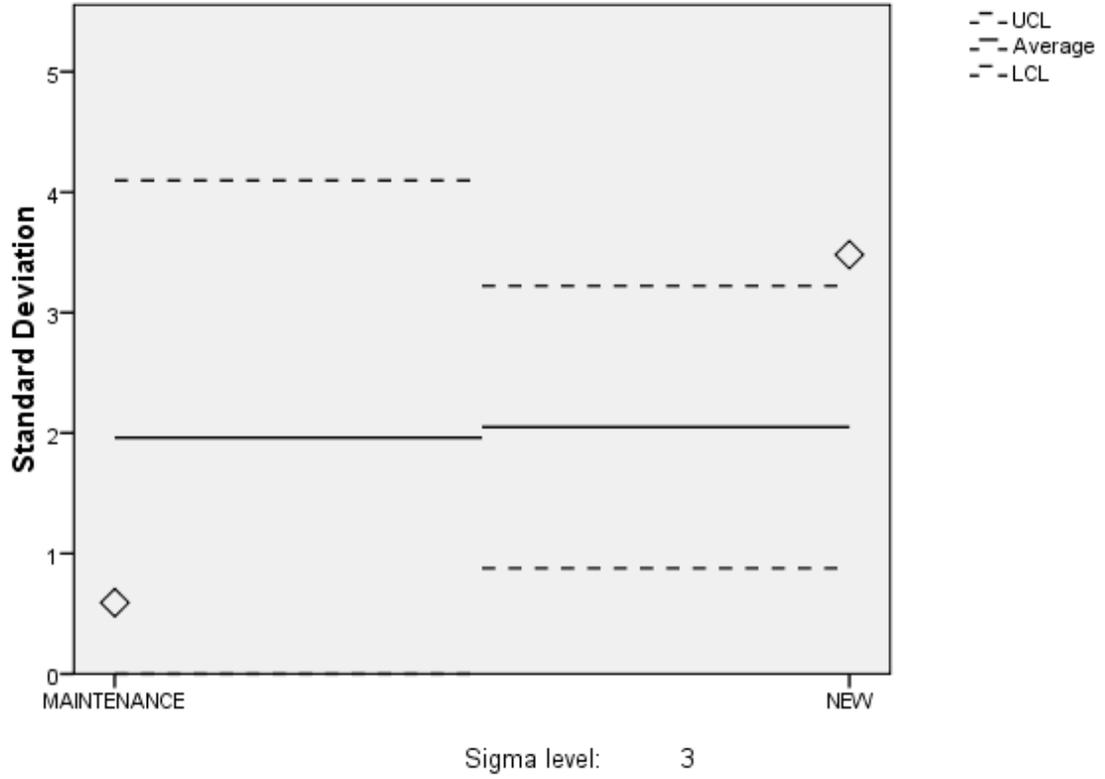


Figure I. 17 Sub - Code 9 New/Maintenance Impact – Standard Deviation

## **17.0 Appendix J: Control Charts – Impact by Construction Type**

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### Control Chart: ConstType\_Impact

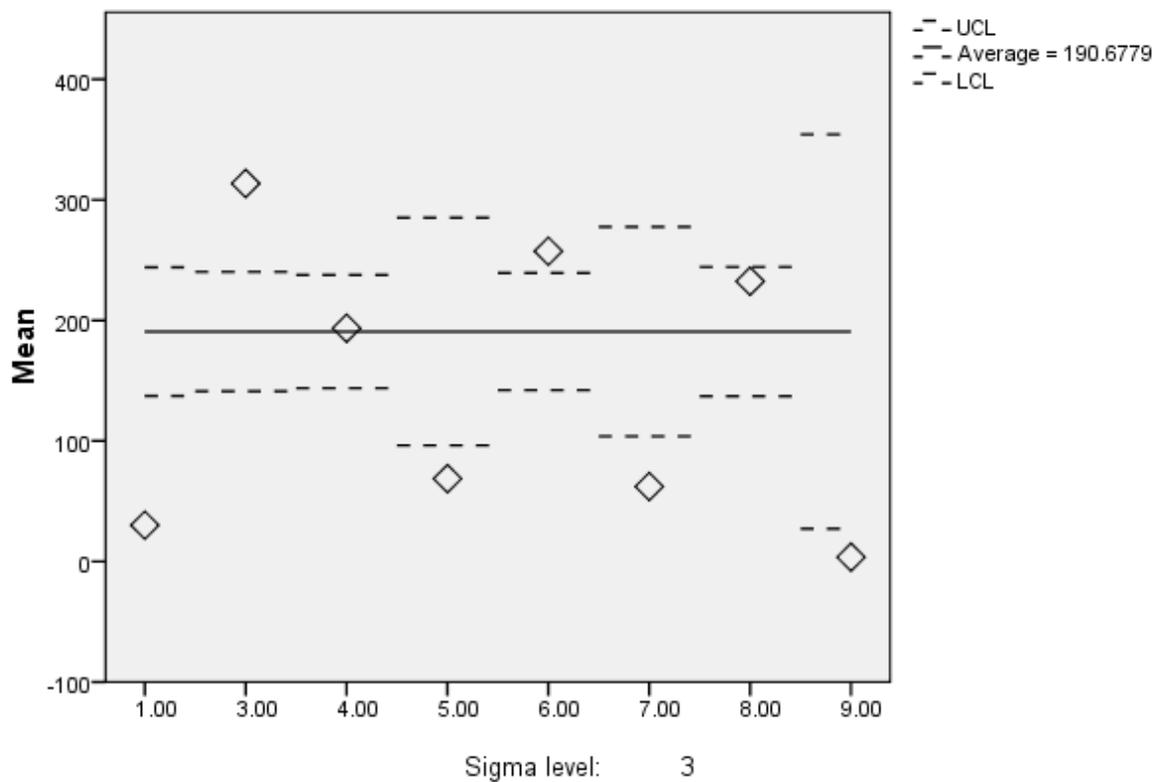


Figure J. 1 Overall Construction Type Impact

### Control Chart: ConstType\_Impact

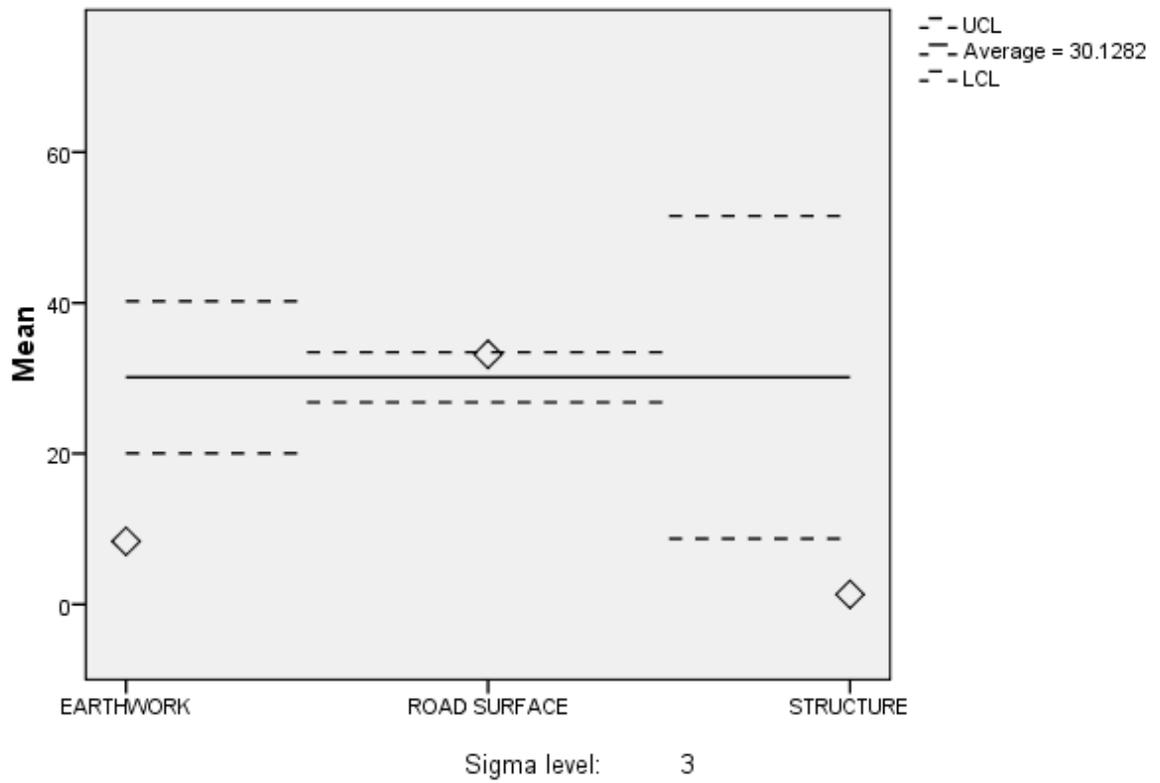


Figure J. 2 Sub - Code 1 Construction Type Impact

### Control Chart: ConstType\_Impact

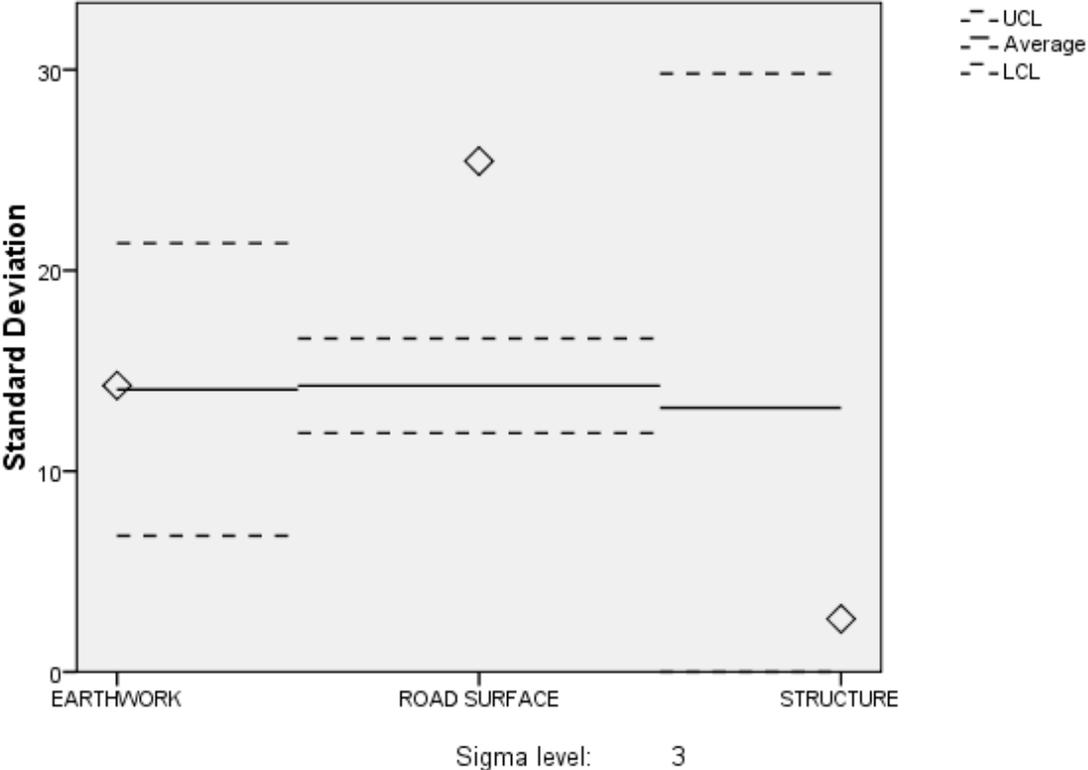


Figure J.3 Sub - Code 1 Construction Type Impact – Standard Deviation

### Control Chart: ConstType\_Impact

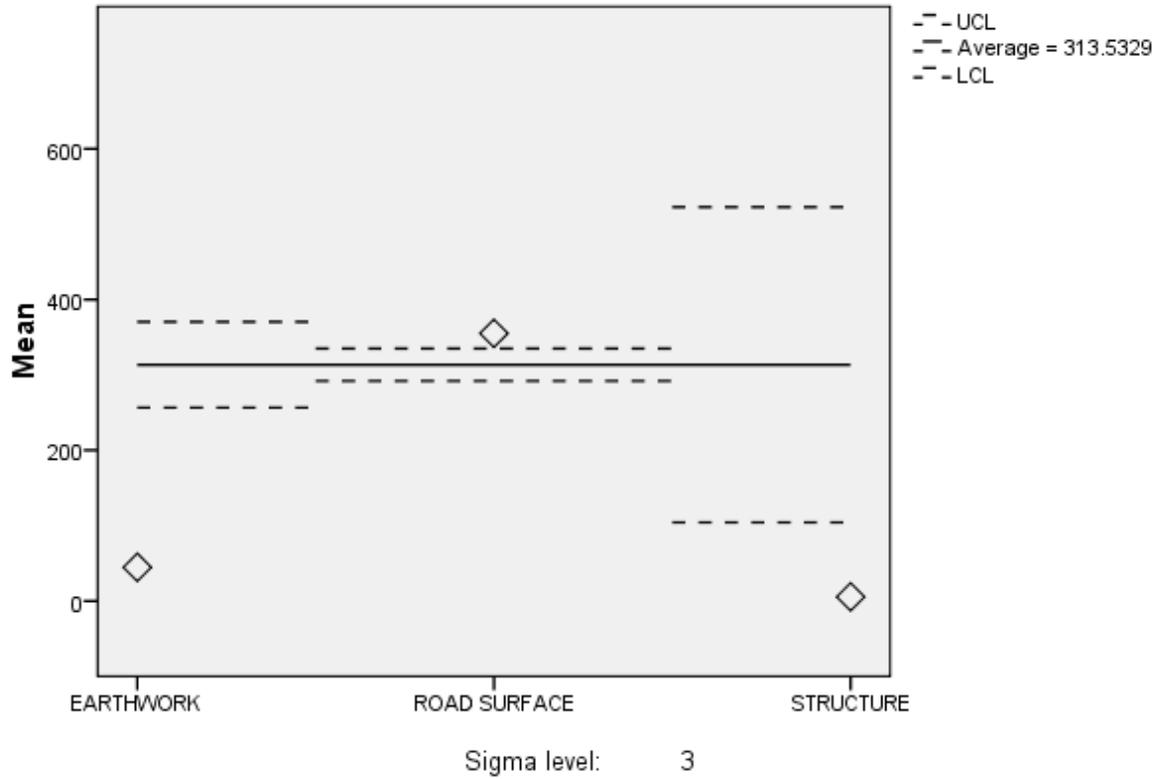


Figure J. 4 Sub - Code 3 Construction Type Impact

Control Chart: ConstType\_Impact

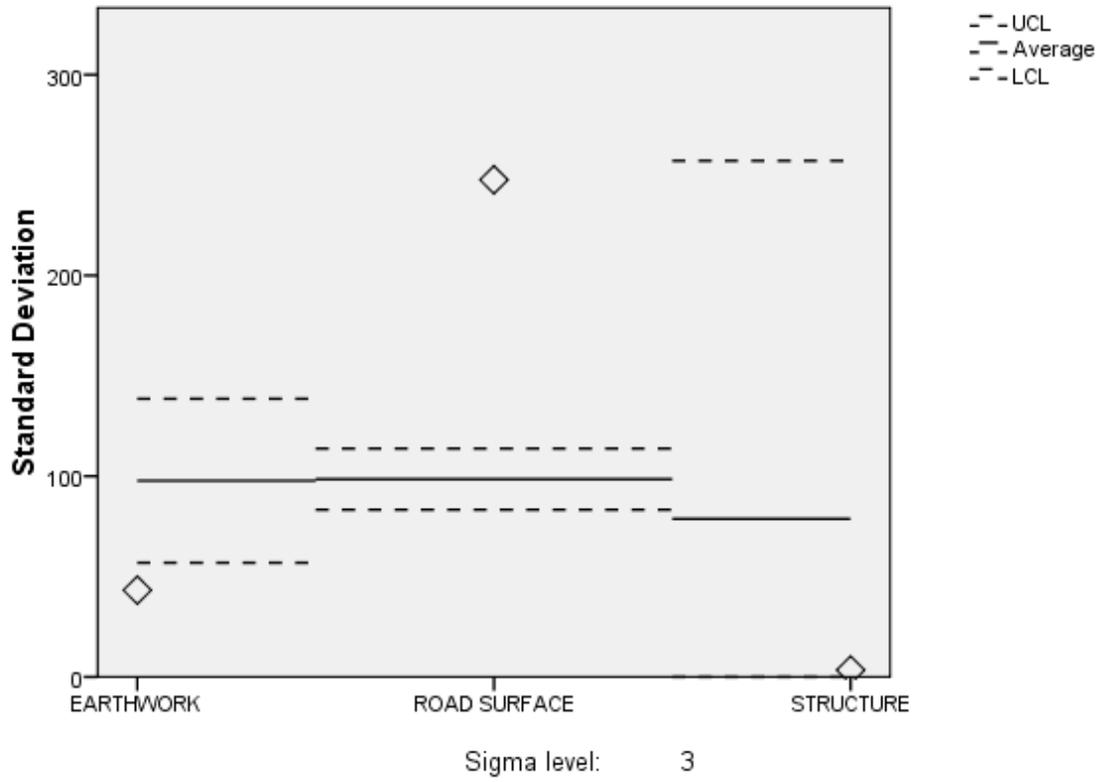


Figure J. 5 Sub - Code 3 Construction Type Impact – Standard Deviation

### Control Chart: ConstType\_Impact

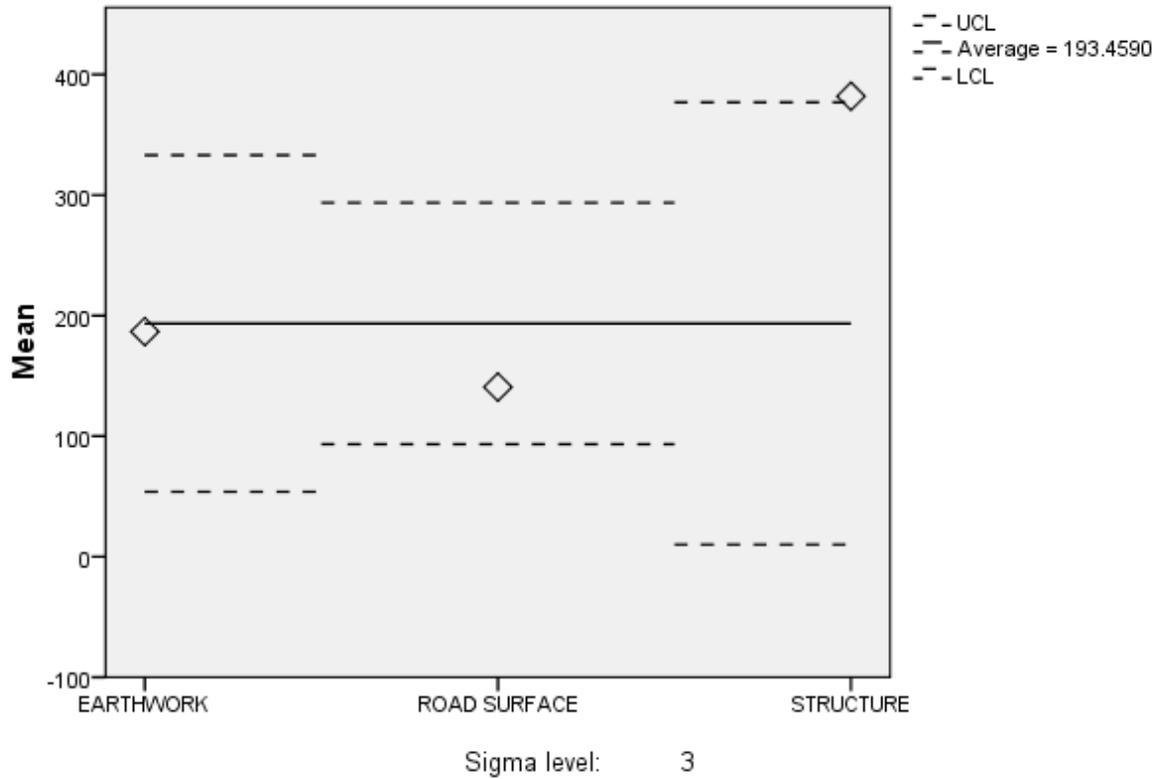


Figure J. 6 Sub - Code 4 Construction Type Impact

Control Chart: ConstType\_Impact

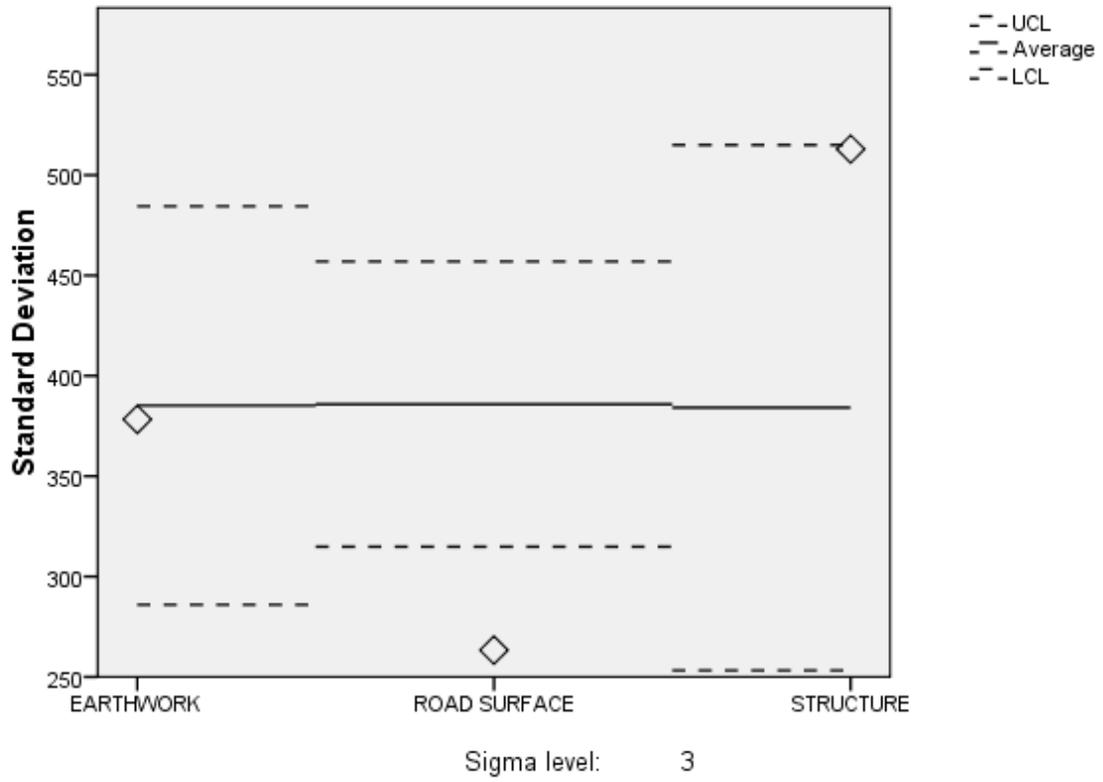


Figure J. 7 Sub - Code 4 Construction Type Impact – Standard Deviation

### Control Chart: ConstType\_Impact

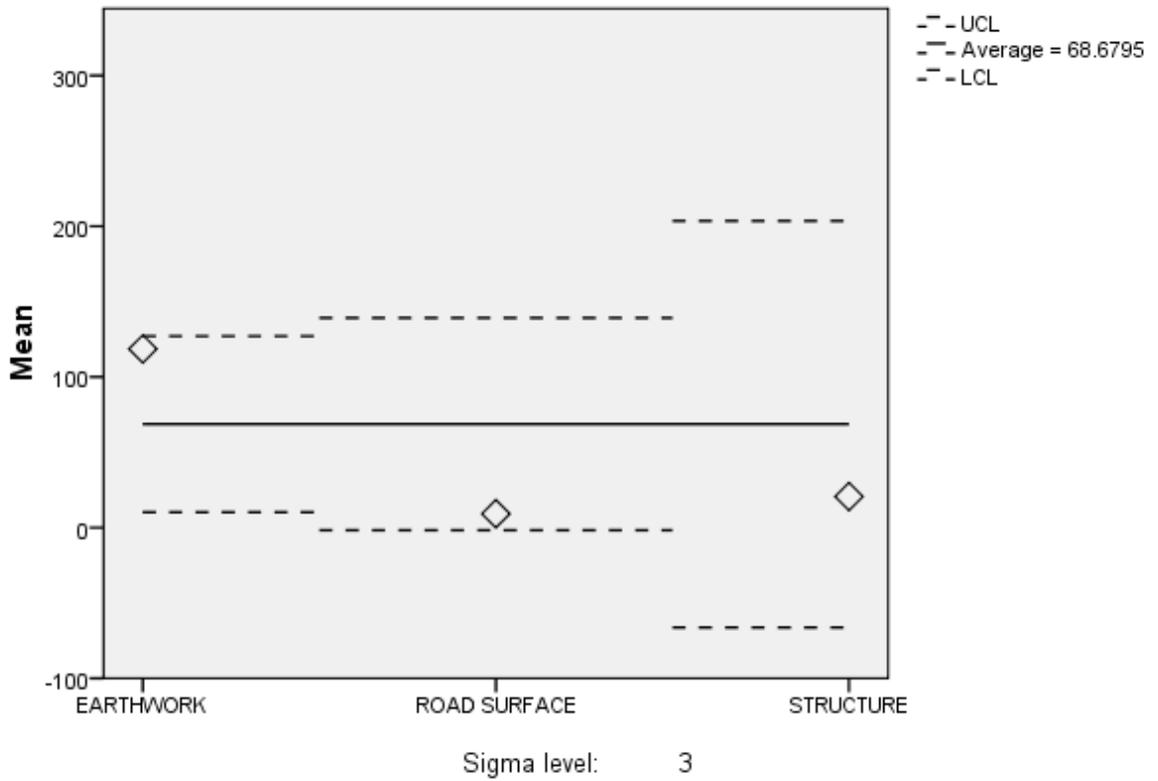


Figure J. 8 Sub - Code 5 Construction Type Impact

### Control Chart: ConstType\_Impact

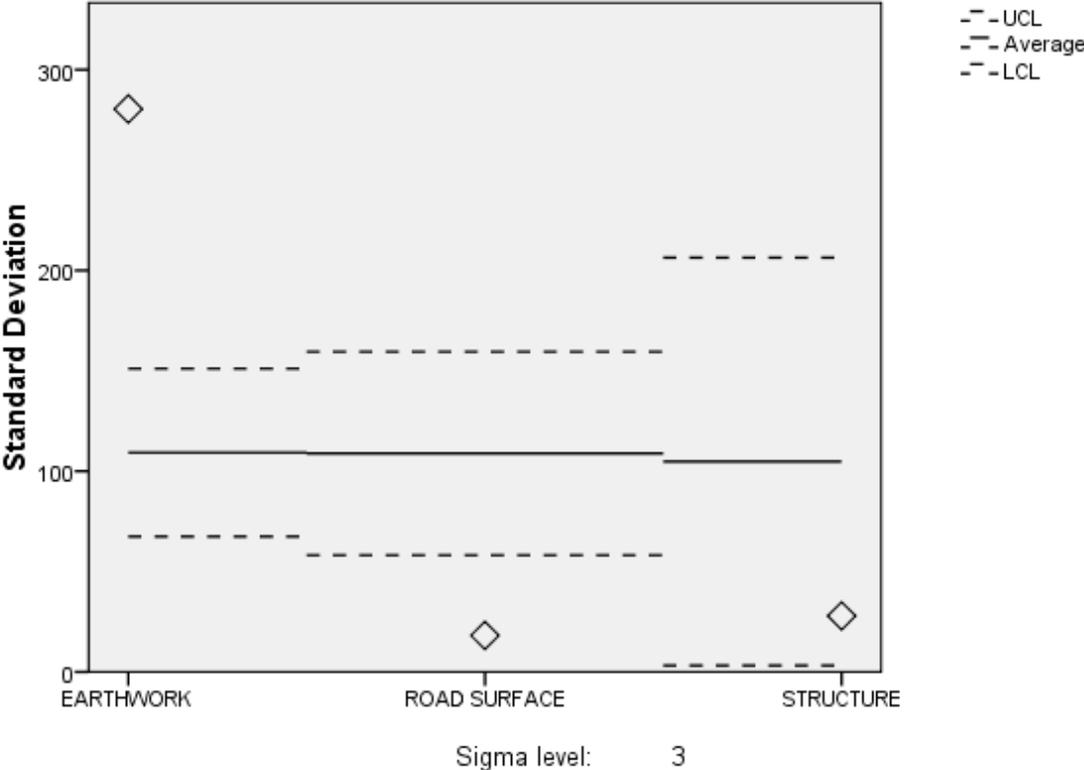


Figure J.9 Sub - Code 5 Construction Type Impact – Standard Deviation

Control Chart: ConstType\_Impact

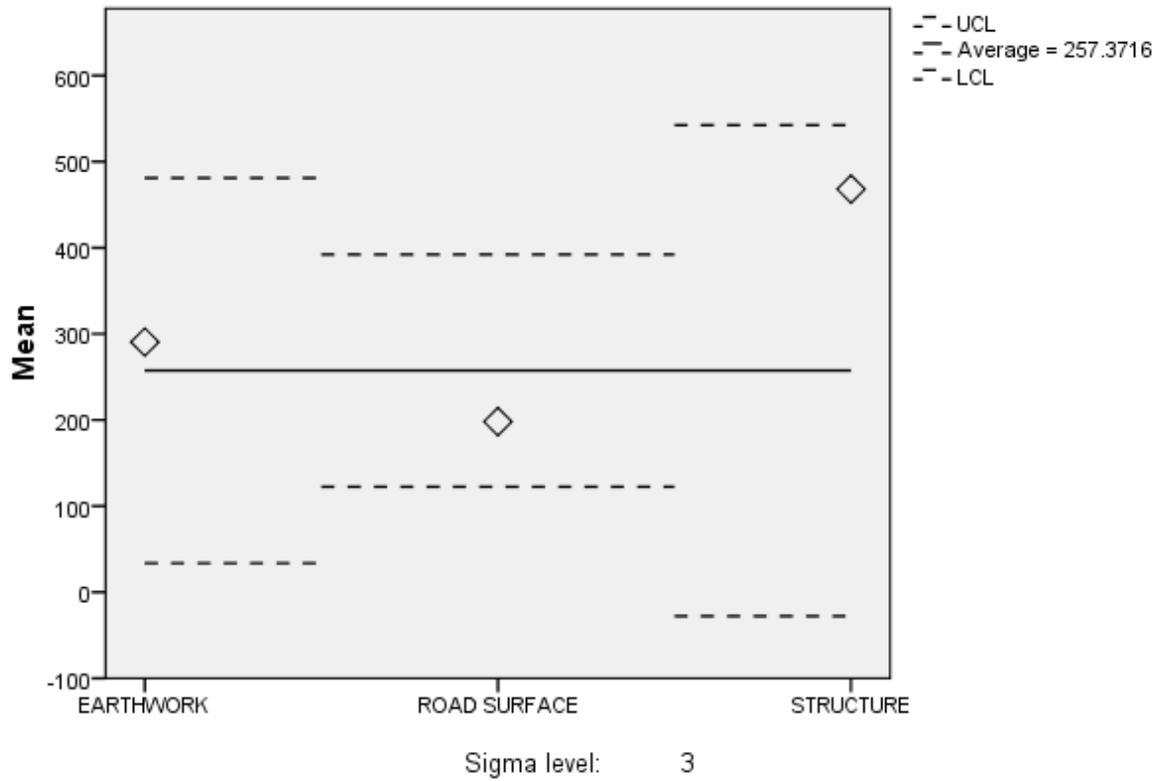


Figure J. 10 Sub - Code 6 Construction Type Impact

Control Chart: ConstType\_Impact

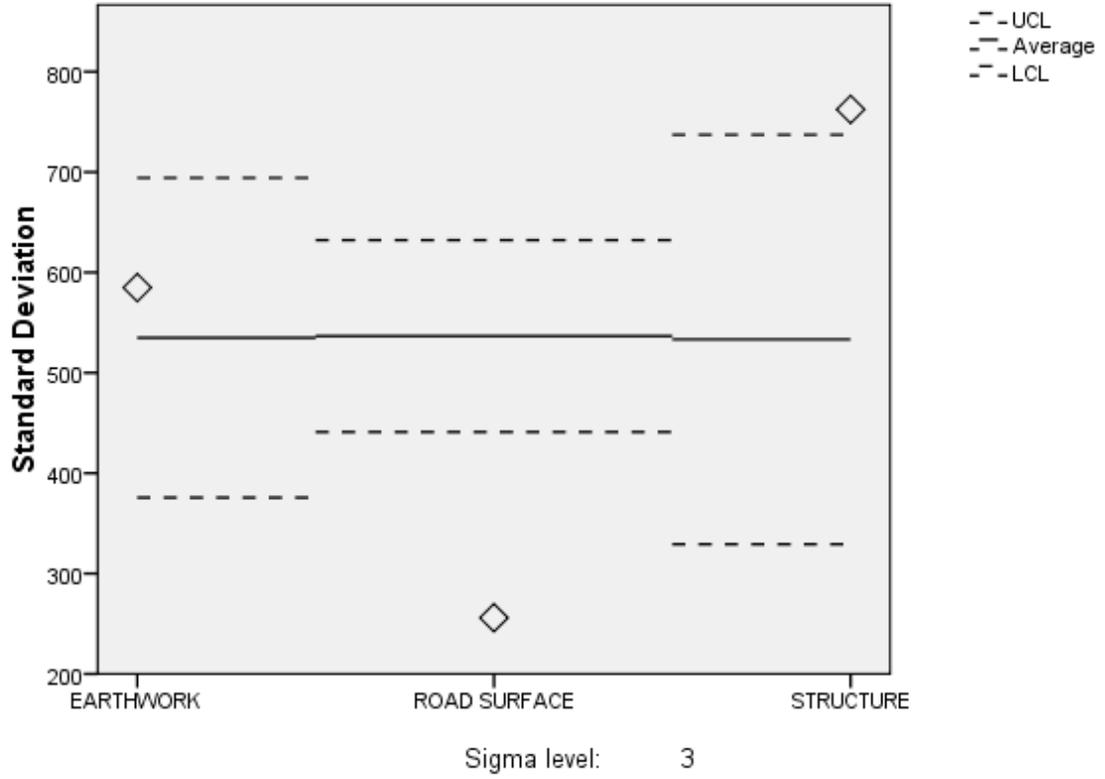


Figure J. 11 Sub - Code 6 Construction Type Impact – Standard Deviation

### Control Chart: ConstType\_Impact

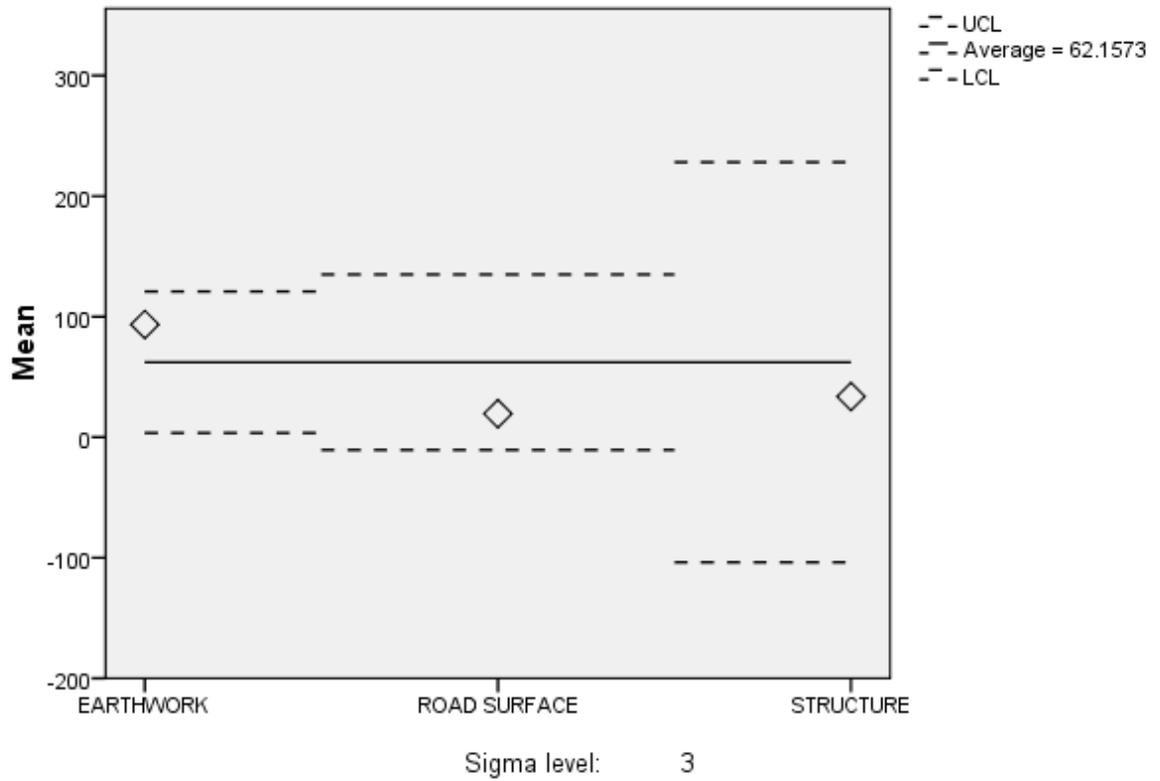


Figure J. 12 Sub - Code 7 Construction Type Impact

Control Chart: ConstType\_Impact

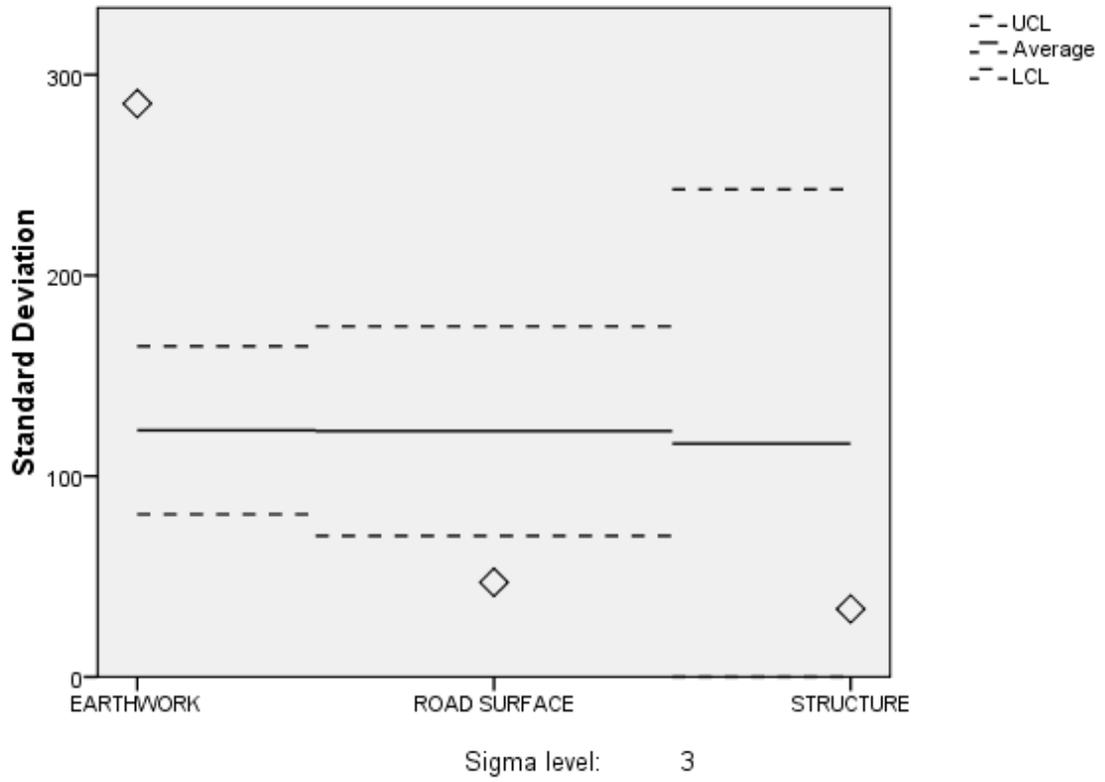


Figure J. 13 Sub - Code 7 Construction Type Impact – Standard Deviation

### Control Chart: ConstType\_Impact

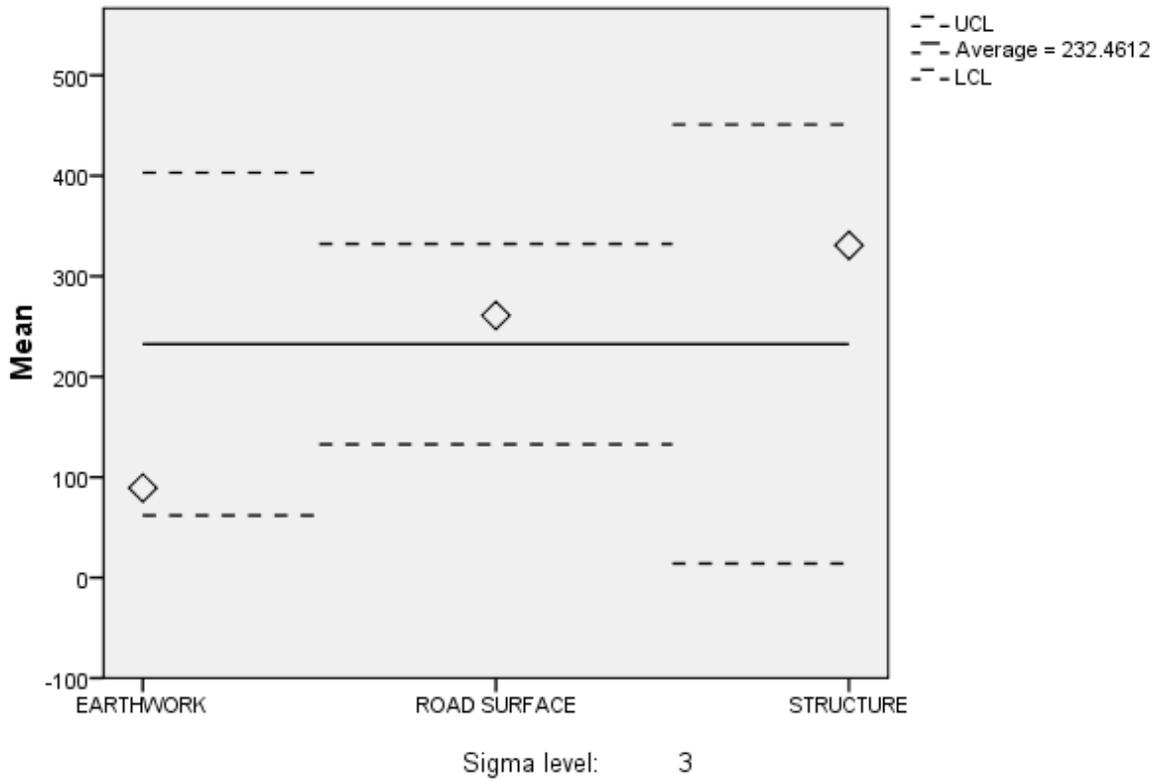


Figure J. 14 Sub - Code 8 Construction Type Impact

### Control Chart: ConstType\_Impact

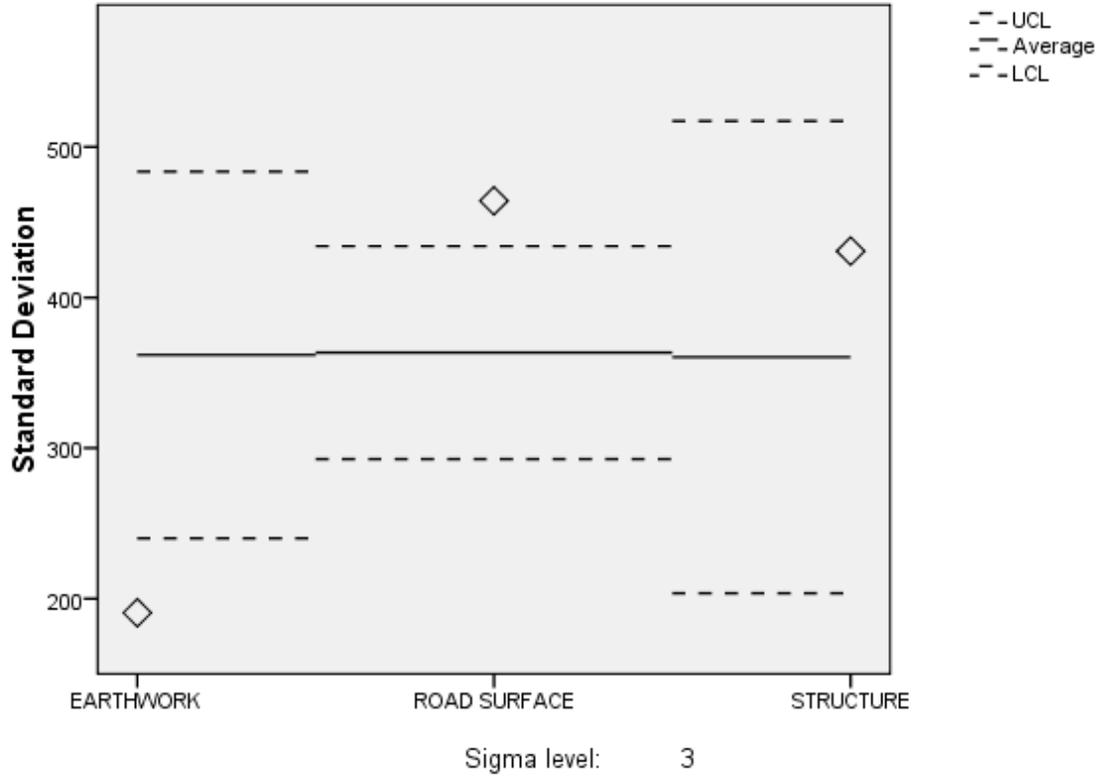


Figure J. 15 Sub - Code 8 Construction Type Impact – Standard Deviation

### Control Chart: ConstType\_Impact

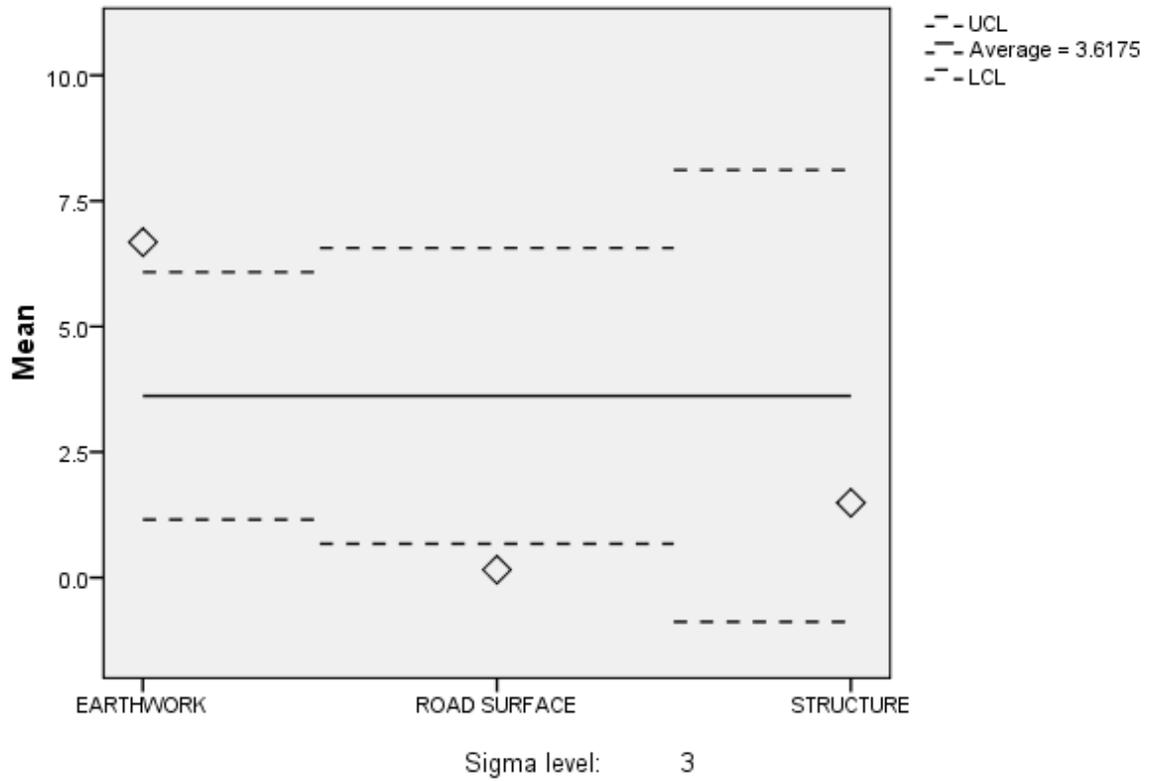


Figure J. 16 Sub - Code 9 Construction Type Impact

Control Chart: ConstType\_Impact

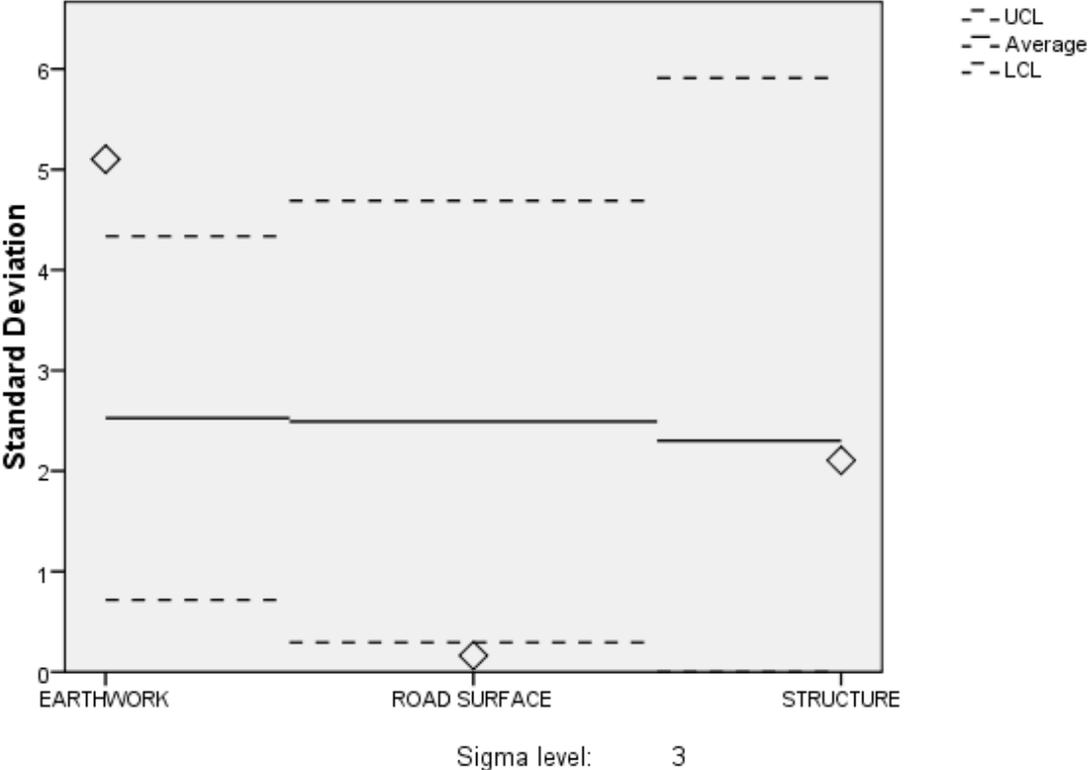


Figure J. 17 Sub - Code 9 Construction Type Impact – Standard Deviation

**18.0 Appendix K: Change Order Reference Cards**

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Quick Guide: Risk of **PERCENT CHANGE** by Reason Code and Road Type

| Reason Code | Description                | Road Type |   |    |     |    |
|-------------|----------------------------|-----------|---|----|-----|----|
|             |                            | CR        | I | KY | PW  | US |
| 1           | Asphalt Lot Pay Adjustment | ○         | ○ | ●  | ○   | ●  |
| 3           | Fuel & Asphalt Adjustment  | ●         | ● | ●  | ●   | ●  |
| 4           | Contract Omission          | ○         | ○ | ●  | ○   | ●  |
| 5           | Utility Issue              | ●         | ○ | ●  | --- | ○  |
| 6           | Contract Item Overrun      | ●         | ● | ●  | ●   | ●  |
| 7           | Geotechnical Issues        | ---       | ○ | ●  | ●   | ●  |
| 8           | Owner Induced Enhancement  | ●         | ● | ●  | ●   | ●  |
| 9           | Environmental Issues       | ---       | ○ | ●  | --- | ○  |

- Low Risk of % change from original contract amount      --- Data Insufficient
- Risk of % change from original contract amount
- Extreme Risk of % change from original contract amount

Figure K. 1 Risk of Percent Change by Reason Code and Road Type

Quick Guide: Risk of **PERCENT CHANGE** by Reason Code and District

| Reason Code | Description                | District |     |   |     |   |   |   |   |     |    |     |     |
|-------------|----------------------------|----------|-----|---|-----|---|---|---|---|-----|----|-----|-----|
|             |                            | 1        | 2   | 3 | 4   | 5 | 6 | 7 | 8 | 9   | 10 | 11  | 12  |
| 1           | Asphalt Lot Pay Adjustment | ○        | ○   | ● | ●   | ● | ○ | ● | ○ | ○   | ●  | ●   | ●   |
| 3           | Fuel & Asphalt Adjustment  | ●        | ●   | ● | ●   | ● | ● | ● | ○ | ●   | ●  | ○   | ○   |
| 4           | Contract Omission          | ●        | ○   | ● | ●   | ● | ● | ○ | ● | ○   | ●  | ○   | ○   |
| 5           | Utility Issue              | ●        | ○   | ○ | ●   | ○ | ○ | ○ | ○ | --- | ●  | ○   | ●   |
| 6           | Contract Item Overrun      | ●        | ●   | ● | ●   | ● | ● | ● | ● | ●   | ●  | ●   | ●   |
| 7           | Geotechnical Issues        | ●        | ○   | ○ | ●   | ● | ● | ● | ○ | ●   | ●  | --- | ●   |
| 8           | Owner Induced Enhancement  | ●        | ●   | ● | ●   | ● | ● | ● | ● | ○   | ●  | ●   | ●   |
| 9           | Environmental Issues       | ---      | --- | ● | --- | ○ | ○ | ● | ● | --- | ●  | ○   | --- |

- Low Risk of % change from original contract amount    --- Data Insufficient
- Risk of % change from original contract amount
- Extreme Risk of % change from original contract amount

Figure K. 2 Risk of Percent Change by Reason Code and District

Quick Guide: Risk of **PERCENT CHANGE** by Reason Code and New/Maintenance Projects

| Reason Code | Description                | New | Maintenance |
|-------------|----------------------------|-----|-------------|
| 1           | Asphalt Lot Pay Adjustment | ○   | ●           |
| 3           | Fuel & Asphalt Adjustment  | ●   | ●           |
| 4           | Contract Omission          | ○   | ●           |
| 5           | Utility Issue              | ○   | ●           |
| 6           | Contract Item Overrun      | ●   | ●           |
| 7           | Geotechnical Issues        | ●   | ●           |
| 8           | Owner Induced Enhancement  | ●   | ●           |
| 9           | Environmental Issues       | ●   | ○           |

- Low Risk of % change from original contract amount
- Risk of % change from original contract amount
- Extreme Risk of % change from original contract amount

Figure K. 3 Risk of Percent Change by Reason Code and New/Maintenance Projects

Quick Guide: Risk of **PERCENT CHANGE** by Reason Code and Construction Type

| Reason Code | Description                | Earthwork | Road Surface | Structures |
|-------------|----------------------------|-----------|--------------|------------|
| 1           | Asphalt Lot Pay Adjustment | ●         | ●            | ○          |
| 3           | Fuel & Asphalt Adjustment  | ●         | ●            | ●          |
| 4           | Contract Omission          | ○         | ●            | ●          |
| 5           | Utility Issue              | ●         | ○            | ○          |
| 6           | Contract Item Overrun      | ●         | ●            | ●          |
| 7           | Geotechnical Issues        | ○         | ●            | ●          |
| 8           | Owner Induced Enhancement  | ●         | ●            | ●          |
| 9           | Environmental Issues       | ●         | ○            | ●          |

- Low Risk of % change from original contract amount
  - Risk of % change from original contract amount
  - Extreme Risk of % change from original contract amount
- Earthwork: Grade & Drain, Flood/Slide Repair  
 Road Surface: Asphalt Surfacing, Asphalt Resurfacing, Jointed Plain Concrete  
 Structure: Bridge Work, Culvert Replacement, Guardrail, Pipe Replacement

Figure K. 4 Risk of Percent Change by Reason Code and Construction Type

Quick Guide: Risk of **IMPACT** by Reason Code and Road Type

| Reason Code | Description                | Road Type |   |    |     |    |
|-------------|----------------------------|-----------|---|----|-----|----|
|             |                            | CR        | I | KY | PW  | US |
| 1           | Asphalt Lot Pay Adjustment | ○         | ○ | ●  | ○   | ●  |
| 3           | Fuel & Asphalt Adjustment  | ●         | ● | ●  | ●   | ●  |
| 4           | Contract Omission          | ●         | ● | ●  | ●   | ●  |
| 5           | Utility Issue              | ●         | ○ | ○  | --- | ○  |
| 6           | Contract Item Overrun      | ●         | ● | ●  | ●   | ●  |
| 7           | Geotechnical Issues        | ---       | ○ | ●  | ●   | ●  |
| 8           | Owner Induced Enhancement  | ●         | ● | ●  | ●   | ●  |
| 9           | Environmental Issues       | ---       | ○ | ●  | --- | ○  |

- Low Risk of impact
- Risk of impact
- Extreme Risk of impact
- Data Insufficient

Figure K. 5 Risk of Impact by Reason Code and Road Type

Quick Guide: Risk of **IMPACT** by Reason Code and District

| Reason Code | Description                | District |     |   |     |   |   |   |   |     |    |     |     |
|-------------|----------------------------|----------|-----|---|-----|---|---|---|---|-----|----|-----|-----|
|             |                            | 1        | 2   | 3 | 4   | 5 | 6 | 7 | 8 | 9   | 10 | 11  | 12  |
| 1           | Asphalt Lot Pay Adjustment | ○        | ●   | ○ | ●   | ○ | ○ | ○ | ○ | ○   | ●  | ●   | ●   |
| 3           | Fuel Adjustment            | ●        | ●   | ● | ●   | ● | ● | ● | ● | ●   | ●  | ●   | ●   |
| 4           | Contract Omission          | ●        | ●   | ● | ●   | ● | ● | ● | ● | ●   | ●  | ●   | ●   |
| 5           | Utility Issue              | ●        | ○   | ○ | ○   | ○ | ● | ○ | ○ | --- | ●  | ○   | ●   |
| 6           | Contract Item Overrun      | ●        | ●   | ● | ●   | ● | ● | ● | ● | ●   | ●  | ●   | ●   |
| 7           | Geotechnical Issues        | ●        | ○   | ○ | ○   | ● | ● | ○ | ● | ●   | ●  | --- | ●   |
| 8           | Owner Induced Enhancement  | ●        | ●   | ● | ●   | ● | ● | ● | ● | ●   | ●  | ●   | ●   |
| 9           | Environmental Issues       | ---      | --- | ● | --- | ○ | ○ | ● | ● | --- | ●  | ○   | --- |

- Low Risk of impact
- Risk of impact
- Extreme Risk of impact
- Data Insufficient

Figure K. 6 Risk of Impact by Reason Code and District

Quick Guide: Risk of **IMPACT** by Reason Code and New/Maintenance Projects

| Reason Code | Description                | New | Maintenance |
|-------------|----------------------------|-----|-------------|
| 1           | Asphalt Lot Pay Adjustment | ○   | ●           |
| 3           | Fuel & Asphalt Adjustment  | ●   | ●           |
| 4           | Contract Omission          | ●   | ●           |
| 5           | Utility Issue              | ●   | ●           |
| 6           | Contract Item Overrun      | ●   | ●           |
| 7           | Geotechnical Issues        | ●   | ○           |
| 8           | Owner Induced Enhancement  | ●   | ●           |
| 9           | Environmental Issues       | ●   | ○           |

- Low Risk of impact
- Risk of impact
- Extreme Risk of impact

Figure K. 7 Risk of Impact by Reason Code and New/Maintenance Projects

Quick Guide: Risk of **IMPACT** by Reason Code and Construction Type

| Reason Code | Description                | Earthwork | Road Surface | Structures |
|-------------|----------------------------|-----------|--------------|------------|
| 1           | Asphalt Lot Pay Adjustment | ●         | ●            | ○          |
| 3           | Fuel & Asphalt Adjustment  | ●         | ●            | ●          |
| 4           | Contract Omission          | ●         | ●            | ●          |
| 5           | Utility Issue              | ●         | ○            | ○          |
| 6           | Contract Item Overrun      | ●         | ●            | ●          |
| 7           | Geotechnical Issues        | ●         | ○            | ○          |
| 8           | Owner Induced Enhancement  | ●         | ●            | ●          |
| 9           | Environmental Issues       | ●         | ○            | ○          |

- Low Risk of impact
- Risk of impact
- Extreme Risk of impact

Earthwork: Grade & Drain, Flood/Slide Repair  
 Road Surface: Asphalt Surfacing, Asphalt Resurfacing, Jointed Plain Concrete  
 Structure: Bridge Work, Culvert Replacement, Guardrail, Pipe Replacement

Figure K. 8 Risk of Impact by Reason Code and Construction Type

**19.0 Appendix L: High Risk Change Order Items Charts**

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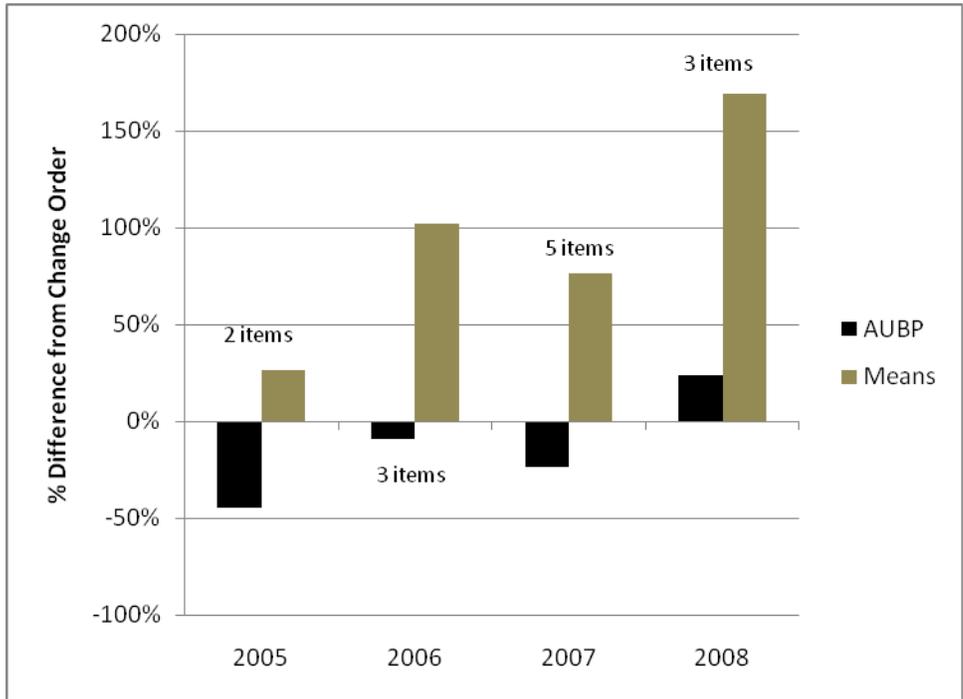
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**Figure L. 1 Average % Difference between approved change order cost and estimated cost using Average Unit Bid Price (AUBP) and Means for Barricades**

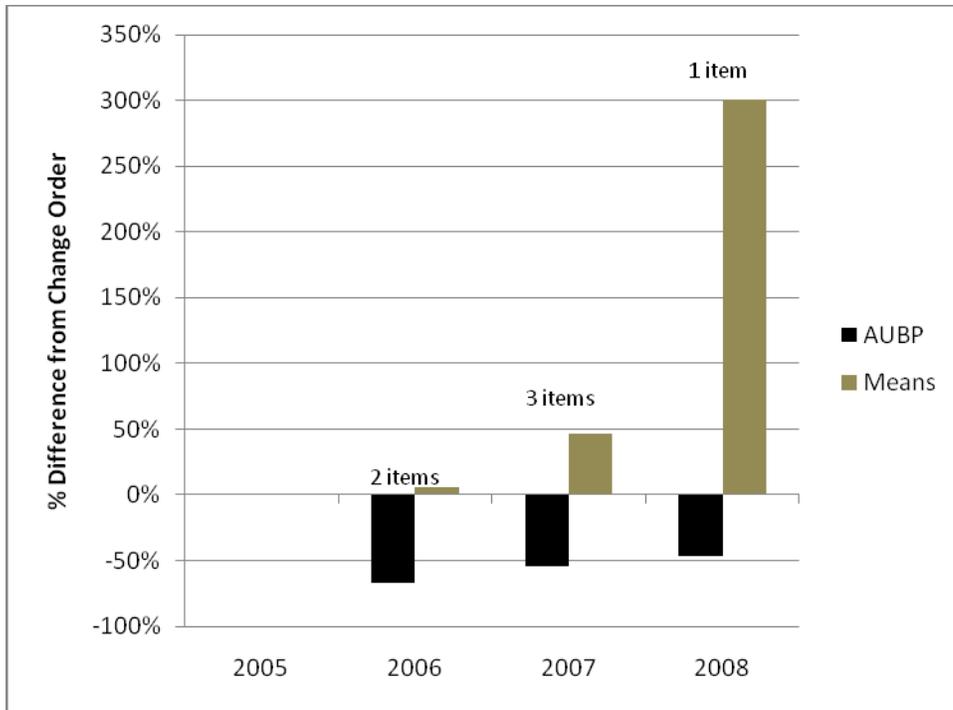


Figure L. 2 Average % Difference between approved change order cost and estimated cost using Average Unit Bid Price (AUBP) and Means for Concrete Barrier Wall

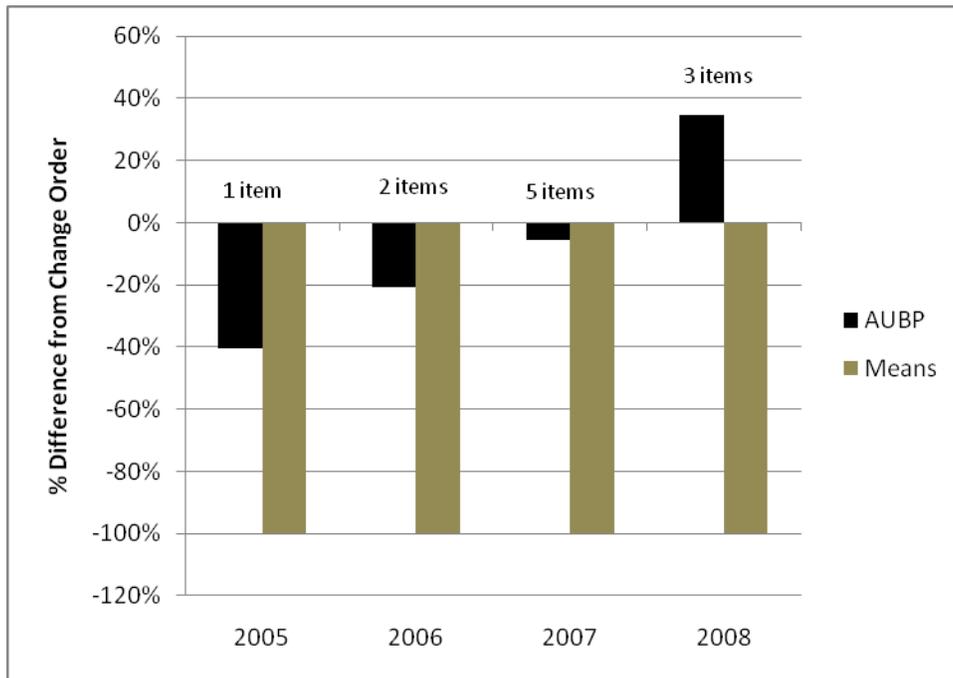


Figure L. 3 Average % Difference between approved change order cost and estimated cost using Average Unit Bid Price (AUBP) and Means for Crash Cushions

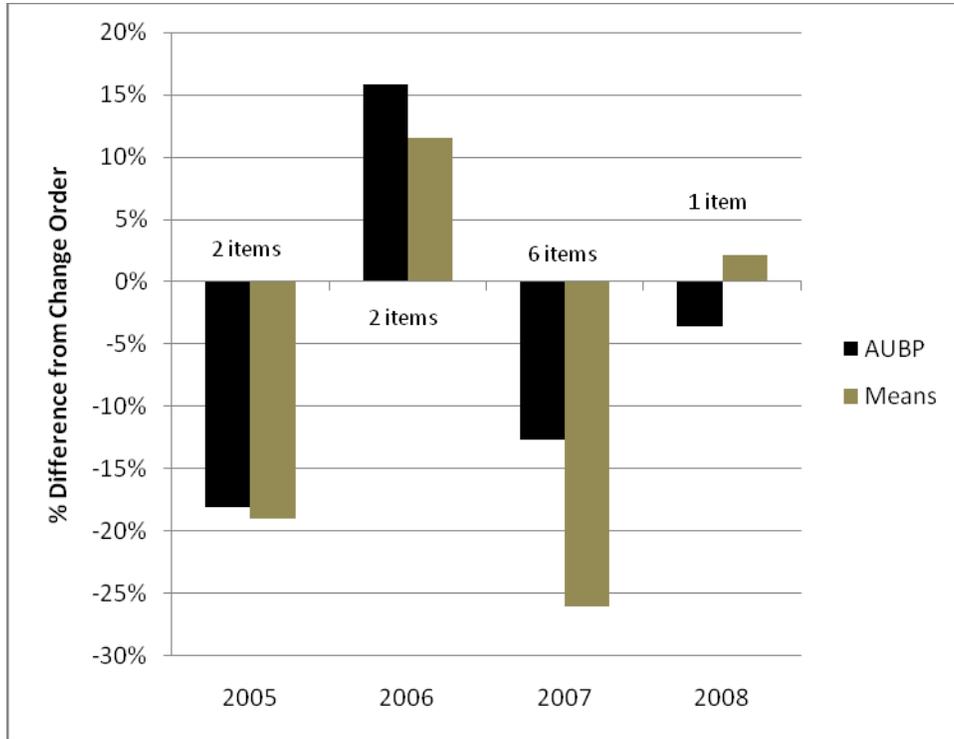


Figure L. 4 Average % Difference between approved change order cost and estimated cost using Average Unit Bid Price (AUBP) and Means for Delimiters for Guardrails and Barriers

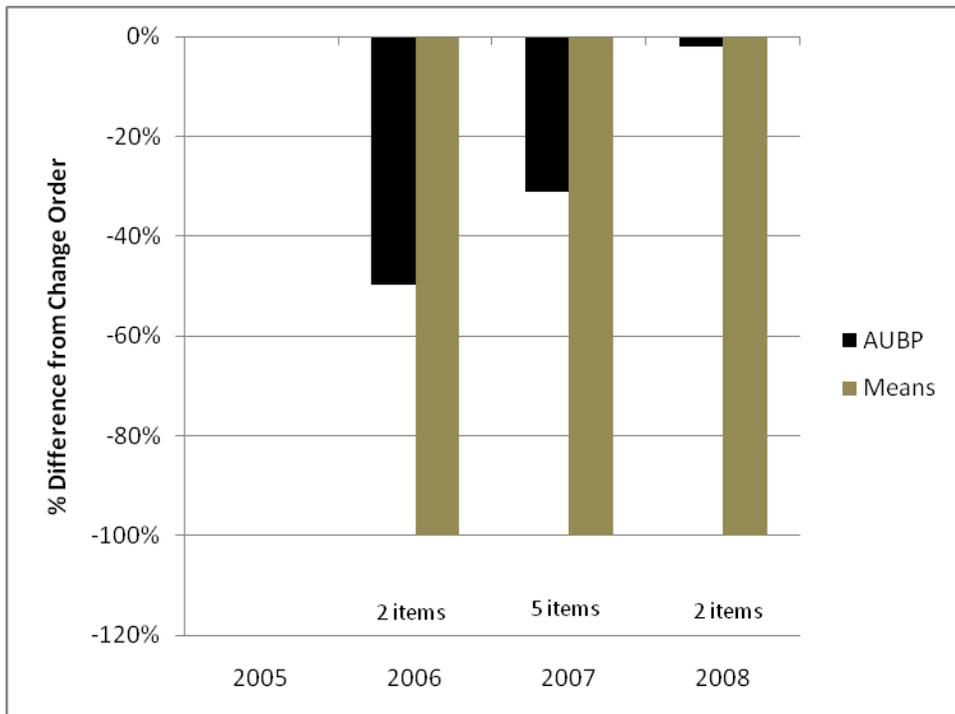


Figure L. 5 Average % Difference between approved change order cost and estimated cost using Average Unit Bid Price (AUBP) and Means for Extra Length Guardrail Post

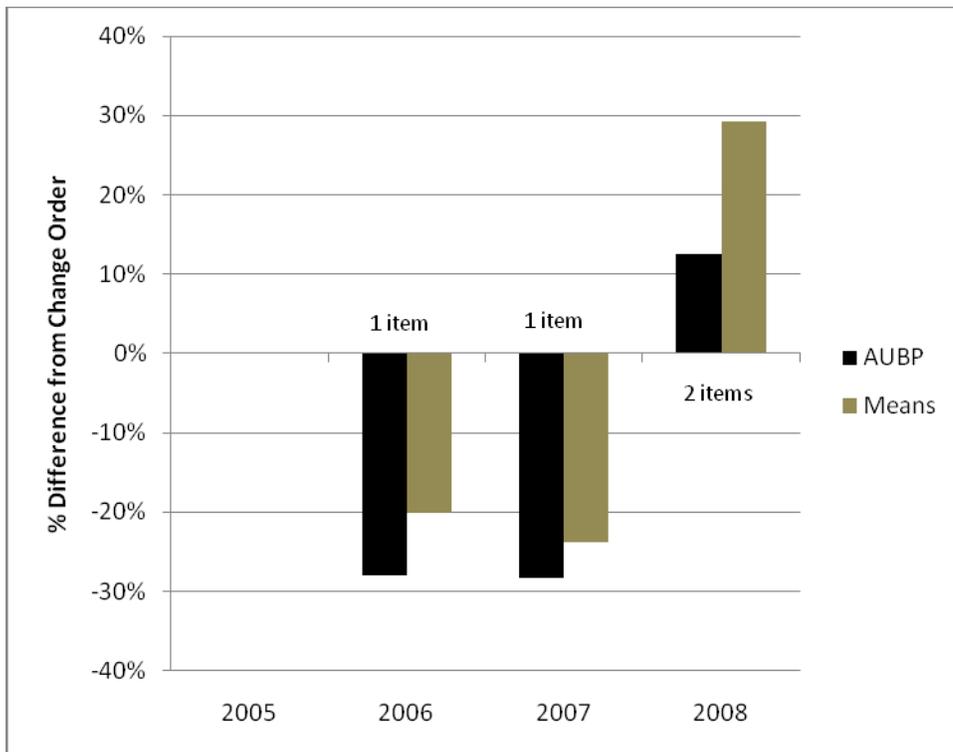


Figure L. 6 Average % Difference between approved change order cost and estimated cost using Average Unit Bid Price (AUBP) and Means for Flexible Delineator Post

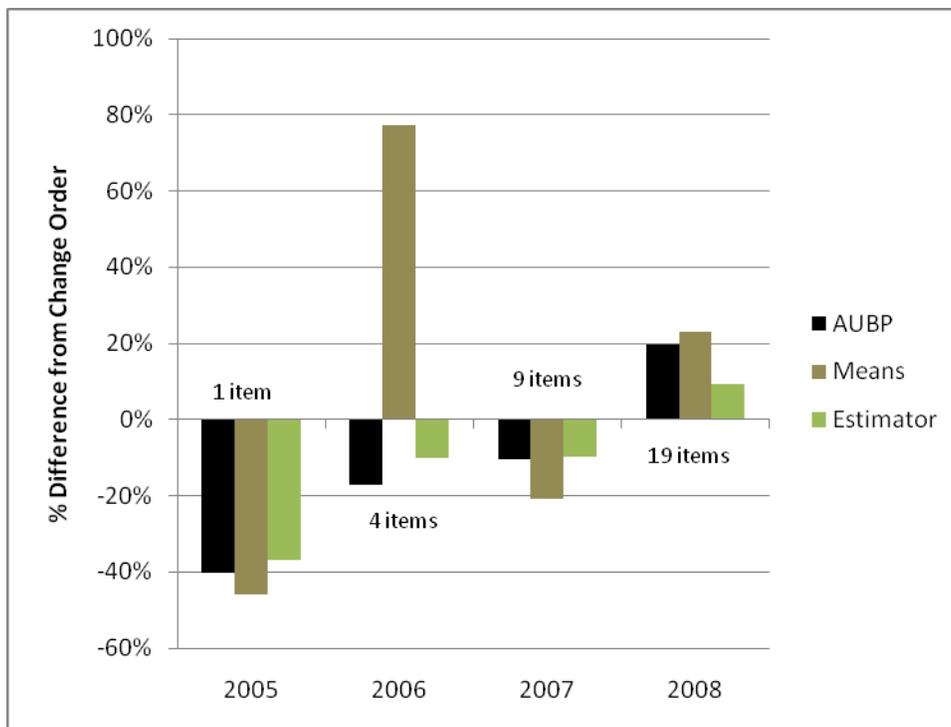


Figure L. 7 Average % Difference between approved change order cost and estimated cost using Average Unit Bid Price (AUBP), Means and Estimator for Guardrail Connector to Bridge End

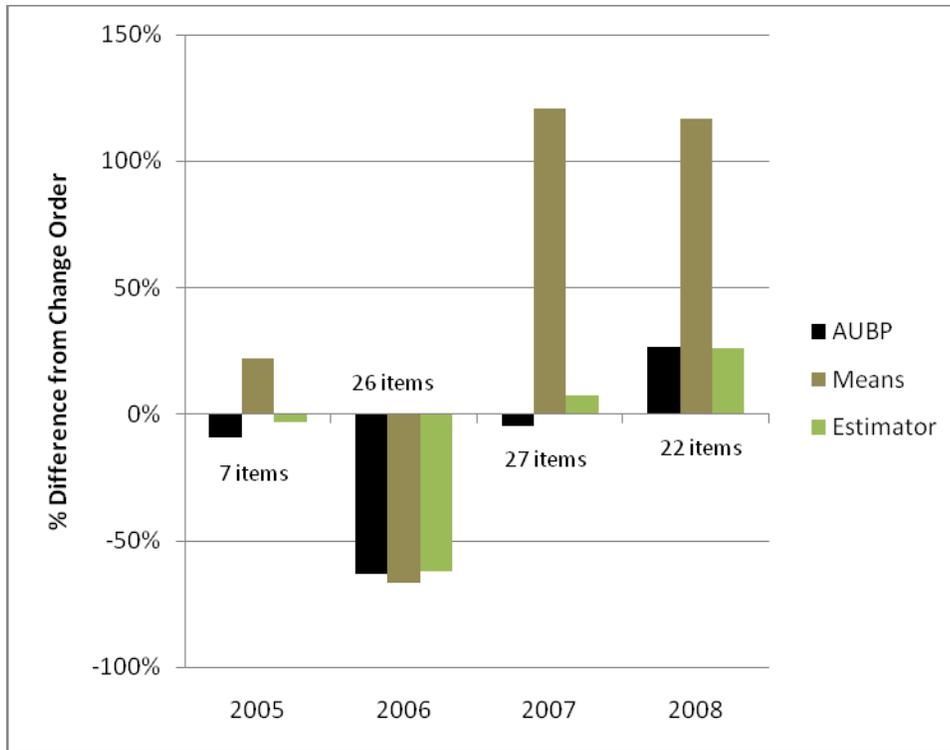


Figure L. 8 Average % Difference between approved change order cost and estimated cost using Average Unit Bid Price (AUBP), Means, and Estimator for Guardrail End Treatment

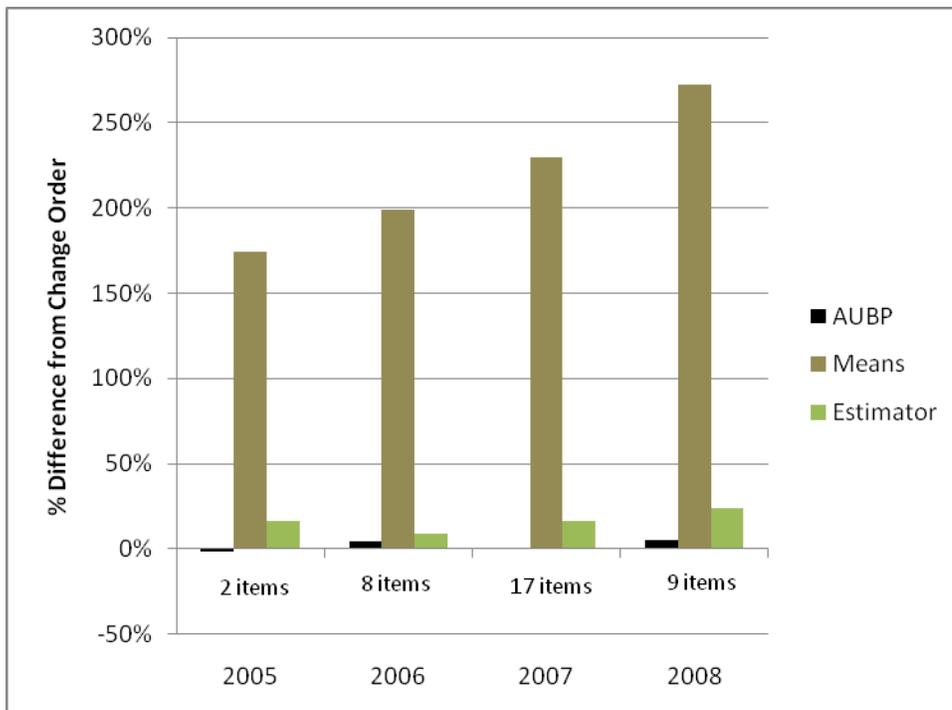


Figure L. 9 Average % Difference between approved change order cost and estimated cost using Average Unit Bid Price (AUBP), Means, and Estimator for Guardrail Terminal Sections

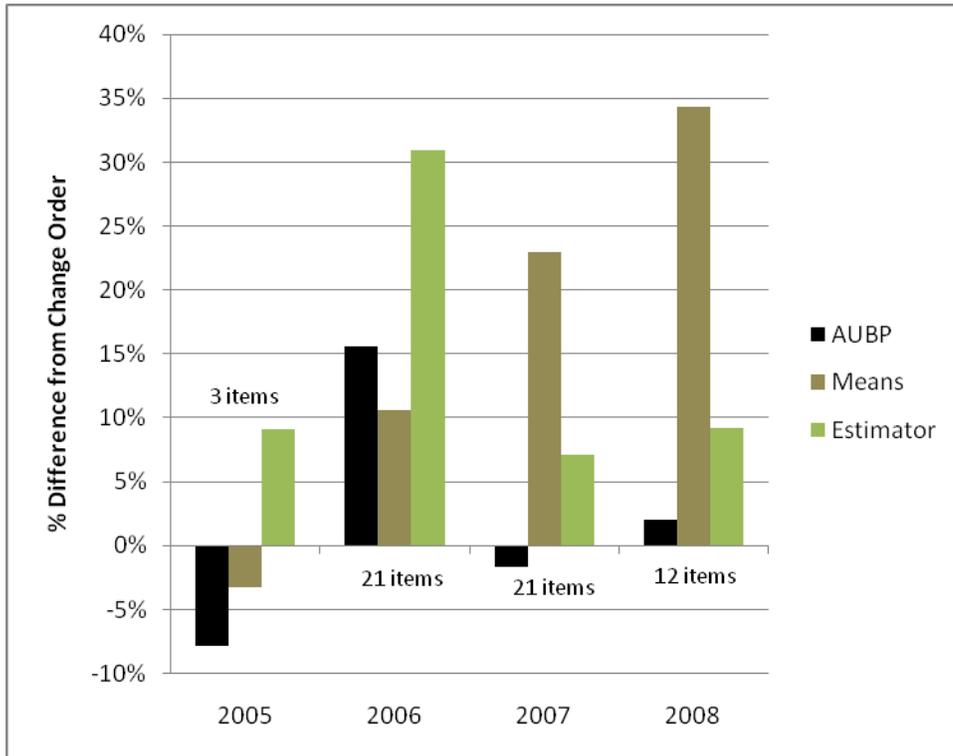


Figure L. 10 Average % Difference between approved change order cost and estimated cost using Average Unit Bid Price (AUBP), Means and Estimator for Guardrail-Steel W Beam

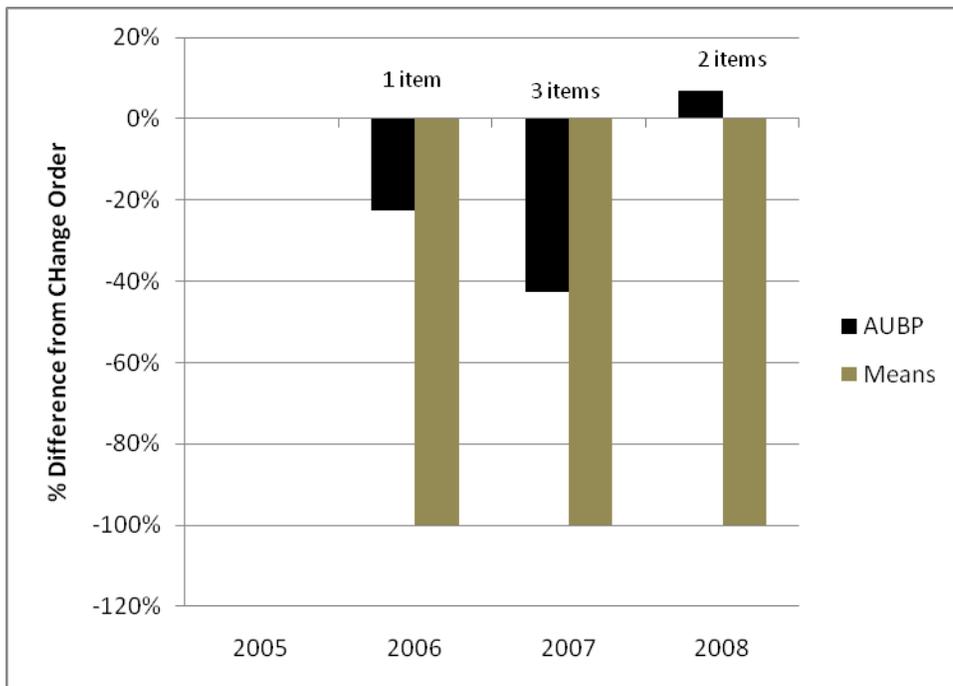
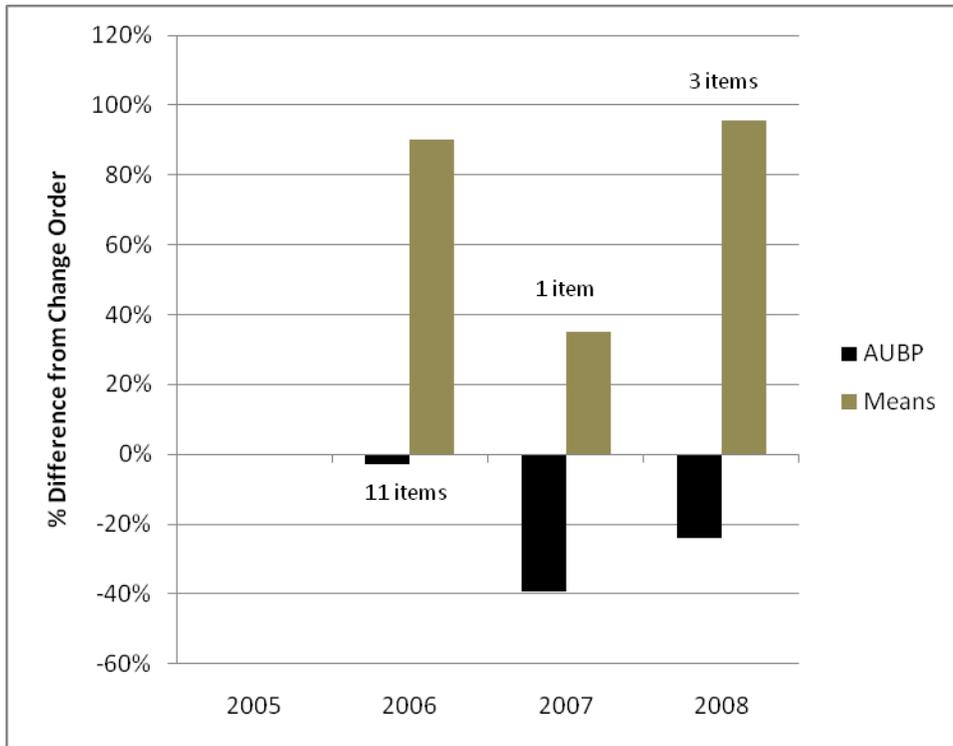
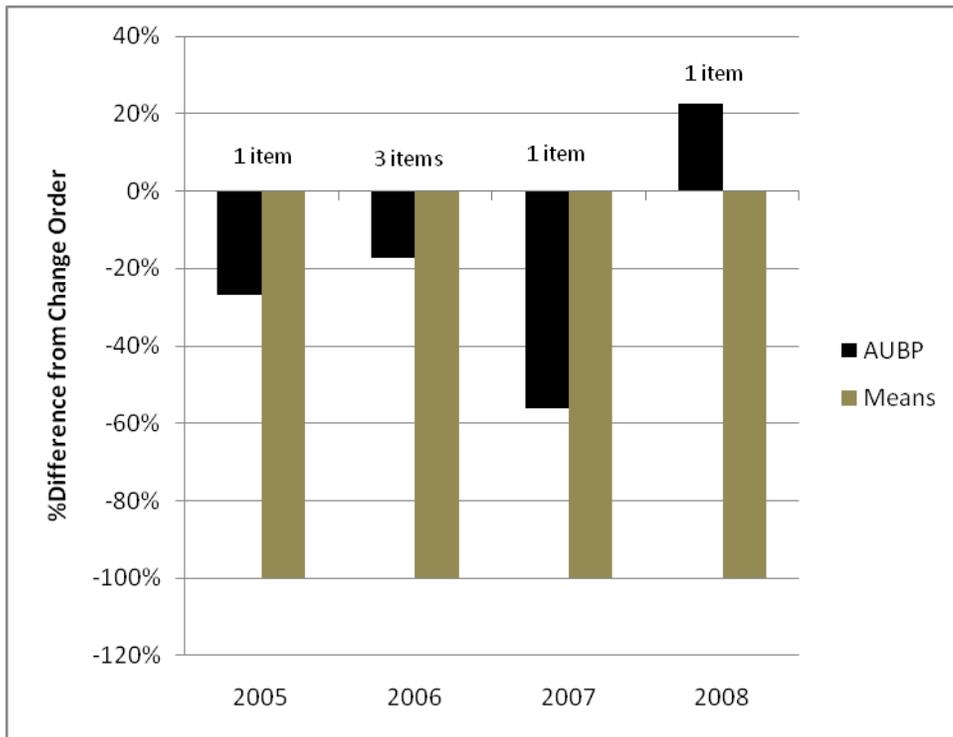


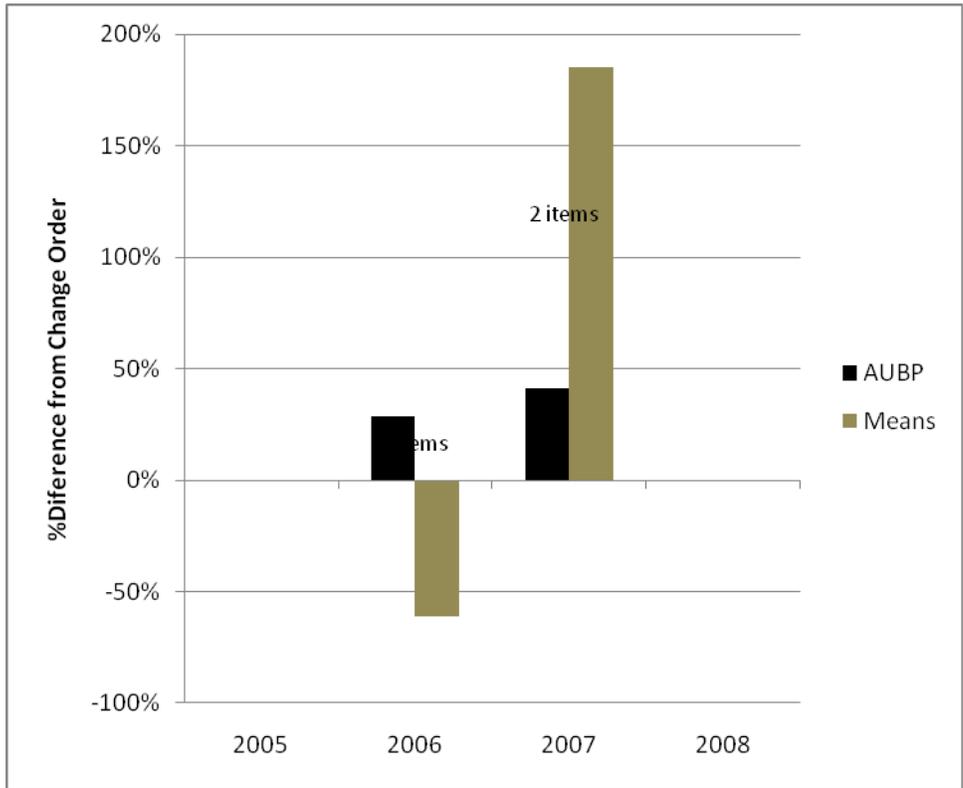
Figure L. 11 Average % Difference between approved change order cost and estimated cost using Average Unit Bid Price (AUBP) and Means for Relocating Crash Cushions



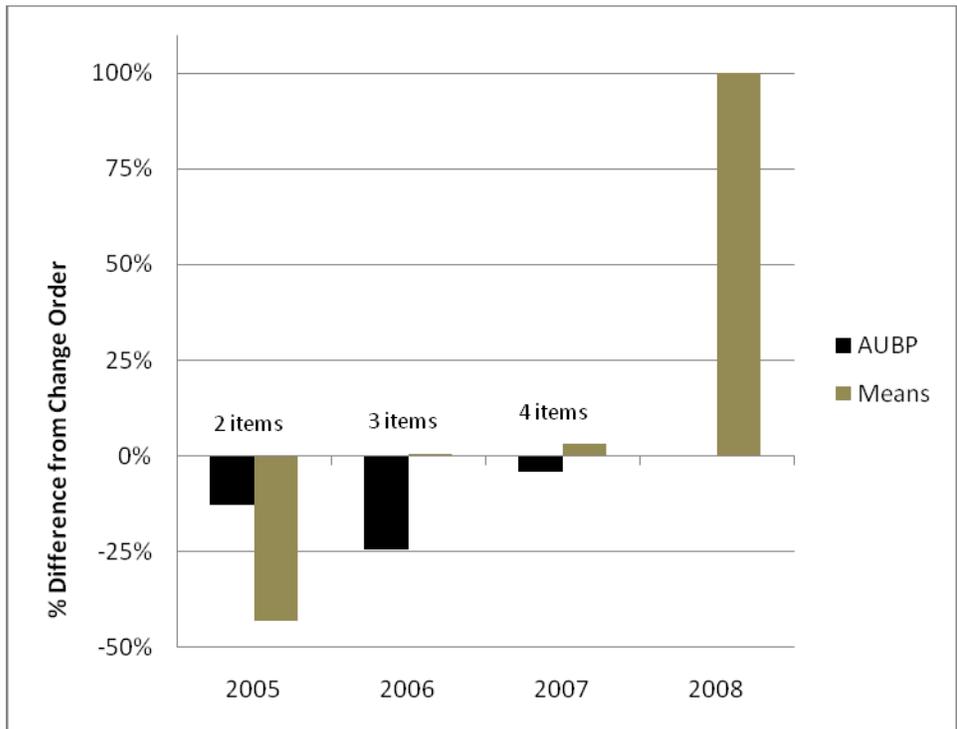
**Figure L. 12 Average % Difference between approved change order cost and estimated cost using Average Unit Bid Price (AUBP) and Means for Removing and Resetting Guardrail**



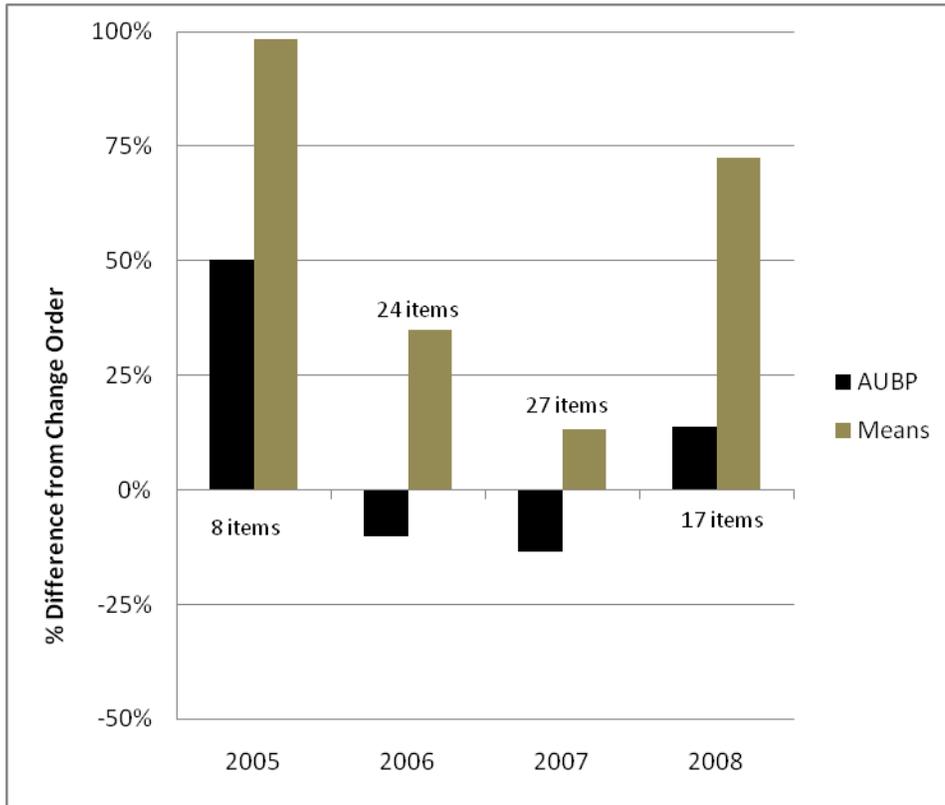
**Figure L. 13 Average % Difference between approved change order cost and estimated cost using Average Unit Bid Price (AUBP) and Means for Removing Guardrail End Treatment**



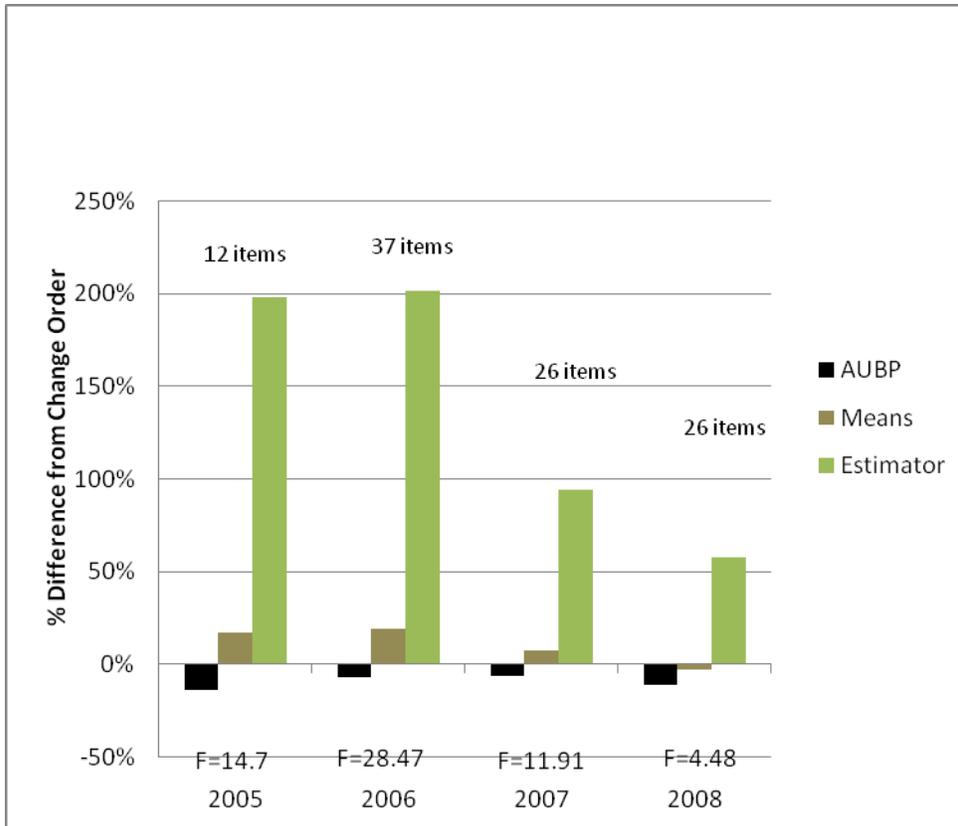
**Figure L. 14 Average % Difference between approved change order cost and estimated cost using Average Unit Bid Price (AUBP) and Means for Temporary Guardrail**



**Figure L. 15 Average % Difference between approved change order cost and estimated cost using Average Unit Bid Price (AUBP) and Means for Asphalt Mix for Pavement Wedge**



**Figure L. 16 Average % Difference between approved change order cost and estimated cost using Average Unit Bid Price (AUBP) and Means for Asphalt Pavement Milling & Texturing**



**Figure L. 17 Average % Difference between approved change order cost and estimated cost using Average Unit Bid Price (AUBP), Means, and Estimator for Asphalt Bases, Surfaces & Binders**

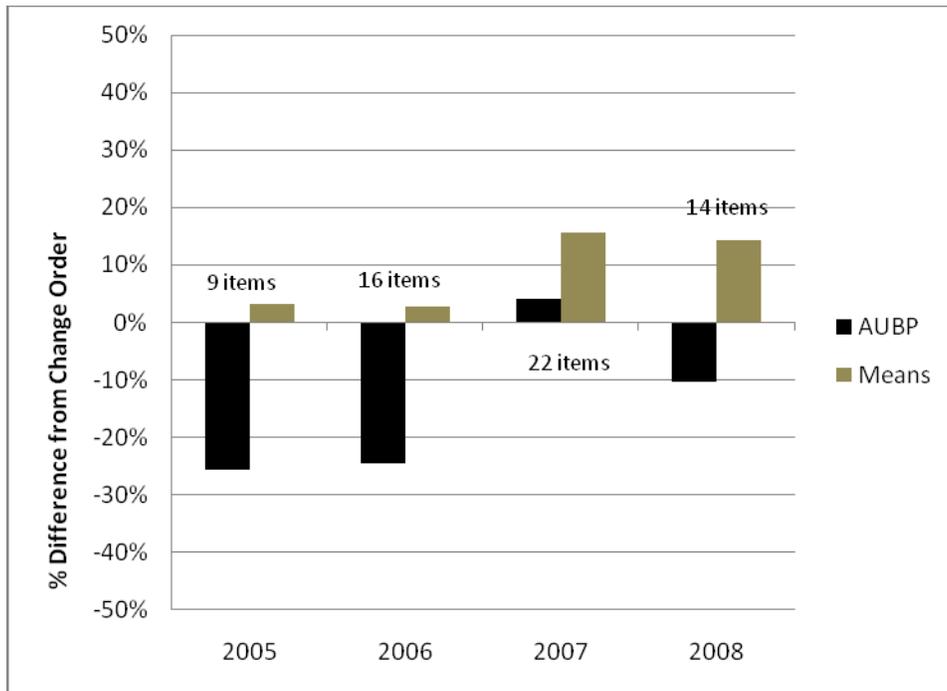
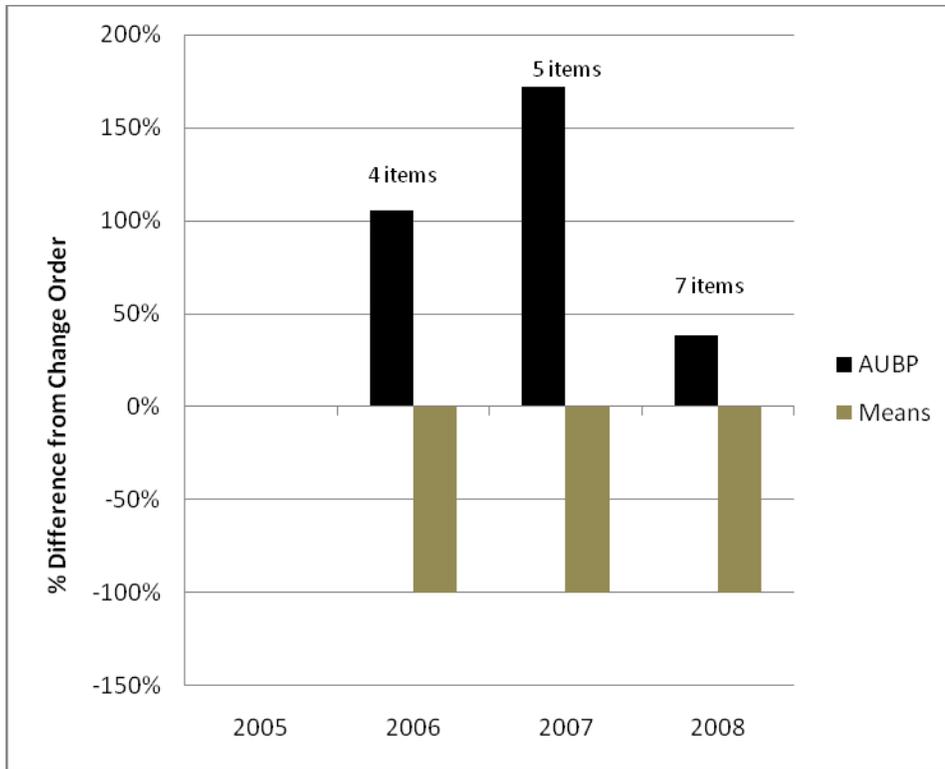


Figure L. 18 Average % Difference between approved change order cost and estimated cost using Average Unit Bid Price (AUBP) and Means for Leveling and Wedging



**Figure L. 19 Average % Difference between approved change order cost and estimated cost using Average Unit Bid Price (AUBP) and Means for Mobilization for Milling & Texturing**

## 22.0 Appendix M: Proposed Change Order Pricing Model

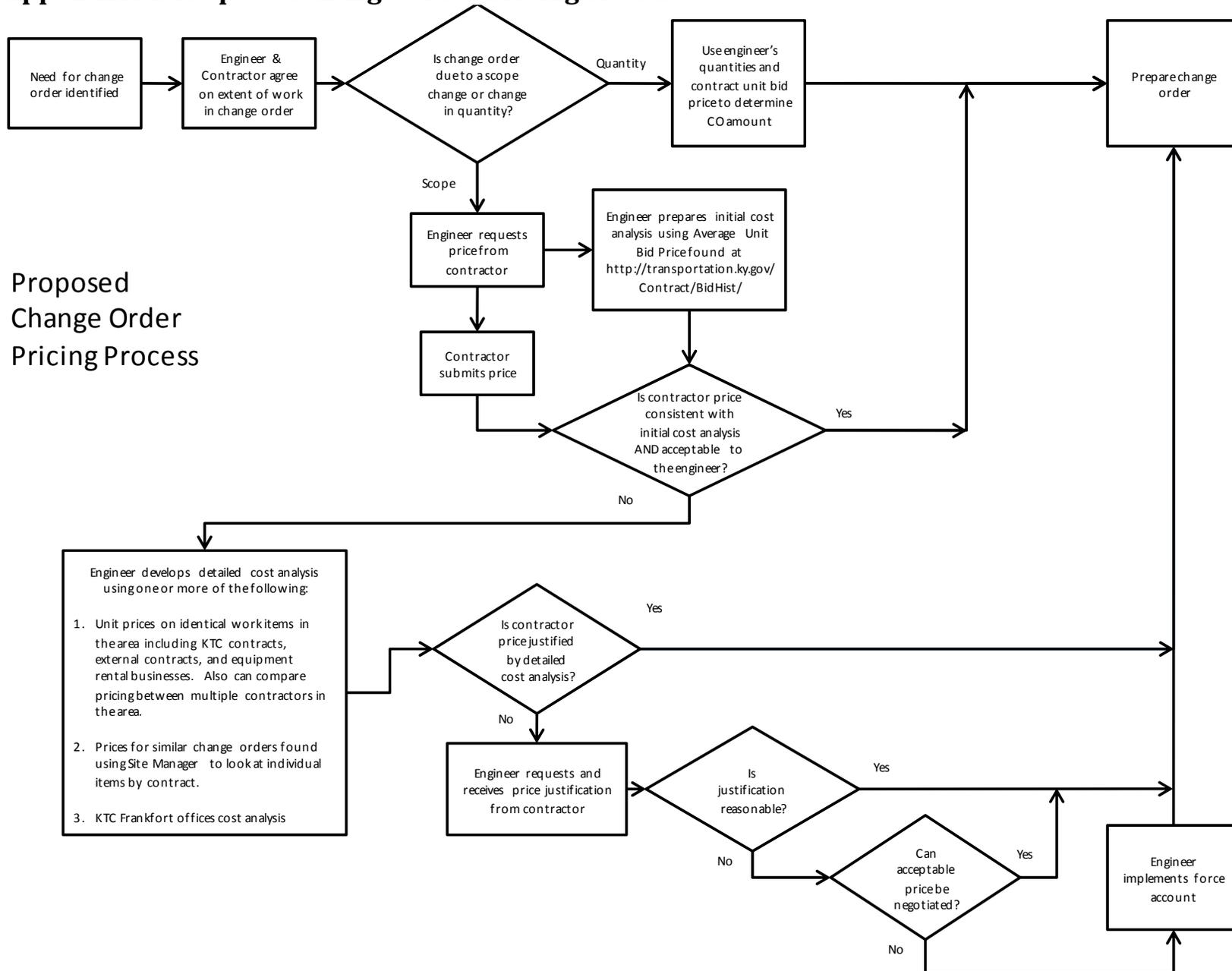


Figure M. 1

## **23.0 Appendix N: KTC Change Order Questionnaire**

### **KTC Change Order Research Interview Questions**

#### **Information for the Interviewee**

The goal of this study is to examine the cause and effects of construction change orders on transportation projects in Kentucky. With the effect understood, understanding how to effectively administer construction change orders through proper pricing by the Cabinet is needed to ensure proper stewardship of state funds for executing the change orders.

The following objectives have been identified for this study:

Analyze the leading causes of change orders on Kentucky transportation projects.

Identify project characteristics that are correlated with higher frequency and magnitude of construction change orders.

Identify best practices within the Cabinet, other state transportation agencies, and through existing research for pricing construction change owner on behalf of the transportation agencies or other owner types.

This interview will focus on the processes, techniques, and methodologies used to prepare estimates for contract cost and time adjustments. Data collected from this interview will be reported in aggregate to maintain the confidentiality of the interviewee.

#### **General Information**

Interviewee:

Interviewee Title:

Interviewer(s):

Date:

Location:

### **Interview Questions**

- 1) Do you have a process that you use when preparing change order cost and time adjustment estimates (e.g. scoping, quantifying, etc.)?

If a formal process is used, can we have a copy of the process?

Are there any elements of this process that you feel could be improved?

Could you provide us an example of this process (e.g. calculations, change order, etc.)?

- 2) When estimating contract cost and time adjustments, what data do you use? How do you determine quantities?
- 3) In your opinion, what are the most challenging aspects of estimating contract cost and time adjustments?
- 4) Is there any additional information that we may not have inquired about that you feel would be beneficial to the research?

### **Additional Misc. Questions**

- 5) Do you have different process for large vs. small change orders? Maintenance vs. new construction?
- 6) Do you use different processes for estimating contract cost and time adjustments for different types of change orders (e.g. geotech vs. a fuel adjustment change order)?
- 7) What level of detail do you employ when estimating contract cost and time adjustments?
- 8) Do you draw on support from other state personnel when preparing contract cost and time estimates for change orders (e.g. design personnel, right of way engineers, bridge design engineers, etc.)?
- 9) What type of contingency plan do you use if an impasse is reached with the contractor during contract cost and time adjustment negotiations?
- 10) Is there an official hierarchy for change order approval related to the dollar value/time extension of the change order?

## 24.0 Appendix 0: Change Order Personnel Interview Summary

**Date:** 9/2009 – 12/2009

**Interviewers:** Paul Goodrum, Tim Taylor, Bill Lester

### I. Change Order A. Policies

1. In previous administration change orders had to be signed by contractor before approval given. (Interview #2)
2. Current administration the section engineer will review the price and determine if the money may already exist on another item of the project that may be under run and work off a verbal approval. (Interview #2)
3. This is followed by a standard letter on that same day that indicates that the final approval will be given later that work can commence. (Interview #2)
4. Two types of change orders: change in unit price and changes in quantities. (Interview #2)
5. When contractor and engineer cannot agree on price, engineer requests a justification for the change order price. (Interview #2)
6. If cannot agree on price, then the engineer will do cost plus. (Interview #2)
7. In extreme case if added work is so far out of scope, a new contract will be issued. (Interview #2)
8. Fixed completion date of working day are the two primary types of duration requirements. (Interview #2)
9. Contractors required to submit CPM diagram. (Interview #2)
10. Have to justify prices for change orders. Had to explain where the cost and quantities came from. (Interview #5)
11. Their specification for estimating time for a change order is to use the change order ratio (change cost/ original cost)\*original duration. (Interview #5)
12. Change order is defined as something that happens during construction. Changes originated when design phase is still being determined from schematics are not considered change orders. (Interview #6)
13. If total project including change orders is less than \$250,000 they will handle in house. Typical change orders range from \$6,000 to \$10,000. (Interview #6)
14. A unit price contractor is used which is a line item pricing from the Means. (Interview #6)
15. Only thing being negotiated is the takeoff quantity. (Interview #6)

16. Any project above \$600,000 has to have any change orders approved by the UK Board or as a budgeted line item by the State of Kentucky. (Interview #6)

## **B. Procedures**

1. Uses a cost/time ratio to determine the required time adjustment for extensions of time. (Interview #1)
2. Same process is used for small versus large change order. (Interview #1)
3. No difference on pricing change orders on maintenance vs. new construction. (Interview #1)
4. Engineer drafted a procedure for writing a change order. (Interview #2)
5. Basic procedure is that section engineer will draft the change order and the branch manager will review and approve. (Interview #2)
6. Final approval of a change order is granted by Cabinet's liaison in Frankfort. (Interview #2)
7. Change order is reviewed by contractor for negotiation and agreement. (Interview #2)
8. For cost plus the Cabinet uses an equipment website to price equipment, contractor provides payroll, invoices for material and then approximately 10% markup added. (Interview #2)
9. Any work day that falls on a holiday or weekend would not be charged a working day for time extensions. (Interview #2)
10. If the weather cancels a critical path item, the project would not be charged a working day. (Interview #2)
11. Half working days can be charged if only 4 hours are worked and then the weather shuts down the project. (Interview #2)
12. For force account work, the contractor and engineer agree to what the work was and both will sign daily sheets to confirm. Engineer will work up costs and get a final number. (Interview #3)
13. When justifying prices, if the bid price is used for a line item then just extend the unit price to cover the added costs. (Interview #5)
14. If change order is for a new item then it is best to look at other projects in Site Manager for comparable item. (Interview #5)
15. For time adjustments, if there is a CPM schedule they will look to see if the activity for the change order falls on the critical path for guidance. (Interview #5)
16. When a change order arrives at Central Office the district liaisons will keep an eye on the change order for funding. They will keep central office informed on the pending change order. A verbal approval will be sought from appropriate sources. Change order director will check to see if funding is available. (Interview #5)
17. Two people are dedicated to takeoff estimation for change orders. (Interview #6)

18. All estimating for change orders done out of Timberline software excluding items such as glass, fire alarms and some other items. These items are negotiated. (Interview #6)
19. GC/Contractor typically handles reconfiguration and reconditioning projects. (Interview #6)
20. As change orders revise the schedule and are given approval, the project schedule is updated. (Interview #6)
21. If contractor comes to director with change order for time extension, then it will be analyzed and approved. If not approved, renegotiating will be required. Timberline software will give hours added for change orders and crew size recommended. (Interview #6)

### C. Practices

#### *Anticipation of Change Orders*

1. It is very preferable for resident engineer to be proactive in identifying the need for the change order. (Interview #1)
2. If overrun is seen coming, the resident engineer should try to have the change order written ahead of time to avoid delays. (Interview #2)
3. If he anticipates the change order before it happens he will try to coordinate with the contractor. He says the contractor tends to give a standard breakdown of 1/3 labor, 1/3 material, and 1/3 overhead. (Interview #3)

#### *Identification of Price*

4. Once the need is identified, he will identify the pay item with the contractor. (Interview #1)
5. When the engineer receives a change order he tries to get the price settled first. (Interview #3)
6. Once the engineer requests a price from the contractor on a change order request, he will identify an average unit bid price to compare with the contractor's request. (Interview #1)
7. Engineer will ask for breakdown from contractor. If price seems reasonable then he will use the price. He will also compare the price to the average unit bid price and if it is around 10% difference then he will usually use that. (Interview #3)
8. The field can issue a change order based on the state average bid unit price, plus or minus 10%. If the unit price is higher than this, then he asks for a cost break down. He is careful to examine that the actual resources coincide with their price. (Interview #4)

#### *Price Breakdown*

9. Sometimes the contractor only gives the price breakdown when requested from the engineer. (Interview #3)

10. If he still cannot find a price to compare to he will fall back to the cost breakdown provided by the contractor. If it is a supplemental item he will always request a cost breakdown. (Interview #4)
11. He will ask for justifications of price but finds them useless because he feels the contractor can justify about anything. (Interview #1)

#### *Scope Control Issues*

12. For issues with scope, the engineer will most of the time try to send the change order to the contractor so that they both agree on the scope. (Interview #4)
13. Scope control should be negotiated during the justification process. (Interview #5)
14. The engineer will walk the site with the contractor to better understand the contractor's issues. (Interview #1)

#### *Use of Cost Plus/Force Account*

15. If the original approach of negotiating a price does not work, he will use cost-plus system. (Interview #1)
16. For cost plus, it is best to have a cost breakdown so they can look at manpower requirements. The engineer will look at bluebook rates for comparing hourly rates. (Interview #3)
17. Engineer will try to match up payrolls to the hours stated on the paper work for force account. Equipment and materials are not as hard to verify because you have invoices. (Interview #3)
18. Normally he will determine the quantities for the change order. (Interview #1)
19. For force account work, there used to be no issue with final numbers worked up by engineer. But recent specifications have put all the work up of numbers back in the hands of the contractor. They are supposed to come up with numbers and then the engineer will verify them. But contractors will not produce timely numbers. (Interview #3)

#### *Determination of Prices/Average Unit Bid Price*

20. He will use Site Manager to compare unit prices on projects that occurred locally. (Interview #1)
21. Engineer will compare prices submitted by contractor to 2008 prices in database but if needed will fall back to previous years to find item. (Interview #4)
22. If there are overruns, then the contractor's unit bid prices are typically used. In these cases, the engineer will work on justifying the quantities. (Interview #4)
23. If change order item is an overrun, there is no question on unit pricing. (Interview #2)
24. Engineer has used invoices from other jobs to attain a price especially if it involves more material than labor. He can't validate the labor

- prices. However, most projects are scaled (Davis-Bacon Wages) so it is contradictory that labor is difficult to estimate. (Interview #4)
25. Has not always accepted price from contractor and has made them take his price calculation. (Interview #4)
  26. Price comparisons to maintenance contract are another method for price comparison. This has come about from section engineers overseeing both construction and maintenance. (Interview #5)
  27. To find pricing of other contractors, he will pull separate contracts in site manager and look for bid item in question. (Interview #2)
  28. He will use Cabinet's website to find average unit bid price for previous and or current year of letting. (Interview #2)
  29. Sometimes engineer will use a weighted average in referencing the average unit bid price database so that he adjusts for smaller quantities to adjust for a higher price. (Interview #4)

#### *Time Extension Issues*

30. In settling disputes about time adjustments he will seek input from branch manager or central office construction about the reasonability of a given price. (Interview #1)
31. If weather or utilities shut down the critical path activity, an extension in working days can be granted. (Interview #2)
32. If change order involves additional work then more days are added. (Interview #2)
33. Specifications say the contractor gets one extra day out of a change order. Engineer will check with resident engineer for reasonableness of time extension. (Interview #3)
34. Total cost of project/original schedule = \$/day (this is used to determine required additional work day). (Interview #2)
35. Engineer mainly uses cost/time ratio application to deal with time extensions. (Interview #4)
36. He doesn't adjust the contract for change for time extension. Will examine project towards the end and see if they are having problems finishing and will add days in lump on the end. (Interview #2)
37. For time extensions, engineer feels the key is to do them before the job is done. If time extension needed, the contractor and the engineer need to come to an agreement on that change order. Cost to time ratio needs to be looked at. If reasonable then it is usually accepted. (Interview #3)

#### *Verbal Approvals*

38. Verbal approvals are sometimes provided to the field to allow the field to execute the change order. (Interview #5)
39. Technically change orders need to be approved before work is done but they tend to go ahead and start the work before formal approval is given. (Interview #6)

### *Special Work*

40. Engineer will also examine if work is special in nature. (Interview #4)
41. If the change order is for a specialized item then he will tend to accept contractor's price but he watches for gouging for non specialized items by checking the cost breakdown. (Interview #4)

### *Change Order/Funding Process*

42. Current process for change order approval includes draft approval where it is reviewed by Central Office CO Manager, Executive Director, Director of Construction, Executive Director for Historical Preservation, FHWA liaison and others, and then pending status where it is waiting on monetary approval, and then the approved status. (Interview #4)
43. Originally thought that CO Manager attempts to start the funding process when CO is in draft status, but there is a lot of time waiting on the money. In order to keep the cash flowing, he will borrow from the back side of the contractor, especially for demobilization. (Interview #4)
44. Change orders tend to get approved within 2 weeks. Usually about 75% of projects have at least 1 to 2 change orders. (Interview #6)
45. Turner Construction works with UK CPMD on the new hospital and they have a formal RFQ process to handle change orders. (Interview #6)

### *Other Issues*

46. When he walks a site to be proactive he looks for issues regarding grade (if the grade is uneven then more excavation needed), looks for slides. (Interview #1)
47. Typically contractor provides invoice and info sheet to clarify cost. (Interview #2)
48. Supplemental change orders are an issue where bid items are not included; if small enough they can usually pass through. But if too numerous it becomes hard to agree to changes. When scope becomes undefined, those types will go to tracking time and materials. (Interview #3)
49. Typically the contractor may identify a changed documentation or unforeseen conditions. Typical change orders in his area are undercuts. (Interview #4)
50. Some sources of inaccuracies in the contractor's prices can be due to price gouging or a misinterpretation of the specification. At the very least, the engineer will use the state average unit price. As a scare tactic, he can threaten to use cost-plus or force account to convince contractor to agree to price. (Interview #4)
51. If a project is approaching the \$600,000 threshold, everything humanly possible will be done to keep any change orders from occurring or taking the project cost over \$600,000. (Interview #6)

52. Hospital was bid out in packages (electrical, mechanical, etc) instead of a complete bid package. (Interview #6)
53. Contingency is built by the director but sometimes will receive a lower bid than expected, so it lowers the contingency amount. (Interview #6)
54. There is a person dedicated to being on all new construction sites to make sure things are being built to specifications since they have to maintain the facilities after they are built. (Interview #6)
55. Sharepoint software is used by the director and can track change orders. Sharepoint is a posting place for estimates but approval is not run through it. Real control is through Microsoft Project and it has a link to Sharepoint. Contractor has access to uploading estimate through Timberline. (Interview #6)

#### **D. Opinions and suggestions**

##### *Young Engineers*

1. Believes young engineers become too involved in “horse trading”. It is much better to keep all changes above the table and documented through official change orders. (Interview #1)
2. Problems with young engineers in pricing change orders include lack of understanding, lack of detail in change order explanation on paper work, and a lack of understanding what certain field construction procedures look like. (Interview #2)
3. Engineer feels new engineers coming out don’t have the technical training they need to understand problems in the field. (Interview #3)
4. Suggest getting young engineers out to the field to familiarize them with processes. Feels designers never know how to build what they design. (Interview #4)
5. Engineer feels there needs to be more training for new resident engineers on Site Manager. A better and more qualified resident engineer will help mitigate many of the situations tied to change orders. (Interview #5)
6. Engineer feels that there is not enough support for new engineers like mentors and experienced technicians to assist and guide them. (Interview #5)

##### *Site Manager Software/Old System vs. New System*

7. In addition to the use of change order codes, they should also include comments and detail notes for causes and reasons. (Interview #2)
8. Engineer likes the old system where you could put separate reasons for each line item unlike Site Manger. You could write in a block what the reasoning was for the price and then you could offer an explanation. In Site Manager they have to pick from list of reasons that may not always fit. (Interview #3)

9. Engineer feels the SM list is too cumbersome to look for what reason code might fit his situation. (Interview #3)
10. Site Manager manual needs an update to help field personnel. (Interview #5)
11. In Site Manager, add detailed note to change order documentation to allow for easy understandability. (Interview #2)
12. Engineer felt the old system with excel spreadsheets was easier when dealing with supplemental items on change orders than using the new software. Thought it was better at organizing data. (Interview #3)
13. Engineer says that the Site Manger software can't separate pieces of the change order like you could using the spreadsheets. (Interview #3)
14. Engineer feels it would be useful if in using the software a reason would pull over to identify each item. (Interview #3)
15. Engineer has difficulty in seeking approvals from the supervisors and various levels for the change orders in Site Manager. (Interview #4)
16. Suggested approval for change order pricing: eliminate the draft status and go straight to submitted status. The funding process should begin during the "draft" status. (Interview #4)
17. It is possible to track status of a change order form Site Manager but it is not easy. It is not easy to identify a project that includes a specific item of work that is needed. (Interview #4)

#### *Average Unit Bid Prices*

18. Engineer should also check average unit prices of similar items on other local projects and also check average unit prices of other contractors in the area for reasonableness. (Interview #2)
19. Engineer feels the average unit bid price database has been a useful tool and has been fairly accurate. (Interview #4)
20. Refining the average unit bid price so the user could sort through the unit price by quantity and region may not really help. (Interview #5)
21. Multiple year averages may help with average unit bid price. (Interview #5)
22. Outlier prices should not be thrown out of the average unit bid price database. (Interview #5)
23. It may help to look at the standard deviation of the different averages to see if this is really a concern. (Interview #5)
24. Engineer feels that certain items in the average unit bid price list will skew the entire list. If you had detail information it would help but he does not feel it is that big of an issue. Feels that the more information the contractor has he may try to use against you. (Interview #3)

#### *Biggest Issue*

25. Engineer feels the biggest issue is trying to put all the pieces together after the fact for force account work. Maybe the Federal Highway Contractors Association could put together a uniform policy to give to contractors. (Interview #3)

26. Engineer says that the most difficult part of the process is getting the job finished. (Interview #3)
27. Engineer feels the most challenging aspect of estimating contract cost and time adjustments is accurately predicting the quantity, setting the timeframe, and timely receiving the cost breakdown from the contractor. (Interview #4)
28. Biggest challenges are the time required to execute the change order considering the overall work load of the section engineers. (Interview #5)
29. Director feels the most difficult part of the change order process is trying to get everything put through for the change order as not to delay workers and keep things on track. Tries to avoid disruptions of the process. (Interview #6)

#### *Better Up Front Planning and Work*

30. Need to address the change orders and approve funding as early as possible to avoid cost increases. (Interview #4)
31. Recommend more construction review to avoid large scope changes on projects. (Interview #4)
32. Engineer feels the best way to prevent change orders is through better design, relocating utilities before construction begins and use of old (mothballed) plans needs to be discontinued. (Interview #5)
33. Director feels most change orders come from lack of planning. Unrealistic time frames are given and to accommodate them, usually change orders come about. (Interview #6)
34. More up front work usually means less change orders. Working with the customer more closely usually means less change orders. (Interview #6)
35. Avoid using old plans (example was the state just let out a mothballed set of plans that were designed in metric. State stopped using metric in 1999). (Interview #4)

#### *Documentation*

36. Believes a hard copy of letter be developed for archival after the project. (Interview #2)
37. Documentation of delays is important. Some items they claim are impacting time do not really have an effect and has to be pointed out by the engineer. If you write a change order for every little issue then the days extended add up quickly. If you have a larger change order and time issues come up, and then they only get one day, that is not fair either. (Interview #3)

#### *Verification of Quantities*

38. Best to have as many detail drawings as possible to verify quantities. If something has to be done to move on, then there is some leeway.

Sometimes if utilities are involved, you have their input on quantities as well. (Interview #3)

39. Need to field verify construction quantities whenever possible. (Interview #4)

#### *Contractor Relations*

40. Engineer pushes hard to try and get change order written as soon as possible for contractor to receive money as soon as they can. He feels that by getting the money to the contractor as soon as possible, it removes the unsureness of whether or not they will get paid. (Interview #3)
41. With some contractors you have to verify more than others. At the point where you can't agree with contractor, a lot of times they want details to verify for themselves what is needed to be done. (Interview #3)
42. Having to use cost plus for change orders is not optimal. It is best if the contractor has a breakdown of the pricing. From the breakdown he can look at manpower requirements. (Interview #3)
43. If contractor is ahead of schedule they are more open to timing resolving. (Interview #3)
44. Engineer noted that any plans involving utilities will almost always have a change order involved. Louisville Water Company is the worst offender. (Interview #4)
45. Based on the engineer's lack of time, arguing for a better price could only result in incremental improvements. (Interview #5)
46. Recommend involving construction even more on change orders because the difficulty they run into is scope changes for design issues. Bigger projects run into this a lot. The phasing of the project seems to be a big issue. (Interview #4)

#### *Other Issues*

47. There is a lack of checks and balances. Change orders have been processed without the resident engineer; branch manager has not approved the change order but the change is still processed. (Interview #1)
48. When detailing the change order, it is always good to reference standard specification when possible. (Interview #2)
49. Work on standardizing design criteria. (Interview #4)
50. Engineer feels that there used to be enough resident engineers that could inform them how cumbersome the process was. (Interview #3)
51. Recommend streamlining the approval and funding process. (Interview #4)
52. Recognition by the section engineer that wording a change order must be worded in the same manner as the contract itself is a challenge. (Interview #5)

53. Making sure that the necessity of the change in and of itself and be able to follow the change order after it has been submitted is difficult at times. (Interview #5)
54. Section engineers need to provide support as needed for the central office. (Interview #5)
55. Sometimes history of price increase makes reasonable sense but if it jumps more than that it may be a sign of over inflation. Have to watch for regional pricing differences as well. (Interview #5)
56. There are liquidated damages built into every project but they can only collect on the ones that they can prove loss of use from delays. (Interview #6)

### **E. Examples**

1. Engineer had recent project where trucks were not making a radius turn and they had to widen the radius. There was a need to move the utility strip. Contractor gave a price that was too high and engineer felt it could be done cheaper and easier. He had to convince the contractor they could do it easier. It turned out it was a problem with the subcontractor pricing and was passing it on to the prime. Engineer was able to get them to cut the hours needed. Engineer asked contractor for breakdown on hours and he made them realize they were out of line. (Interview #3)
2. As an EIT, engineer worked in a resident engineer's office. He was always encouraged by the resident engineer to write the change order and get it done. So he was able to see how to them done quickly. He had a lot more lower people to check details that you don't have now. Some of the people that have been moved up to run small jobs don't have a lot of the prior knowledge about writing change orders and are not always sure how to handle them. Tends to fall back to resident engineers and is not always easy with the Site Manager system. (Interview #3)
3. An example of frustration with seeking approval from various supervisors and levels for change order is engineer recently wrote a change order in ten minutes but had been waiting for approval for 3 weeks. Based on his experience, change orders take at least one month before final approval. (Interview #4)
  4. Example of problem with overruns on change order is with bridge deck overlays. A number of overruns on latex over, because most contractors in the past milled deeper than they were supposed to. A lot of the change orders were on bridge maintenance as well. It does not appear that Central Bridge Maintenance is familiar with the field process. Recommend doing a coring on a bridge deck to identify thickness of overlay. (Interview #4)
  5. Example of change order problem with phasing of project involved was a major highway interchange where there was nowhere to drain the boxes and they problems with crossing traffic, problems with

phasing. Designers did not know how to handle it, other processes were not viable, could not bore and jack, and had to redesign drainage calculations. Too many adjustments and too many problems with having to design while building. Hard generally to write a change order for this type of problem. (Interview #4)

6. A noticeable pattern in some change orders that cannot always be prevented has been contract omissions such as switching of paint to thermo from contact. Another example is the time lag of using a design promptly where standards have changed. (Interview #5)

## **F. Other comments**

### *Average Unit Bid Prices*

1. Average unit bid prices do not reflect quantity of materials installed. (Interview #1)
2. Be careful applying average unit bid price for items that are small in quantity versus large quantity. (Interview #2)
3. The contractor also has same access to average unit bid prices so they may inflate their cost to the limit. (Interview #2)
4. It would be beneficial if average unit bid prices could be weighted both on quantities as well as divided by region. (Interview #1)
5. Most contractors appear to be familiar with the rates of the state average bid price. Some contractors will give a price right at the 10% margin. (Interview #4)
6. His experience is that contractors will submit a change order item price that is much higher than the state's average unit bid process. (Interview #1)

### *Cost Plus*

7. While cost-plus reduces risk, most contractors make less on cost plus versus using average unit bid prices. (Interview #1)
8. Engineer feels there are more problems with hours and manpower requirements. The contractor needs to do a better job at quantifying hours. If cost plus is used, you still need to document hours after deciding on crew size. (Interview #3)

### *Change Order Approval*

9. If you can't get the initial change order signed before work begins, it tends to become a problem. (Interview #3)
10. Rarely are change orders completely signed off on before the work is complete. (Interview #4)

### *Contractor Relations*

11. Engineer realizes the contractor is there to make money as well but it is best to find a middle ground when trying to figure proper pricing. If price settlement can't be reached, then they will have to go to tracking time and materials. (Interview #3)
12. Experienced contractors that have been getting jobs will clash with newer resident engineers. (Interview #3)
13. Some prices from contractors seem to be all over the place in comparisons of prices with others. To the engineer, if the price is real low then it seems to be a low ball price. He feels with a low price, he is not getting any value out of the change. (Interview #3)
14. Need to be careful about setting precedence on one project. (Interview #1)

### *Software Issues*

15. Codings within Site Manager are subject to some interpretation. Could be improved. (Interview #5)
16. Timberline software will put out quantities for change orders. (Interview #6)

### *Funding/Monetary Issues*

17. How do you fix a problem when you know there is no money for it? Only when federal people get involved will the state agree to fix things. (Interview #4)
18. Most sensitive sources of funding are for rural roads because counties are only allocated a limited amount of money (although the section managers have helped with this). (Interview #5)
19. FHWA's main goal is to examine whether the change order is eligible for federal funding. (Interview #5)
20. Typical yearly budget for renovations is \$8 to \$10 million. (Interview #6)
21. As long as project engineers are staying within their "bucket of money" on the costs with change orders, they can spend it as they wish. (Interview #6)

### *Miscellaneous Pricing Issues*

22. On supplemental pricing, it is too open ended on setting prices. The average unit price is usually useless 50% of time. (Interview #1)
23. Paving jobs main change order item is fuel adjustments and they are done every month. (Interview #2)

### *Other Issues*

24. Will do whatever he can to avoid change orders. (Interview #1)
25. Scope control is important. (Interview #1)

26. Record keeping for time and materials becoming harder because contractor doesn't seem to keep up with numbers until after the fact. (Interview #3)
27. You can pay a certain percentage of the work based on actual timekeeping. (Interview #3)
28. Trying to find time to do all the paper work is a problem. To keep the project moving, you can't always get the change order written before the problem is an issue. (Interview #3)
29. Replacement engineers may not always know how change orders in the replacement areas are being handled. (Interview #3)
30. Engineer has a problem with central office mandating down change orders and wanting them to sign off but then audit comes about and they want to know what is going on. He feels they need to follow their own rules when doing change orders if they are going to originate them. (Interview #3)
31. Engineer has the most problems writing change orders which involve projects that have phasing or fast tracking. Has problem with verbiage and just tends to put them aside. (Interview #4)
32. Each governor's administration tends to change the process. (Interview #5)
33. Hospital dislikes use of cost plus for change orders, except that it is called force account. (Interview #6)
34. There is no formal coding system in place for Physical Plant Division. (Interview #6)

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