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Evaluation of the Most Significant Factors Influencing the Production Rates of Highway Construction Activities

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EVALUATION OF THE MOST SIGNIFICANT FACTORS INFLUENCING THE PRODUCTION RATES OF HIGHWAY CONSTRUCTION ACTIVITIES.

A Thesis

by

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ABSTRACT

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The utilization of realistic production rates is key for the accurate estimation of the contract time in highway projects. The Texas department of Transportation has been noticing that the estimated timelines are far from the reality and want to investigate the factors causing this discrepancy. Some of the factors that have an impact on production rates and were considered in this study include the systems used to schedule highway projects, weather conditions, temperature, location, and workers shifts. This paper aims to investigate how these factors affect productivity rates. Past highway projects developed in Texas, were used to perform statistical analysis and determine if these factors have a significant effect on the productivity rates of construction activities.

DEDICATION

First, I dedicate this study to my Almighty God, thank you lord for your guidance, strength, power of mind, protection and for giving me the opportunity of completing this stage of my life. I offer this achievement to you.

The completion of my masters' studies would not have been possible without the support and love of my family. My husband, Ricardo Neira, my daughter, Mariana Neira, and my son Luciano Neira, who have been my source of inspiration and gave me the strength when I thought of giving up, who continually provide their moral, spiritual, and emotional support.

To my grandparents, my mother, my brother, relatives, mentors, friends, and classmates who shared their words of advice and encouragement to finish this study.

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CHAPTER I

INTRODUCTION

1.1 Overview

Each year, hundreds of highway projects are developed by the Texas Department of Transportation (TxDOT); these projects go through an in-depth planning phase that includes project duration estimation; determining activities' duration becomes a lengthy process for a long-term project. Effective project scheduling plays a crucial role in ensuring project success. Highway projects involve expensive equipment, tremendous overhead, significant manpower, and large payrolls for the DOT and contractors alike. The longer a job takes, the higher the costs and the greater the potential for litigation. A solid schedule helps keep costs down and allows the DOT to operate according to their estimated budget. Due to the high costs of untimely performance, contractors and the DOT usually require well-planned and often complex schedules.

Several factors can affect the estimated duration of highway projects. One of the factors studied are the systems used to determine the duration of the projects. TxDOT currently uses two different scheduling tools to determine contract time: Contract Time Determination System

(CTDS) and Highway Production Rate Information System (HyPRIS). Engineers have noticed that these tools do not always estimate accurate projects schedule.

Other external factors may also affect the duration of the projects. Among them, we can include weather, project's location, construction type, etc. These factors cannot be controlled but can be accounted for when scheduling highway projects. This study compiles and analyzes information from previous projects developed by TxDOT. Focusing on the evaluation of these two systems as reliable tools for determining contract time and the assessment of the different factors that can affect project duration.

The study will consist of four main work plan implementations. 1) To collect and extract the data, 2) To investigate scheduling tools and understand the production rates, 3) Evaluate the CTDS and HyPRIS scheduling tools accuracy in determining the appropriate time estimates for a construction project and 4) Model variability due to weather scheduling error.

1.2 Background of the Study

TxDOT builds and maintains thousands of miles of roadway annually. Before a project can be bid on by a business, TxDOT must let it, or make it available for bidding. The letting and bidding process with TxDOT allows the DOT to get the most competitive pricing on a project and allows multiple businesses to compete for business with TxDOT. In the letting phase the DOT has to determine the time it will take contractors to complete the whole project and its cost. The projects and financial obligations in the schedule are based on current estimated construction costs and schedule. That being one of the reasons why schedules could change in the development phase

1.2.1 Definition of Contract

Contract time is the maximum time allowed for completion of all work described in the contract documents (Herbsman & Ellis, 1995). Contract time often arises as an issue when the traveling public is being inconvenienced and the contractor does not appear to be aggressively pursuing the work. There may be a number of reasons for a project to appear dormant, such as weather limitations, concrete-curing times, materials arriving late, etc. However, all too often the causes are traceable to excessive time originally established by the contracting agency to complete the project or poor contractor scheduling of construction operations.

1.2.2 Importance of Contract Duration

In many instances, the duration of highway construction projects is more critical today than it was in the past. Several of the reasons are: proper selection of contract time allows for optimization of construction engineering costs and other resources, traffic volumes on most highways are significantly greater and are continuing to increase thereby creating a greater impact on the motoring public in both safety considerations and cost.

Determining an appropriate contract time is important to all parties involved: the DOT, contractors and the driving public. Excessive contract time is costly, extends the construction crew’s exposure to traffic, increases risks for the contractor and the owner, and prolongs the inconvenience to the public. Insufficient contract time results in higher bids, overrun of contract time, increased claims by contractors, substandard performance, and safety issues.

1.3 Problem Statement

Determining the duration of a project is one of the most important pre-construction processes. As previously mentioned, project duration is a significant factor for determining the cost of a construction project, it is necessary to have accurate tools for determining the required construction time line. Concerns about the reliability and accuracy of the tools used by the DOT planners to determine contract time, have arisen. TxDOT has realized that in many cases, contractors either are delayed or have too much time available to finish a project. These inconsistencies lead to changes of order in the contracts, and TxDOT has to compensate the contractors either with the proper time or with funding to finish the projects. This study pretends to examine the scheduling tools used during the planning and scoping phases of the project life cycle to determine if that aspect of the project (i.e., overly optimistic schedules) might be an inherent source of delay.

Managing bad weather is one of the most difficult, yet important aspects of the planning process of any construction project. Highway projects are exposed to inclement weather conditions and construction schedulers use their experience and their knowledge of the region to make accurate predictions. Anticipating weather conditions can have a huge effect in terms of completing the project on time and on budget and his study aims to quantify the effects of weather conditions on the duration of highway construction activities

Several factors have an impact on production rates and change the total duration of construction projects. Some of the factors considered in this study are weather conditions, temperature, location and shifts. This paper aims to investigate how these factors affect projects' schedules in order to help schedulers create more realistic timelines.

1.4 Research Questions

This study aims to investigate the factors affecting productivity rates of highway construction activities causing delays on the projects' schedule. Can the source of these timeline delays be attributed to the current scheduling tools/systems used? It is important to determine if these systems are providing unrealistic project schedules. Another factor that has TxDOT questioning the source of timeline inaccuracies is the weather. How does weather affect the duration of highway construction activities? Weather should be taken into consideration while scheduling activities, since highway construction projects are always exposed to it. Other factors can also affect the production rates and the total duration of the project. Throughout the years, many research studies have been able to identify these factors and investigate how they affect the production rates. This research will focus on weather, location, temperature and workers shift and determining how they affect the productivity rates of highway construction activities.

1.5 Methodology and Objectives

The scope of this study is limited to TxDOT highway projects. Details that are required to determine the contract time such as costs, are not considered in this study. Also, cost aspects related to highway projects are beyond the scope of this study.

The main objective of this research is to determine the factors affecting contract time and causing delays. Based on the problem statement, the following are the listed research objectives:

1. Literature review, survey with TxDOT engineers and data collection
2. Evaluation of the current systems used by TxDOT
3. Weather assessment on past projects developed by TxDOT using two different weather models found in the literature.
4. Assessment of the impact of location, temperature, workers shift and type of weather on production rates using the collected data from past projects.

1.6 Thesis Organization

In the chapter 2, literature of previous studies is reviewed and discussed to gather relevant information on the different systems used by TxDOT to determine contract time. Other factors such as weather, location, temperature etc. are also studied. Chapter 3 presents the evaluation of the CDTS and HyPRIS and recommendations. Chapter 4 presents the weather effects on productivity rates. This chapter will discuss two different models that were used to quantify this impact. Chapter 5 discusses the impact of different factors on the productivity rates of past projects developed by TxDOT. Chapter 6 concludes the research and provides some recommendations for future research.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

The determination of contract time is one of the most important objectives in the planning process of any construction project. An accurate contract time estimate facilitates the optimization of resource allocations and construction costs at a later stage. The criticality of contract times to the successful completion of highway projects has been addressed thoroughly in the literature. The Federal Highway Administration (FHWA) stresses the importance of an accurate contract time for the successful completion of the project and controlling the project budget. FHWA requires individual states to create and implement contract time determination procedures for construction projects. Recommendations to assist in implementing the procedures are provided in the FHWA guide for contract time determination (Technical Advisory 5080.15, FHWA Guide for Construction Contract Time Determination Procedures, 2002). This guide suggests establishing production rates and adapting them to project conditions considering other factors that can affect the contract time, such as location, traffic maintenance, type of weather, etc.

Estimating realistic production rates is essential for determining an appropriate contract completion time. Some DOTs maintain a database of average production rates or durations based on historical data for common highway and bridge construction activities (Hancher et al., 1992).

2.2 Definition of Construction Production Rates

To fully understand the impact of inaccurate activity durations on the project schedule, it is essential to first investigate the relationship between the project estimated duration and the work item's production rates. This relationship is given in :

$$Estimated\ Activity\ Duration = \frac{Estimated\ Quantity\ of\ Work}{Estimated\ Production\ Rate}$$

Estimating realistic production rates is important when determining appropriate contract completion time. The production rate is commonly defined as the quantity of work executed per unit time. As such, the calculation of the activity duration depends on two estimates. The first estimate is the quantity of work, and the second one is the production rate. Both estimates are rarely 100% accurate all the time (Odeh, 2002). Hence, the source of errors in estimating the activity duration can be attributed to either a wrong production rate estimate, a wrong estimated work quantity, or a combination of both. However, there are several other sources of errors that need to be investigated in detail.

2.3 Current Practices in TxDOT

Many TxDOT projects were planned and scheduled using unrealistic contract time (Research Project Statement 17-12, FY 2017 Annual Program: Enhanced Production Rate Establishment to Ascertain Construction Activity Durations, 2016). In many cases, the contractors are either delayed or have an unreasonably large amount of time to finish the project. These inaccuracies in the project schedule usually lead to a multitude of change of orders in the contracts. This results in a dramatic increase in the total project cost as TxDOT has to compensate the contractors either with the proper time or money to complete the projects (Curtis et al., 2011) TxDOT is questioning whether the source of these timeline inaccuracies can be attributed to the systems used currently (CTDS and HyPRIS) creating unrealistic projects schedules. Due to the inaccuracies of the current systems, some engineers reverted to using their experience to determine the project time. Unfortunately, this can lead to an inconsistency in the methods of determining the contract time across the state.

2.4 Factors Affecting Contract Time Determination

According to the literature review, factors were classified in two types of variations that affect the production rate, and consequently the activity duration estimate, as shown in Figure 1 these types of variations are:

1. Common Cause Variation: This variation is part of the process of scheduling the project. It demonstrates how reliable the scheduling method is; it affects all activities in the

project. In this case, the common cause variation is the scheduling tools and systems used by TxDOT, CTDS and HyPRIS.

2. Special Cause Variation: This variation is an exceptional event that might occur with a certain impact on the production rates, such as: weather, operator skill, and technology, which cannot be controlled but can be accounted for. Figure 1 is a graphical demonstration of the the previous mentioned variation causes.

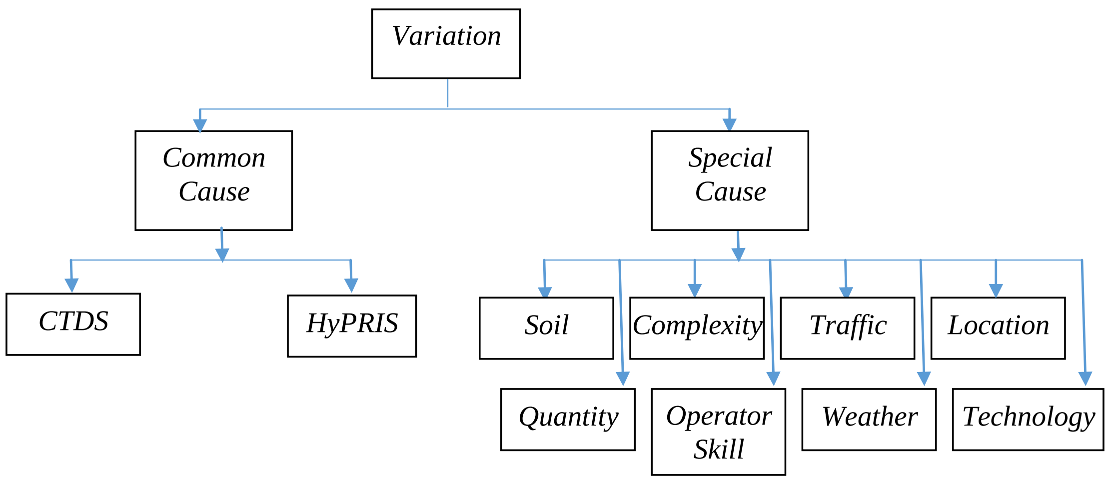


Figure 2. 1: Different causes of variation affecting contract time determination

2.4.1 Common Cause Variation

The literature included several articles discussing the different contract time systems developed by different states DOTs. The format recommended by the FHWA has been adopted by most states. Taylor et al. (2017) examined the different procedures that DOTs implement to estimate the contract time of highway construction projects. For instance, Oklahoma Transportation Center (OkTC) uses a custom-developed user interface connected to a Microsoft Access database that contains default project type templates and production rates. After selecting the project type, the user needs to input bid item quantities for different activities. The users also have the option of adjusting the simple finish-to-start logic of the activities in the template. The duration is then exported to Microsoft Project, which creates a Gantt chart with the total project duration and schedule (Jeong et al. 2008). Florida DOT also uses Gantt charts to develop the project schedule; however, the estimation of the activity productivity rates is based on the engineer's experience (FDOT, 2010).

Other states use agency-specific production rates to estimate the time required to complete each task within a project. For example, Wisconsin DOT has a production rate database that includes a minimum, average, and max rates. These rates are adjusted considering factors that could affect them, such as location and projects size (Aoun, 2013). Indiana DOT (INDOT) utilizes a production rate database connected to Visual Basic program that is equipped with two different methods for calculating the contract time, which are: 1) regression equations, and 2) mean production rate of critical activities method (Jiang & Wu, 2004). Other states have applied similar methods for estimating contract durations. Louisiana classified construction projects and created 23 different templates using Lotus 1-2-3 R5 software; production rates for each work item were generated using the mean value from the activities in the selected template (McCrary et Al, 1995). Kentucky Transportation Cabinet (KyCT) uses Kentucky Contract Time Determination System (KY-CTDS). This system utilizes Microsoft Excel and Microsoft Project for determining contract time. The KY-CTDS contains default production rates which can be modified by the user; MS Project is then used to create the project schedule and determine the project duration (Werkmeister et al. 2000, Taylor et al. 2013). As mentioned earlier, TxDOT has developed and utilized two different systems to determine contract time, which are CTDS and HyPRIS.

2.4.1.1 Contract Time Determination System (CTDS). CTDS was initially developed by Hancher et al. in 1992. Their research focused on developing a reliable system for TxDOT that could determine the time required to complete a construction contract for different types of highway projects. The system was developed to complement the existing TxDOT Pre-Construction Management System, which categorizes all highway projects into fourteen different classes. CTDS is a computer-based conceptual estimating system, which includes, both a manual method and a computerized method. The user inputs the actual work quantities for a project, and by applying standard production rates, or preferred rates, the contract duration is determined. The computerized version uses a combination of Flash-Up, Lotus 123, and SuperProject (Hancher et al., 1992).

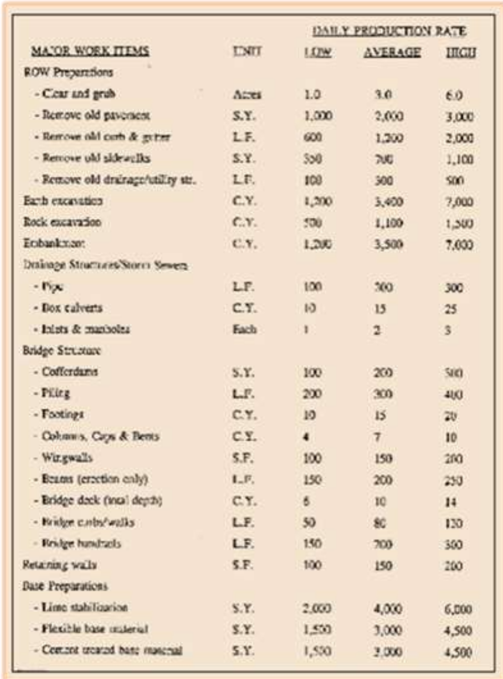
During the development of CTDS, surveys about construction production rates were sent to DOT districts in all 50 states as well as the different TxDOT district offices. The surveys discussed productivity rates and the factors that influenced them. The survey responses received were used to create the productivity rate database for the CTDS. For each work item, three production rates representing low, average, and high values were provided. In addition, the surveys also helped to determine five adjustment factors for the established production rates, which are location, traffic, complexity of project, soil conditions, and quantity of work (Hancher et al., 1992).

In CTDS, users can select from 14 project templates of which 13 templates represents TxDOT different project classification. The 14th template was included to accommodate any new type of project that is not listed among the 13 project categories. To schedule a project, the system uses a default production rate, unless otherwise specified by the user. Users also have the option of applying different adjustment factors for each activity. However, it was recommended to only apply a maximum of two adjustment factors simultaneously at a given time due to the correlation between factors. The program final product is a Gantt chart created using the different scheduled project activities (Hancher et al., 1992). Screenshots from the automated versions are shown in Figure 2.2a.

2.4.1.2 Highway Production Rate Information System (HyPRIS). HyPRIS is another productivity rate software that was developed in 2004 for TxDOT; it was created using Microsoft Excel and MS Visual Basic platforms (O’Connor el al., 2004). This system was developed to improve the production rates information system that TxDOT was using at the time in attempt of increasing the accuracy of estimating the contract time. Several work items that normally lie on the critical path (controlling activities) were studied; and the production rates were statistically determined based on data collected from the site (O’Connor el al. 2004).

The development of HyPRIS started with investigating the work items and production rates from the CTDS program. Those production rates were compared to observed data using descriptive analysis, such as boxplots, scatterplots, and t-tests. The HyPRIS program is divided into 5 categories matching the first five the divisions work items (100's to 500's) in the TxDOT Standard Specifications for Construction and Maintenance Of Highways, Streets, and Bridges (Standard Specifications For Construction and Maintenance of Highway Streets and Bridges, 2004). When users select a work item, various information is provided based on the statistical analysis that was conducted. The production rates for the items are provided with decile tables as well as scatterplots, as shown in Figure 2.2 b. For certain work items like reinforced concrete pipes, the production rates are based on the length of the pipe and its orientation. For instance, the software provided different production rates based on whether the pipe is parallel or perpendicular to the road. It should be noted that HyPRIS does not produce Gantt charts or schedules, but instead it calculates that production rates that can be used to determine the activity durations. However, the accuracy of these rates can be compromised since the system does not give the user the options to account for other factors that might have an impact on the production rates.

(a)



MAJOR WORK ITEMS	UNIT	DAILY PRODUCTION RATE LOW	AVERAGE	HIGH
ROW Preparations				
- Clear and grub	Acres	1.0	3.0	6.0
- Remove old pavement	S.Y.	1,000	2,000	3,000
- Remove old curb & gutter	L.F.	600	1,200	2,000
- Remove old sidewalks	S.Y.	350	700	1,100
- Remove old drainage/utility str.	L.F.	100	300	500
Earth excavation	C.Y.	1,200	3,400	7,000
Rock excavation	C.Y.	500	1,100	1,500
Embankment	C.Y.	1,200	3,500	7,000
Drainage Structures/Storm Sewers				
- Pipe	L.F.	100	200	300
- Box culverts	C.Y.	10	15	25
- Inlets & manholes	Each	1	2	3
Bridge Structure				
- Cofferdams	S.Y.	100	200	500
- Piling	L.F.	200	300	400
- Footings	C.Y.	10	15	20
- Columns, Caps & Bents	C.Y.	4	7	10
- Wingwalls	S.F.	100	150	200
- Beams (erection only)	L.F.	150	200	250
- Bridge deck (total depth)	C.Y.	6	10	14
- Bridge curbs/walks	L.F.	50	80	120
- Bridge handrails	L.F.	150	200	300
Retaining walls	S.F.	100	150	200
Base Preparations				
- Lime stabilization	S.Y.	2,000	4,000	6,000
- Flexible base material	S.Y.	1,500	3,000	4,500
- Cement treated base material	S.Y.	1,500	3,000	4,500

(b)

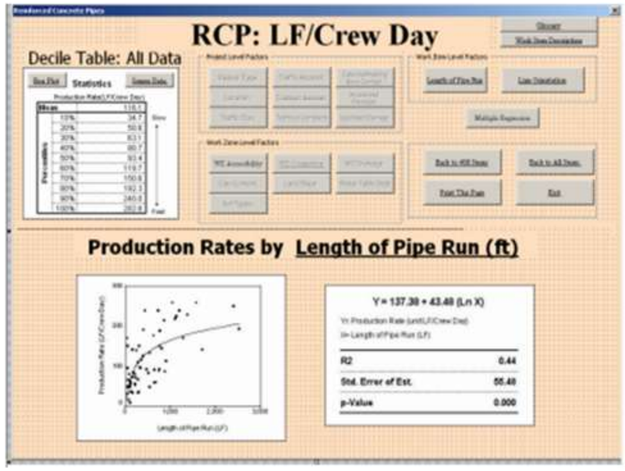


Figure 2. 2: a) CTDS Production Rates (Hancher et al., 1992), b) HyPRIS Output Window Displaying Productivity Rates for a Reinforced Concrete Pipe (RCP) (O’Connor el al. 2004)

The major shortcoming with CTDS and HyPRIS is that both systems use deterministic values for the production rates. In reality, activities durations and their associated production rates are probabilistic. Production rates cannot be deterministic since it is inevitable that highway projects will be exposed to external factors that will impact the rate of production such as, inclement weather, high and low temperatures, equipment technology, operator skills, etc. As such, these values should be modeled using probability distribution, and probabilistic scheduling should be deployed to determine the project contract time.

2.4.2 Special Cause Variation

There are various special cause factors that can also affect the production rates and the total duration of the project (Herbsman, 1990). Previous research studies have identified some of these factors and investigated their impacts on the production rates of highway activities. TxDOT in a recent request for proposal for a research problem statement has expressed interest in assessing the impacts of weather, equipment operator skill, and equipment technology on production rates (Research Project Statement 17-12, FY 2017 Annual Program: Enhanced Production Rate Establishment to Ascertain Construction Activity Durations, 2016). The literature includes studies that have addressed the effect of some special cause factors on production rates, such as weather, project location, traffic conditions, work shift, and soil type. It should be noted that there are correlations between some of these factors. As such, the effect of these factors should be considered holistically. In other words, it is advised not to quantify the impact of such factors on the production rates individually.

2.4.2.1 Weather. Weather is the one of the most common factors discussed throughout the literature review for it can have a very negative impact on the contract time. Since most construction projects are located outdoors, weather becomes a critical factor that should be accounted for. Planners should use their knowledge of the region, past experiences, and available databases to estimate the impact of weather on production rates.

Several studies have addressed the impacts of different weather attributes on the production rates of construction activities. The most common weather attributes discussed include precipitation, wind speed, and temperature.

Precipitation is considered the major weather factor that has the most adverse impacts on construction productivity in highway projects. According to Riley (1999), it causes "productivity loss, complete suspension, work stoppage, and cost overrun." Riley's study presents a model that utilizes historical daily rainfall data and experts' knowledge to assess the impact of rain on project completion. The author mentions how different projects, such as highways or bridges, are negatively impacted during rainfall and even days after it stops. Most materials exposed to rainfalls are discarded because of the absorbed water; and operating machines becomes more difficult due to muddy terrains. Another research study by El-Rayes and Moselhi (2001) designed a system to quantify the impact of rainfall on the productivity of highway construction. The system, named WEATHER, is a user-friendly software system that determines the productivity rates of different highway construction activities during rainfall and displays the various probabilities of activity duration. Similarly, Pan (2005) created a model that utilizes historical daily rainfall data and experts' knowledge, to assess the impact of rain on project duration. Based on this model, a scheduling system called FRESS is proposed. Smith (1989), presented a conceptual model for evaluating precipitation impact. His method utilizes a Markov process for prediction of rainfall events, combined with an impact evaluation utilizing basic fuzzy-set operations.

Wind Speed is another factor that has been considered by researchers. For instance, Dytczak et Al. (2013) recognized that the effects of construction project execution depend on the influence of the surrounding environment including wind. It is, therefore, necessary to consider the local conditions affecting the construction site to generate a reliable project schedule. Jung et al. (2016) developed a model to estimate weather delay that is specific to high-rise buildings since weather conditions differ with altitude. According to this study, weather delays are generally estimated as a monthly average; however, this approach was found to be inappropriate for high rise buildings that approach is incorrect. The study presented a simulation model which integrates the weather modeling and construction planning to overcome the shortcoming in estimating weather delays for high-rise buildings projects. Similarly, Senouci (2018) studied the impact of temperature, humidity, and wind speed on labor productivity in Qatar for four construction trades, namely, formwork, masonry, plaster, and ceramic tiles. Linear regression models were developed to predict trade productivity on a given day of the year. Results showed that weather conditions have a high impact on trade labor productivity.

Temperature has not been studied as often as precipitation and wind speed; however, this factor can have an equal or an even more significant impact on the productivity rates. A study conducted by Koehn and Brown (1985) compared the productivity rates at different temperatures. This study devised two nonlinear equations, one for cold or cool weather and another for hot or warm weather. The overall findings show that temperatures below −10°F and above 110 °F are challenging to achieve efficient construction operations. The study also provided a table which contained production rates at different temperatures and humidity percentages. The study concluded the best conditions to perform construction work would be at temperatures ranging from 50°F to 80°F. According to Thomas (1999), who studied the loss of labor productivity due to delivery methods and weather, significant losses of productivity occurred because of snow (41%) and cold temperatures (32%). Similarly, Shan (2014) found that both temperature and humidity are factors that constantly exert forces on workers and influence their performance and efficiency.

Several research studies have attempted to simulate weather conditions to assess its impact on the project time. A study by Shahin et al. (2007) presented a weather simulation model specifically for cold weather. In this study, weather-related variables that affect productivity rates in construction projects were identified, which included precipitation, temperature, wind speed, humidity, and frost penetration. The model used a stochastic weather generator for the different weather factors; and the cold weather was integrated using a process simulation model. The study presented a useful framework for the simulation of construction work in cold regions. Similarly, Apipattanavis et al. (2010) created an integrated framework consisting of two key components, which are: 1) the identification of attributes of weather that cause construction delays, and 2) generation of synthetic weather sequences using a stochastic weather generator to quantify and provide probabilistic forecasts of weather threshold values. Ballesteros-Peraza et al. (2017) developed a holistic model that enabled practitioners to use weather data for forecasting project durations. In this model, the categories of weather that impact standard construction operations were identified. This made it possible to define the likelihood of performing those standard construction operations. The probability was expressed as a proportion of working days per month which was called Climatic Reduction Coefficients (CRCs). These CRCs are based on location and the time of the year in which the activity is performed.

2.4.2.2 Equipment Operator Skill and Technology. Measuring labor skill (psychomotor skills) is a cumbersome task, and rarely accurate. According to Sage's (1984), the definition of a skilled performance is the production of high-quality output with consistency. However, there are many factors that affect the psychomotor skills of a construction equipment operator such as, motivation, fatigue, boredom, temperature, etc. (Bernold 2007). The literature contains – if any- very limited studies on the impact of the construction equipment operators' skills on the production rates.

Equipment technology can increase productivity and consistency in work. However, no matter how automated the machine is, there are other factors that will affect the production rate of a piece of equipment, such as altitude and rolling resistance. Several studies have been conducted to assess the impact of equipment technology on productivity rates. One discussed the productivity in earthmoving using different types of equipment study (Smith 1999). Another study focused on the effect of technological advances on construction productivity. In this study, a technology index was used to measure the advancement in the equipment technology over time (Goodrum and Haas, 2002). In a different study, Goodrum and Haas (2004) examined 200 construction activities to assess the effect of equipment technology on the labor productivity from 1976 to 1998. Ok and Sinha (2006) conducted a study to estimate the productivity of dozers using regression analysis and dozers.

While the literature discussing the impact of equipment technology on construction productivity is also limited, the conclusion is that the technological advancement in construction equipment has led to an increase in the production rates of various activities. The different models developed has definitely contributed to enhancing the estimating of productivity rates.

2.4.2.3 Location. The factor of location refers to whether the construction is being executed in an urban or a rural area. The location of the project may affect the productivity rates of various activities in the project. A study by Koehn and Ahmed (2001) discussed the production rates in different projects executed urban and rural areas in Dhaka, Bangladesh. The study found that construction activities in rural locations is more labor intensive compared to similar activities in urban areas. This was attributed to the availability of more contractors, advanced equipment and technology, and new materials in urban areas than in rural areas. The article also relates the low productivity rates in rural areas to the lack of skillful construction laborers since the majority of them prefer to work in urban areas because of the higher wages. that most of the skillful construction laborers tend to work in urban areas.

Alternatively, an article published by Jiang and Wang (2007) studied the impact of location on construction productivity. The study was conducted in the U.S. and the data used were provided by the Indiana Department of Transportation. A statistical analysis was performed to determine different activities production rates using the construction projects available in the DOT database. The authors were then able to compare the productivity of construction activities at rural and urban locations. The comparison showed that the production rates are higher at rural sites than in urban ones. The impact on the productivity rate was attributed to the high average daily traffic in urban locations, which tends to create traffic congestion. In turn, this congestion can decrease the productivity in construction projects due to delays in deliveries of materials and mobilization of resources. Traffic flow is an important factor, which correlates with location, and has a direct impact on the production rates in construction projects.

2.4.2.4 Traffic. The traffic factor in production rates relates to other factors such as location and soil. Since urban locations have a higher ADT, traffic becomes a problem during construction. An article by Jiang (2003) focused on how the traffic flow affects the productivity on asphalt pavement construction. Different types of work zones were discussed and the traffic for those work zones was observed in research he had previously conducted in 1999. Equations that can be used to estimate the cycle time or traffic delays were provided in his article. They were used to study the effect of traffic on hot mix asphalt for 24 hours. The results from the study showed that the traffic delayed caused a decrease in the material delivery productivity. This delay in material delivery decreases the productivity and changes the project scheduled time, so to make up for it, it was recommended to have additional trucks. The article concluded that traffic management is important throughout project planning since it decreases productivity and can influence the schedule of the project.

Statistics are often used to find production rates of highway activities. Jian and Wu (2007) performed an analysis of daily work reports (DWR's) from the Indiana Department of Transportation and used the data in them to get productivity rates. The data gathered was used in normal, lognormal, and exponential distribution plots and used to find their mean. One of the factors that they studied was the location factor and related to it was the traffic conditions in the site. As mentioned in the location Page 14 of 278 factor section, they found that rural areas were greater than urban areas due to the lower traffic volumes. Not only does a higher traffic rate increase the traffic control, but material delivery is also delayed longer because of the greater amount of traffic. Since traffic becomes a problem in construction sites, many articles have tried identifying the effects and different programs that can be used to do that. Edara and Cottrell (2007), conducted literature reviews and surveys of different state DOT's to assess traffic impacts. Once the survey was sent, they were able to get responses from 19 state DOT's and received information on the tools they used for capacity and delays. Another more recent article by Hyrari et. al (2015) found the impacts that construction sites have on traffic. They performed site visits and focus groups to try and develop mitigation plans for the traffic impact. While they were successful in that, there was no discussion on how traffic also reduces productivity rates in work zones.

2.4.2.5 Work Shift. The work shift refers to the timing when construction activities take place. The work can be executed during day or night. A survey-based study by Hancher and Taylor (1999) focused on the factors affecting night-time construction. Some factors were related to traffic, others to construction; some social, economic, and environmental factors were also identified. The study concluded that night-time operations can decrease construction time on critical highway projects and that night-time construction of highway projects would become more prevalent in the future.

Work shift was also correlated to other special cause factors such as weather and location. For instance, there is a drop in the temperature and traffic flow during night time, which might increase the productivity in very hot regions. Mosfavi et al. (2012) studied night operations of asphalt pavement. The objective of this study was to assess how the production rate is affected by the nighttime shift. They developed a simulation model and verified it using a construction project from Indiana. Although the study discussedproduction rates during nighttime shifts, it did not determine how the different construction operations are affected by the time of the shift.

2.4.3 Other Factors

So many factors can affect the project's schedule. A research study by Herbsman and Ellis (1995) found seventeen factors affecting overall construction duration. Most of them are inter-related, and trying to consider the impact of all these factors at the same time could be an extremely complicated task. For example, soil type is another factor that affects the productivity rates of construction activities; this factor is correlated with the site location. It is evident that the production rate of the same construction activity varies as the soil types differ. For instance, drilling a shaft in dry soil is considerably faster than constructing one close to a riverbank (Chong et al. 2011). This factor was not considered in this study, but the comprehensive literature review helped the research team better focus our efforts on the factors often studied and considered of higher importance by researchers. These factors include: the systems currently used, weather conditions, temperature, location, and workers shift.

CHAPTER III

EVALUATION OF THE CURRENT CONSTRACT TIME DETERMINATION SYSTEMS USED BY TXDOT

3.1 Introduction

The first objective of this study consisted of studying the systems the Department of Transportation (DOT) uses to determine contract time. TxDOT is one of the first DOTs that established a system to determine contract time. As described in the previous chapter, the current systems available for TxDOT are 1) Contract Time Determination System (CTDS), and 2) Highway Production Rate Information System (HyPRIS). The information provided by CTDS (Hancher et al. 1992) includes production rates for selected work activities and their adjustment factors. Planners can use these factors to adjust the provided productivity rates to account for sources of variability. The adjustment factors aims to obtain more realistic rates when certain project conditions change, such as location, traffic conditions, soil conditions, etc. On the other hand, HyPRIS (O'Connor et al. 2004) was developed due to a concern about the accuracy of the productivity rates in the CTDS.

HyPRIS investigated 26 controlling activities, that were believed to always lie on the critical path, and provided more accurate productivity rates based on data collected from the site. However, the nature of these activities is bridge-related; and HyPRIS did not allow the adjustment of the determined rates with respect to any variation. As such, the accuracy of the contract time estimates developed using the CTDS and HyPRIS are questionable. TxDOT engineers have noticed that these tools do not always estimate accurate projects schedules, and many planners have resorted to relying solely on their experience and other published productivity rates for determining the activity durations (Taylor et. Al, 2013. Herbsman, 1987). Hence, there is a need to evaluate the efficiency of these systems in estimating the project time to an acceptable level of accuracy.

This chapter evaluates the CTDS and HyPRIS systems as reliable tools for determining the contract time. This includes the assessment of the accuracy of the construction production rates set in each system. To accomplish this objective, historical data from previous projects were collected and analyzed to compare actual versus estimated different activities durations and quantities to determine if there is any significant difference between them.

3.2 Methodology

The work plan devised to investigate the inaccuracy in determining the contract time due to common cause variations, such as the CTDS and HyPRIS is comprised of five main phases: 1) literature review, 2) data collection, 3) data classification, 4) data analysis, and 5) results and conclusions, as shown in Figure 3.1.

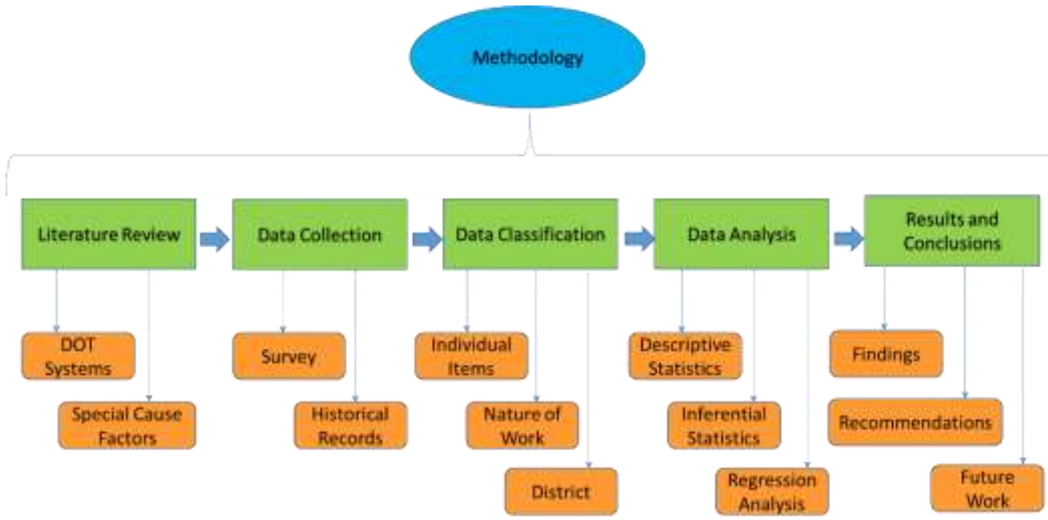


Figure 3. 1: Methodology flow chart of this chapter

First, an extensive literature review was performed in order to collect information on the systems that different state DOTs are currently using. Also, it deemed essential to identify the common factor (special cause) reported by previous studies that affect the production rates. The second step was to collect historical data from different district offices that utilize CTDS and HyPRIS to determine the project contract time. The data collected were classified and statistically analyzed to evaluate the systems performance. The obtained results assisted to draw final conclusions on the performance and accuracy of the CTDS and HyPRIS.

3.3 Implementation

To evaluate the accuracy and reliability of the CTDS and HyPRIS, it was necessary to obtain actual real-life data from projects developed by TxDOT. The project selected for analysis had to be scheduled using production rates from either CTDS, HyPRIS, or combination of both. The implementation stage consists of three main milestones, which are: Data identification, data extraction, and data analysis, as shown in Figure 3.2.

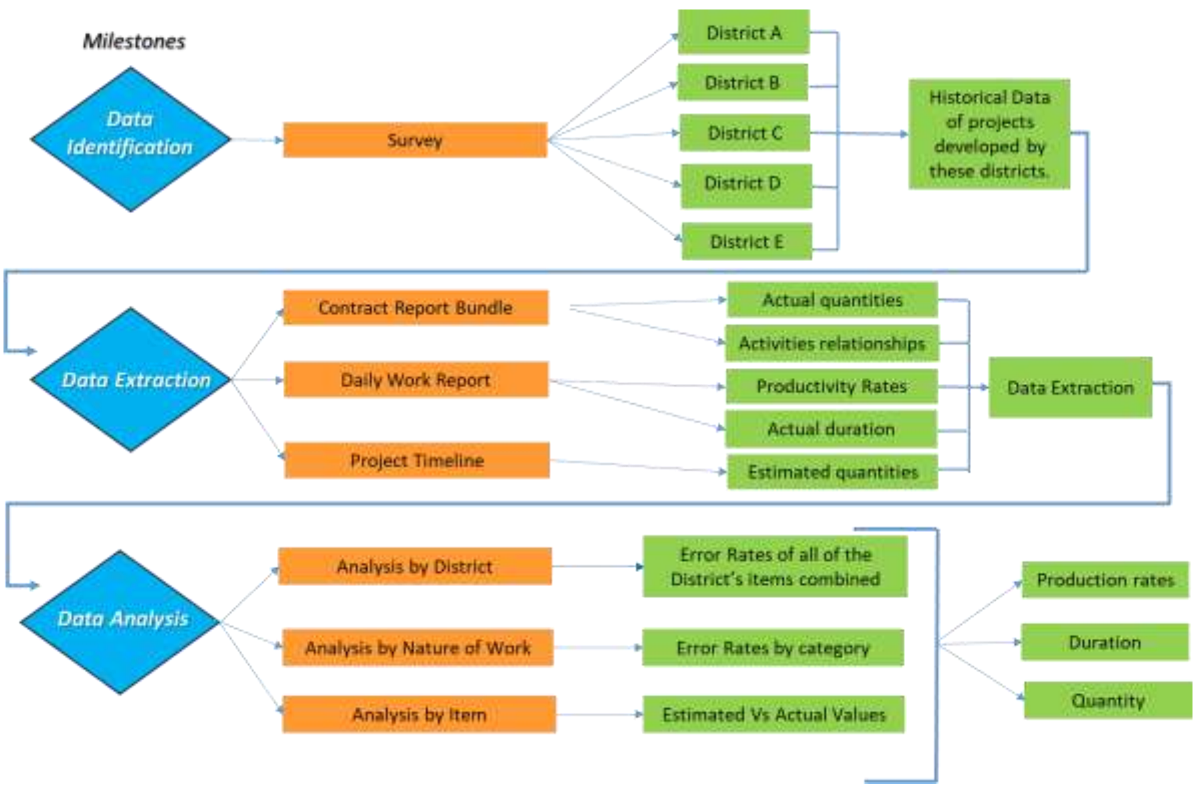


Figure 3. 2: Different Milestones of the Implementation Stage

3.2.1 Data Identification

The first step in the data identification stage was to identify the District Offices that use the CTDS and HyPRIS to determine the planned project contract time (total duration). To accomplish this goal, a survey was circulated among the 25 District Offices of Texas to identify the ones that utilize these tools. Next, the identified District Offices were approached to request data about past completed projects. The data collected were the actual and estimated: a) work quantities, b) production rates, and c) activities durations for different work items.

To obtain these data a survey -see Appendix 3.1- was designed to qualitatively solicit experts' opinions about the methods they use to estimate the contract time. The survey was sent to the 25 TxDOT district offices requesting information on the system(s) that their offices use to establish the contract time durations and any production rate sources that they use. The survey was comprised of three simple questions about 1) whether the experts use CTDS and/or HyPRIS, 2) the effectiveness of these systems, and 3) any other system/database they use to estimate the contract time. The survey also identified the district offices that have used the CTDS and HyPRIS to estimate their projects durations. A total of 47 responses were received from 21 different districts; some of the district offices sent multiple responses.

Results show that only 16% of the experts use CTDS, while 31% of them use HyPRIS. As for the effectiveness of the systems, the majority of the experts do not consider the systems effective in providing accurate production rates. The breakdown of the expert's opinions about the effectiveness of the two systems is shown in Figure 3.3. For overall survey results see Appendix 3.2.

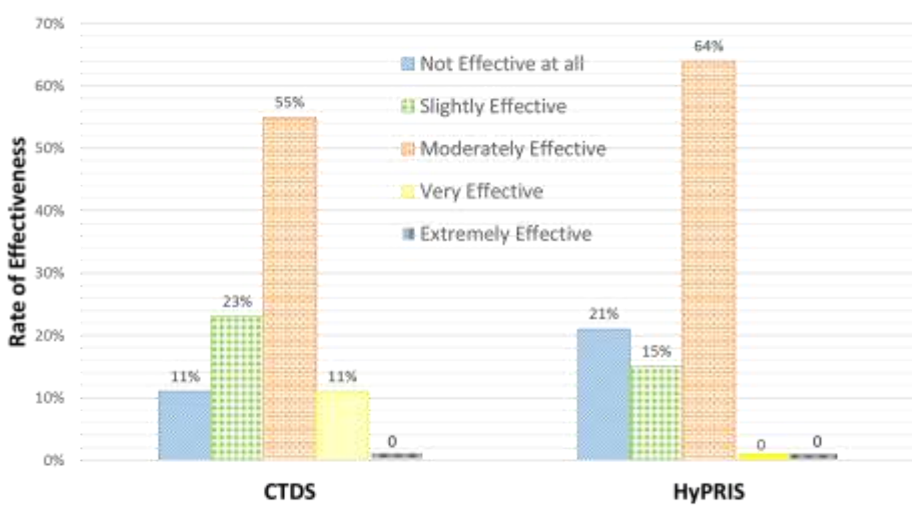


Figure 3. 3: CTDS and HyPRIS effectiveness rates**.**

Survey results led to the identification of five TxDOT districts that are currently using both CDTS and HyPRIS to determine contract time. As such, these districts offices were approached to collect historical data about different types of highway construction projects. Two district offices agreed to provide the needed data. For confidentiality purposes, they will be referred to as District A.

3.2.2 Data Extraction

The District Office provided three types of data sources: 1) Contract Report Bundles, 2) Daily Work Reports (DWR), and 3) Project Timelines. Each source contains important information about the projects executed. The data included in these sources were used to conduct statistical analyses to evaluate the efficiency of CTDS and HyPRIS. Additionally, the Standard Specifications for Construction and Maintenance of Highways, Streets and Bridges (*2015*) was consulted for verification of the work items (activities) descriptions.

3.2.2.1 Contract Report Bundles. The contract report bundle is an official summary for the whole project and it was the main source of information in the data extraction process. This report includes essential data about the work items executed in the project, such as the estimated quantities, the actual quantities installed, dates performed, and the daily production rates. The information extracted from this source was critical to develop the analysis of the CTDS and HyPRIS.

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3.2.2.2 Daily Work Report (DWR). The DWR is a report submitted by the TxDOT inspector, it provides valuable documentation of the work executed daily and unusual events. It records in detail the activities performed daily; it also includes weather conditions, the work in progress, arrival and departure of equipment, important instructions to the contractor, decision-making discussions, unusual work conditions, etc. The report provides the exact quantities and durations of the different project activities. Although the report bundles also provides similar information, it was important to verify these quantities using both reports since they are the key for finding the production rates for all the different activities.

3.2.2.3 Project Timeline. The third source of information is the project timeline, which is Gantt Chart developed by TxDOT engineers; it provides a graphical illustration of the estimated duration of the project activities. The project timelines provide the overall estimated project duration, start and finish dates for each activity, and the relationship between activities.

3.2.2.4 Data Extraction Software. The different types of data in the aforementioned reports are very extensive. As such, it deemed essential to develop a spreadsheet-based software to automate the process of data sorting, extraction, and organization, as shown in Figure 6. This software expedited the process of data extraction, ensured consistency, and minimized the chances of error.

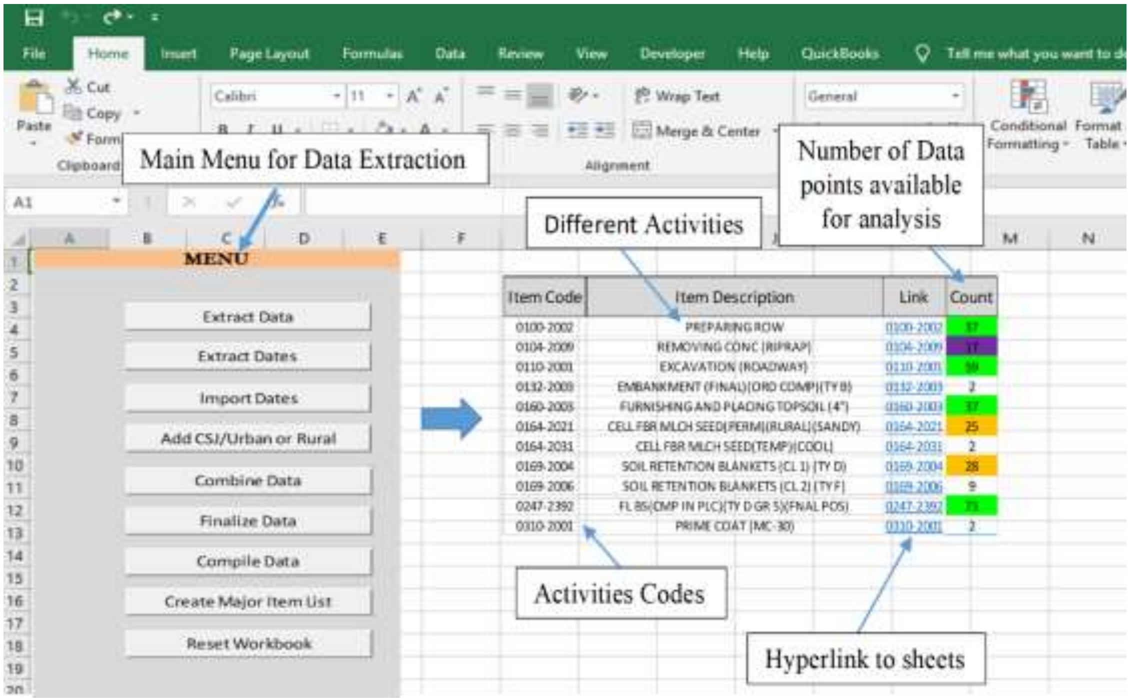


Figure 3. 4: Data Extraction Software: Master Sheet and Menu Output**.**

The software extracts all the needed data from the three reports report and organizes them in different sheets, see Table 3.1. -see Appendix 3.3 for software template. After the completion of the data extraction and organization in different sheet, a menu of the work items, their codes, and data point counts is automatically created to serve as a table of contents of the new MS Excel workbook. Also, the menu items are generated as hyperlinks to facilitate browsing the workbook to view and collect the extracted data.

Table 3. 1: Template of Data Extracted from CRB.

CSJ	ItemCode	ItemDescription	EstQty	ActQty	Unit	EstDur	DurDays	DayOrNight	UrbanOrRural	County	District	Date	TypeOfWork
0015-08-116	0247-2044	Flexible Base	19,826.00	19,826.00	CY		17.00	Day	Urban	Williamson	Austin	40,990.00	Bridge Replacement
0015-08-134	0247-2044	Flexible Base	7,870.00	7,462.22	CY	20.00	3.00	Night	Urban	Williamson	Austin	42,272.00	Bridge Replacement
2719-01-008	0247-2366	Flexible Base	9,190.00	9,190.00	CY	28.00	5.00		Rural	Gillspie	Austin	41,509.00	Widen Non-Freeway
0211-02-024	0247-2392	Flexible Base	1,193.00	1,193.00	CY	16.00	4.00	Day	Rural	Lee	Austin	41,963.00	Bridge Replacement
0252-02-046	0247-2392	Flexible Base	1,595.81	1,595.81	CY		3.00	Day	Rural	Burnet	Austin	41,085.00	Bridge Replacement
0440-02-101	0247-2392	Flexible Base	88,302.06	88,302.06	CY		28.00	Day	Urban	Williamson	Austin	41,418.00	Widen Non-Freeway

3.2.3 Data Analysis

The data collected were then analyzed to assess the performance of CTDS and HyPRIS as reliable tools for contract time estimation. Statistical analyses were deployed to perform comparisons between the estimated activity durations, quantities, and production rates obtained using the two systems versus the actual values from the field.

Although CTDS and HyPRIS do not affect the precision of the quantity estimate, it was necessary to compare the estimated and actual quantities to determine the root cause of the error in estimating the contract time. It is known that the activity duration is calculated as the quantity divided by the productivity rate. Hence, an error in the quantity estimate will yield an inaccurate activity duration, which will impact the estimate of contract time negatively even with the use of accurate production rates.

In order to conduct a meaningful evaluation of CTDS and HyPRIS, it was essential to analyze the collected data statistically from three different perspectives. First, a macro-level evaluation of the two systems was conducted by grouping all the work items of all the projects together; performance measures were then used to statistically evaluate the performance of the systems as will be explained in detail in the following sections. Second, mid-level analysis was conducted by statistically assessing the performance of the systems with respect to the nature of work. Four work categories were specified, namely, 1) Earthworks, 2) Finishing Works, 3) Asphalt works, and 4) Concrete works. Items of the same nature were grouped together, and their data were statistically analyzed to evaluate the performance of CTDS and HyPRIS holistically with respect to the designated work categories. Finally, a micro-level examination was conducted to provide a comprehensive evaluation of the systems through the analysis of each work item individually. Every work item was listed in a separate sheet; data on the work quantities, durations, and production rates of the specific item were collected from all the projects provided by the District Office, see Table. It should be noted that data collected comes from the same District Office; this is to ensure that the performance of the systems is assessed with respect to the same geographical and climatic conditions as well as the same group of users' expertise and knowledge.

The pooling and categorization of the work items required grouping them together. However, it deemed inappropriate to include them in a single data set with their differing units. To overcome this dilemma, the error ratio was used to assess the performance of each of the two systems. The error ratio (ER) is unitless and reflects the difference between actual and estimated values. Error ratios were computed for the work quantities, activity durations, and productions rates of different work items according to Equation (3.1).

For the first level of analysis, the error ratios of all items were pooled together. The objective was to assess the performance of CTDS or HyPRIS holistically for all the projects performed by District A. The error ratios were first studied individually and then multiple linear regression analysis was used to determine how the productivity rates and the quantity of work affect the estimated duration.

$$ER = \frac{Estimated - Actual}{Estimated} \tag{3.1}$$

Next, the systems were analyzed with respect to the nature of work; the analysis included descriptive statistics, one-sample T-Test, Wilcoxon signed rank Test, and Multiple linear Regression. To obtain a robust conclusion, each work category was analyzed separately using the ER performance measure. The statistical analysis helped determine if the CTDS and HyPRIS have better performance in estimating the production rates of work items of one category compared to others.

Finally, the analysis of each work item included descriptive statistics, and paired T-Tests. The data sets were used to compare the actual and estimated values; comparisons included work quantities, activities durations, and productivity rates. In order to obtain significant statistical results only items with a sample size greater than 30 were considered for the evaluation.

3.3 Statistical Analysis Results

The analyses were conducted on data extracted from 26 highway projects provided by District A. The data were analyzed with respect to the 1) district level, 2) work category, and 3) individual work items. Overall results of statistical analyses can be found in Appendix 3.4.

3.3.1 Statistical Analysis of the Error Ratios at the District Level

The first step in the analysis was compiling all the data collected on work items from all the 26 projects completed by District A. The data were then organized in three groups, which are the work item: 1) work quantity, 2) activity duration, and 3) production rate. The error ratios for each of these data groups were calculated and studied separately using descriptive and inferential statistics. An error ratio close to 1 means that estimated value is much larger than the actual value, while an error rate close to 0 indicates that difference between the estimated and actual values is very minimal.

First, descriptive statistical analysis was conducted on the error ratios to get initial evaluation of the performance of the CTDS and HyPRIS using the projects completed by District A. Second, a normality test was performed on the error ratios data sets to determine whether the calculated errors follow a normal distribution or not. For normal probability distributions, the parametric one sample T-test was performed to determine if the mean error was significantly greater or less than zero. The null hypothesis (H_0) assumes that the means (μ) is less than or equal to zero. Conversely, the alternative hypothesis (H_1) is stated as follows:

H_0: $\mu \leq 0$, H_1: $\mu > 0$

When the data could not be assumed to be normally distributed, the non-parametric one-sample Wilcoxon signed rank test was performed. The test was used to determine whether the median of difference between ERQty, ERDur, ERPr and the population median is greater or less than 0. The different cases of null hypothesis and alternative hypothesis are defined as follows:

$H_0: m_d \leq 0$, $H_1:\ m_d > 0$

$H_0: m_d \geq 0$, $H_1:\ m_d < 0$

$H_0: m_d = 0$, $H_1:\ m_d \neq 0$

where, H_0 is the null hypothesis, H_1 is the alternative hypothesis; μ is the mean of the error ratios, m_d is the median of difference between the error ratios.

Lastly, multiple linear regression was used to explain the relationship between one continuous dependent variable (Errors in Duration (ERDur)) and two or more independent variables (Errors in quantity (ERQty) and production rate (ERPr)) by fitting a linear equation to the observed data. The objective is to assess the impact of the errors in estimating the quantity (ERQty) and production rate (ERPr) on the errors of activity duration (ERDur). In other words, this test was conducted to determine whether the errors in estimating the activity durations is mainly rooted to errors in estimating the work quantities (ERQty) or errors in the production rates (ERPr). In general, the null hypothesis of a multiple regression analysis assumes that there is no relationship between the independent variables and the dependent variable. The objective was to assess the impact of errors in estimating the activity quantity (ERQty) and production rates (ERPr) on the overall error realized in the activity duration (ERDur), as expressed by Equation (3.2).

$$ERDur = a + \beta_1 ERPr + \beta_2 ERQty \quad (3.2)$$

where, β_1 and β_2 are the regression coefficients or the slopes, and a is the intercept.

The descriptive statistics of the error ratios for District A are shown Table 3.2. The boxplots in Figure 3.5 illustrates the boundaries of error ratios for work quantity, activity duration, and productivity rates. Figure 3.5b shows that for instance, the error in calculating the quantity (ERQty) is limited to ±10% since the majority of the error ratios are bounded between ± 0.1 – see Figure 3.5a. The majority of the ERDur are bounded between 0 and 1; however, there were a few outliers located in the distribution. It is clear that the distribution is positively skewed since the majority of data greater than 0, which indicates an overestimation of the work items duration – see Figure 3.5b. Conversely, the distribution of the ERPr values - Figure 3.5c - is negatively skewed indicating an underestimation of the production rates.

Table 3. 2: Summary Statistics for the Error Ratios of the Work Items of District A.

Descriptive Statistics	***Error Rates for Qty***	***Error Rates for Dur***	***Error Rates for Pr***
Mean	-0.21	0.60	-32.00
Median	0.00	0.75	-0.03
Std Deviation	1.20	0.48	31.83
Range	20.97	3.99	197.96
Minimun	-19.98	-197.00	-3.00
Maximun	1.00	0.99	-0.96
Count	2,081.00	424.00	424.00

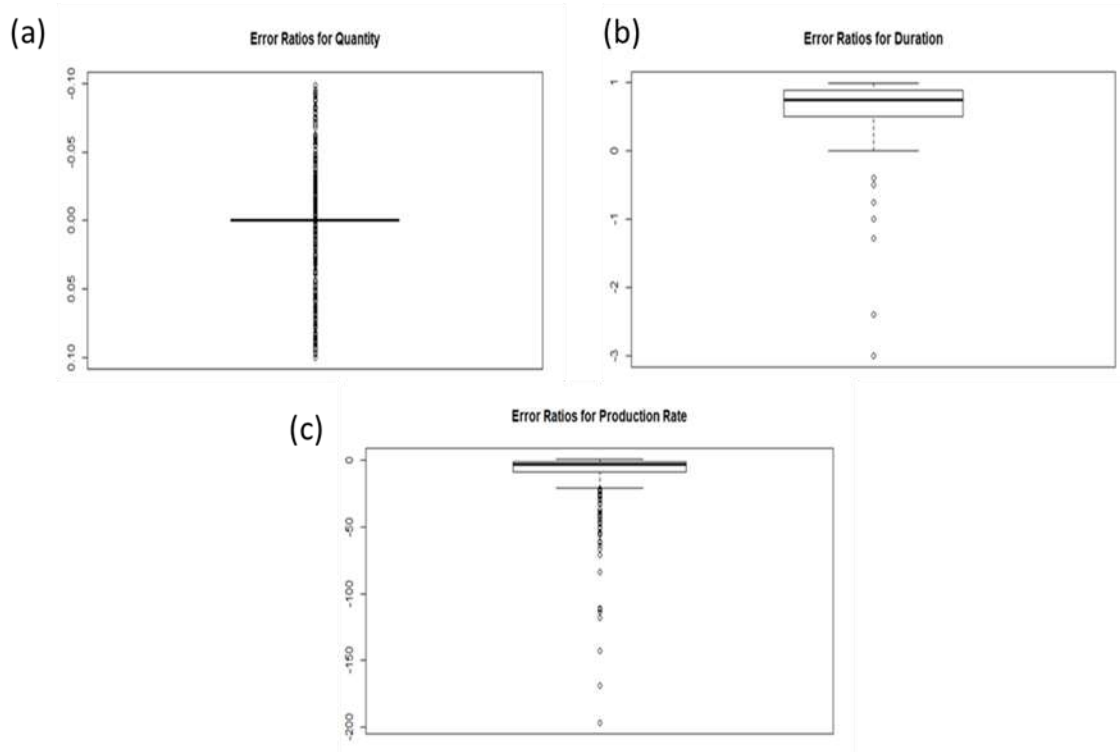


Figure 3. 5: Boxplots of Error Rates for the Different Work Items of District A.

Based on the descriptive analysis, it was hypothesized that the inaccuracy in determining the activity duration and consequently the project contract time is rooted to the utilization of inaccurate production rates rather than an imprecise estimation of the work quantities. However, descriptive statistics were not enough to determine whether there was a significant difference between the means of estimated and actual work quantities, activities durations, and productivity rates. Hence, inferential statistics were used to reach conclusions that extend beyond examining the data alone. The objective of this analysis was to determine if values for work quantities, activity durations, and productivity rates were in general over or underestimated.

The normality test results show that the error ratios do not follow a normal distribution. Hence, the non-parametric one-sample Wilcoxon signed rank test was used to determine whether the median of the sample was less than or greater than zero.

For work quantity, the Wilcoxon signed rank test was conducted to test whether the median differences of the ERQty were greater than zero. Results showed significant evidence (p-value < 0.01) that the median of ERQty is less than 0. The confidence interval at 95% for ERQty is (-0.1, -0.04). The effect size (Hodges-Lehmann estimator) turned out to be -0.5 indicating a moderate effect. These results indicate that the estimated work quantities are significantly less than actual quantities. This can be rooted to the multiple change orders that could occur during the construction phase of the project.

The medians of the errors in calculating the activity duration (ERDur) were also assessed using the non-parametric Wilcoxon Signed Rank Test. In this case, the test was used to determine whether the median differences of the ERDur were less than or equal to zero. The p-value was less than 0.001 and the 95% confidence interval for ERDur is (0.72, 0.77). The effect size (Hodges-Lehmann estimator) turned out to be 0.66 indicating a moderate effect. As such, the null hypothesis (H0) was rejected as there is a significant evidence that the median of the error rates for duration is significantly greater than 0. This means that the durations of the different project work items are usually overestimated.

For productivity rates, the Wilcoxon signed rank test was also conducted to test whether the median differences of the ERPr were greater than zero. Results showed a p-value is less than alpha (0.05), which indicates that there is a significant evidence that the median ERPr is less than 0. The confidence interval at 95% was bound between (-6.2, -4.0). The effect size (Hodges-Lehmann estimator) turned out to be -4.17 indicating a large effect. As such, it can be deduced that that the production rates used to estimate the activity durations are underestimated. These results are in concurrence with the analysis results of the ERDur.

The determination of the activity duration and consequently the project time estimate depends on two estimates. The first estimate is the quantity of work, and the second one is the production rate. The errors in estimating the duration (ERDur) can be rooted to either an error in estimating the quantity (ERQty) or errors in estimating production rate (ERPr) or both. As such, multiple linear regression analysis was performed to study how the errors in estimating the quantity (ERQty) and errors in estimating production rate (ERPr) contribute to the errors in estimating the duration (ERDur).

First, the Pearson correlation factor was used to quantify the association between two variables (e.g., between ERDur and ERQty or ERPr).The data exploration revealed that the linear correlation between ERDur and ERQty was very weak (0.29), while the correlation between ERDur and 1/ERPr (ERPr2) was strong (0.83). Both of these correlations were significant.

The linear regression model is given on Equation (3); the overall model fit was assessed using the (adjusted) R^2 and significance of the p-value. The R^2 (or coefficient of determination) indicates the degree to which the model explains the observed variation in the dependent variable, relative to the mean. The model explained 87% of the variation in ERDur and was found to be significant with a p-value < 0.001. The unstandardized β coefficients indicate the effect of a 1-unit increase in the independent variable (on the scale in which the original independent variable is measured) on the dependent variable. This means that if ERQty is increased by one unit, ERDur is expected to increase by 0.26, and one unit increase of 1/ERPr (ERPr2) will lead to 0.37 unit increase of ERDur. In general, it can be concluded that ERPr has a higher impact on ERDur than ERQty for District A. Regression analysis results are reported in Table 3.3.

Table 3. 3: Regression Analysis Results for District A Error Rates.

Parameter/Variable	***Coefficient***	***P-Value***
ERPr2	0.37	<0.01
ERQty	0.26	<0.01

3.3.2. Analysis of Work Items Based on the Nature of Work

To analyze the systems with respect to the nature of work, the work items were grouped in four main categories: earthworks, finishing works, asphalt works, and concrete works. The four categories were then statistically analyzed using the error rates previously defined, as shown in Figure 3.6.

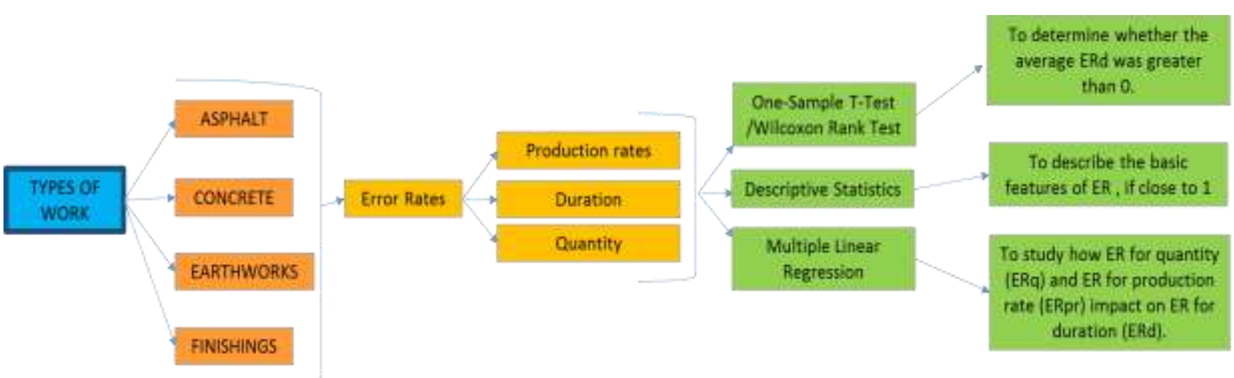


Figure 3. 6: Data analysis approach used for the different types of work.

First, descriptive statistics on the error ratios were conducted, see Table 3.4. The boxplots of all the error ratios are also shown in Figure 3.7. For ERQty (Figure 3.7a), the boxplot shows that the errors are very close to zero with very few outliers. This indicates that the estimated and the actual quantities are close in values. The boxplot for ERDur (Figure 3.7b) shows that the majority of the ERs are greater than zero. This indicates that the activity durations for different work categories are overestimated. These results were confirmed through the boxplots of the ERPr (Figure 3.7c), which show that the production rates for different work categories are underestimated as most values are less than zero.

Table 3. 4: Summary of Descriptive Statistics of the Error Ratios for Different Work Categories.

Descriptive Statistics	***Earthworks***			***Finishing Works***			***Asphalt Works***			***Concrete Works***		
	ERQty	***ERDur***	***ERPr***	***ERQty***	***ERDur***	***ERPr***	***ERQty***	***ERDur***	***ERPr***	***ERQty***	***ERDur***	***ERPr***
Mean	-0.58	0.62	-23.12	-0.20	0.61	-9.03	-0.15	-0.11	-4.13	-0.25	0.77	-28.49
Median	0.00	0.75	-3.00	0.00	0.75	-2.94	0.00	0.50	-1.14	0.00	0.87	-6.50
Std Deviation	3.17	0.39	72.49	1.01	0.40	21.95	0.99	2.58	8.63	2.48	0.33	43.18
Range	34.12	1.99	530.77	14.00	3.39	118.62	9.44	18.96	51.74	46.62	1.99	169.60
Minimum	-33.12	-1.00	-530.24	-13.01	-2.40	-118.00	-8.44	-18.00	-50.79	-45.64	-1.00	-169.00
Maximum	1.00	0.99	0.53	0.99	0.99	0.62	1.00	0.96	0.96	0.98	0.99	0.60
Count	266.00	72.00	72.00	1,231.00	196.00	196.00	178.00	55.00	55.00	410.00	101.00	101.00

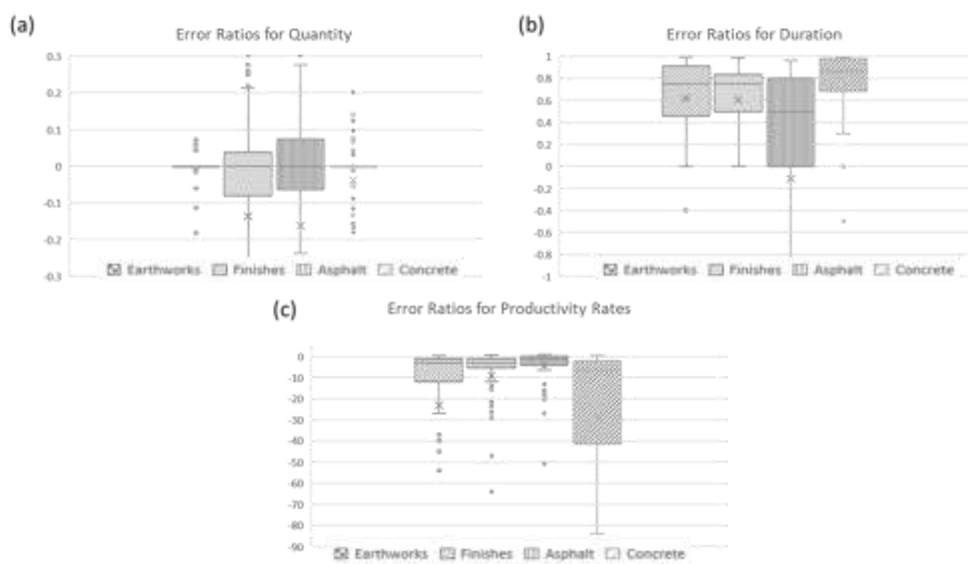


Figure 3. 7: Boxplots of Error Rates a) Duration (ERDur) b) Productivity Rates (ERPr) c) Quantity (ERQty) District A

3.3.2.1 Earthworks. Earthworks consist of roadway excavations (cuts) and roadway embankments (fills) for highways and associated work items. Earthworks include but not limited to excavating, loading, hauling, dumping and spreading, compaction, grading, and construction of embankments. (DOT Specifications Manual, 2004). The earthwork category was analyzed using the methodology described in Figure 3.6.

Descriptive Statistics for the earthwork category showed that the average error rate for earthwork-related activities durations was greater than zero. The normality test was conducted, determined that the ERDur follows a normal distribution. As such, a one sample T-test was performed to determine if the mean ERDur is less than or equal to zero (H_0: $\mu \leq 0$). The test yielded significant results to reject the null hypothesis, since the p-value (4.58×10^{-21}) is less than alpha ($\alpha = 0.05$) and the T-Stat (13.36) was higher than the critical value (1.99). This indicates that the estimated activity durations are significantly greater than actual durations for earthworks operations for District A. Since ERDur depends on errors in estimating the work quantities and production rates, it was essential to further the analysis to determine the root cause for the inaccurate durations. Hence, the non-parametric Wilcoxon signed rank was conducted to test whether the medians differences ($m_d = ER - median$) of work quantity and productivity rates were equal to zero (H_0: $m_d = 0$). As such, the null hypothesis (H0) was accepted as there was significant evidence that the median of the error rates for work quantity is equal to 0 (p-value: 0.152> α (0.05)). Which means that there is not big difference between the estimated and actual work quantities. Similarly, the null hypothesis of the test for error in production rates could not be rejected (p-value: 1 > α (0.05)). The median of error rates of productivity rates was found to be -3, this means that the production rates used to estimate the duration of earthwork operations are underestimated.

In addition, The data exploration revealed a Pearson correlation between ERDur and ERQty of 0.13 (Weak) , while the Pearson correlation factor between ERDur and ERPr2 was 0.59 (Strong). Both of these correlations were found to be significant.

Multiple linear regression analysis was conducted to study how ERQty and ERPr impact the accuracy of the activity duration estimation (ERDur). When interpreting the R^2, higher values indicate that more of the variation in duration is explained by variation in production rates and quantity; the linear regression model described in Equation 3.4, explained 86% (R^2) of the variation in ERDur with a significance (p-value) of 1.07x10-6. The unstandardized β coefficients were found to be 0.22 for productivity rates and 0.15 for quantity. This means that one unit increase of ERQty will lead to a 0.15-unit increase of ERDur, and one unit increase of ERPr2 will lead to a 0.22-unit increase of ERDur. In general, it can be concluded that ERPr2 has a higher impact on ERDur than ERQty for earthworks. Regression analysis results are reported in Table 3.5.

$$ERDur = 0.48 + 0.15ERQty + 0.22ERPr2 \qquad (3.4)$$

3.3.2.2 Finishing Works. The finishing category includes any work developed in the final stage of the highway project after the completion of the asphalt surface of the road. Finishing works include but not limited to pavement marking, protection, signals, and aesthetics.

The initial analysis showed that ERDur for the finishing work categories also follows a normal distribution. As such, a one-sample T-test was performed to determine if the mean ERDur is less than or equal to zero (H_0: $\mu \leq 0$). The test yielded significant results showing that the values of ERDur for the finishing works are significantly higher than zero. The null hypothesis was rejected since p-value (4.26×10^{-52}) is less than alpha (0.05)). Hence, it can be inferred that the durations of the finishing works are overestimated.

Conversely, the ERQty and ERPr values did not follow a normal distribution. The non-parametric Wilcoxon signed rank test was used to test whether the medians difference of work quantity was equal to zero (H_0: $m_d = 0$). Results showed significant evidence to accept the null hypothesis (p-value: $0.12 > \alpha$ (0.05)) , which means that there is not a big difference between the estimated and actual values. For productivity rates, the Wilcoxon signed rank test was conducted to test whether the median differences of the ERPr were greater than zero (H_0: $m_d \geq 0$) . The test yielded a p-value less than alpha (p-value: $0.0001 < \alpha$ 0.05), which indicates that there is a significant evidence that the median ERPr is less than 0. As such, it can be deduced that that the production rates used to estimate the activity durations are underestimated.

Pearson correlation test showed that the linear correlation between ERDur and ERQty was found to be very weak (0.06), while the correlation between ERDur and ERPr2 was strong (0.64). Both of these correlations were significant.

Multiple linear regression analysis was performed; the model given in Equation 3.5 yielded a R^2 of 85% and a p-value of 9×10^{-19}. The linear regression model determined that one unit increase of ERQty would lead to 0.38 unit increase of ERDur, and one unit increase of ERPr2 would lead to 0.59 unit increase of ERDur. Once again, ERPr2 had a higher impact on ERDur than ERQty. Regression analysis results are reported in Table 3.5.

$$ERDur = 0.47 + 0.38ERQty + 0.59ERPr2 \quad (3.5)$$

3.3.2.3 Asphalt Works. Asphalt works refer to all types of highway construction works that uses hot-mix asphalt (HMA). Initial assessment of the data revealed that none of the error ratios followed a normal distribution. As such, a one sample Wilcoxon signed rank test was conducted for all error ratios. The application of the one sample non-parametric Wilcoxon Rank test to compare the medians of the duration and productivity rates showed enough evidence to accept the null hypothesis ($H_0: m_d = 0$). The ERPr follows a symmetric distribution around the population median that has a value of -1.14. The inferential statistical analysis yielded a p-value (0.827) that is significantly higher than alpha (0.05). Therefore, it was concluded that the estimated production rates are considerably lower than the actual production rates for asphalt works in District A. For ERDur, the p-value was 0.885, which is significantly greater than alpha (0.05). Since the median of ERDur is 0.50, it can be concluded that the durations are overestimated.

For quantity, the Wilcoxon signed rank test was conducted to test whether the median of the differences of the ERQty was less than zero ($H_0: m_d \leq 0$) . The results showed that the p-value (0.827) is greater than alpha (0.05). As such, the null hypothesis was accepted, and it was concluded that work quantities of asphalt items are generally underestimated.

The Pearson correlation factor between ERDur and ERQty was 0.10, while the factor between ERDur and ERPr2 was 0.72. Both of these correlations were significant.

The linear model given in Equation 3.6 explained 77% of variation in ERDur and was significant with a p-value of $8x10^{-8}$. The unstandardized β coefficients were found to be 0.49 for productivity rates and 0.29 for quantity. This means that one unit increase of ERQty will lead to 0.29 unit increase of ERDur; and one unit increase of ERPr2 will lead to 0.49 unit increase of ERDur. Regression analysis results are reported in Table 3.5.

$$ERDur = 0.31 + 0.29ERQty + 0.49ERPr2 \quad (3.6)$$

3.3.2.4 Concrete Works. Concrete works refer to construction work items that utilize concrete as the main material including rigid pavements. The values of the ERDur follow a normal distribution. Hence, a one sample T-test was performed. The results showed that there is significant evidence that the mean is ERDur significantly greater than zero sin the p-value (1.11×10^{-42}) was significantly less that alpha (0.05), which indicates an overestimation in the durations of the concrete activities.

For the ERQty and ERPr, a non-parametric Wilcoxon Rank test was used to test whether the medians of differences were equal to zero (H_0: $m_d = 0$). The results indicated that there is a significant evidence that the medians of difference of the ERPr and ERQty were equal to zero. This means that production rates used for concrete work items were underestimated. On the other hand, the Wilcoxon Rank test indicated not big difference between estimated and actual quantities for concrete works.

Pearson correlation results revealed that the linear correlation between ERDur and ERQty was found to be very weak (0.02), while the correlation between ERDur and ERPr2 was strong (0.70). Both of these correlations were significant.

The linear model given in Equation 3.7 explained 77% of variation in ERDur and was significant with a p-value of 1.21×10^{-11}. The unstandardized β coefficients were found to be 0.15 for productivity rates and 0.06 for quantity. This means that one unit increase of ERQty will lead to 0.06 unit increase of ERDur; and one unit increase of ERPr2 will lead to 0.15 unit increase of ERDur. Regression analysis results are reported in Table 3.5.

$$ERDur = 0.69 + 0.06ERQty + 0.15ERPr2 \quad (3.7)$$

Regression analysis results confirmed once again that the production rates have a higher impact on the activity duration than the quantity installed for concrete works. Results of regression analyses and inferential statistical analyses conducted for the different types of work categories are summarized in Table 3.5 and 3.6 respectively.

Table 3. 5: Regression analysis results per category of work for ERQty and ERPr2.

Work Category	***Parameter/Variable***	***Coefficient***	***P-Value***
Earthworks	Intercept	0.488	1.07×10^{-6}
	ERQty	0.153	
	ERPr	0.22	
Finishing Works	Intercept	0.478	9×10^{-19}
	ERQty	0.385	
	ERPr	0.59	
Asphalt Works	Intercept	0.315	8×10^{-8}
	ERQty	0.296	
	ERPr	0.494	
Concrete Works	Intercept	0.699	1.21×10^{-11}
	ERQty	0.064	
	ERPr	0.153	

Table 3. 6: Summary Results of Error Rates by Category of Work.

Type of Work	***Parameter***	***Null Hypothesis***	***Test***	***Significance***	***Effect size***	***Decision***	***Conclusion***
Earthworks	**Quantity**	$m_d = 0.$	One Sample Wilcoxon Signed Rank Test	0.15	0.00	Retain the null hypothesis.	No big difference between the estimated and actual quantities
	Productivity rate	$m_d = 0.$	One Sample Wilcoxon Signed Rank Test	1.00	-2.68	Retain the null hypothesis.	The productivity rates are underestimated
	Duration	$\mu \leq 0$	One Sample T-test	4.58×10^{-21}	NA	Reject the null hypothesis.	Durations are overestimated
Finishing	**Quantity**	$m_d = 0.$	One Sample Wilcoxon Signed Rank Test	0.78	-0.12	Retain the null hypothesis.	No big difference between the estimated and actual quantities
	Productivity rate	$m_d \geq 0.$	One Sample Wilcoxon Signed Rank Test	0.00	-0.57	Reject the null hypothesis.	The productivity rates are underestimated
	Duration	$\mu \leq 0$	One Sample T-test	4.26×10^{-52}	NA	Reject the null hypothesis.	Durations are overestimated
Concrete	**Quantity**	$m_d = 0.$	One Sample Wilcoxon Signed Rank Test	0.86	0.00	Retain the null hypothesis.	No big difference between the estimated and actual quantities
	Productivity rate	$m_d = 0.$	One Sample Wilcoxon Signed Rank Test	1.00	-5.50	Retain the null hypothesis.	The productivity rates are underestimated
	Duration	$\mu \leq 0$	One Sample T-test	1.11×10^{-42}	NA	Reject the null hypothesis.	Durations are overestimated
Asphalt	**Quantity**	$m_d \leq 0.$	One Sample Wilcoxon Signed Rank Test	0.83	-1.14	Retain the null hypothesis.	Work quantities of asphalt work are underestimated
	Productivity rate	$m_d = 0.$	One Sample Wilcoxon Signed Rank Test	0.07	-0.78	Retain the null hypothesis.	The productivity rates are underestimated
	Duration	$m_d = 0.$	One Sample Wilcoxon Signed Rank Test	0.89	0.16	Retain the null hypothesis.	Durations are overestimated

3.3.3 Statistical Analysis of Individual Work Items

Individual work items were analyzed separately using the same statistical methods described prior. For District A, there were 171 items retrieved; however, only 18 items had a sample size greater than 30. Each activity is represented by three digits; these digits are unique codes outlined in the TxDOT specifications manual. For all work items, units were also specified in the code. For example, item 0644_EA, refers to small roadside sign assemblies, and the unit is "Each". A sample of the descriptive statistics results for the work quantities, activity duration and productivity rates of "installation of safety end treatments for drainage structures" (Item 0467_EA) is shown in Table 3.7. For this item, the means for the estimated and actual work quantity are quite close in values; however, there is a big difference between the means of the estimated and the actual productivity rates. Consequently, this big difference occurs between the mean estimated and actual durations. Since the exploration of each of the work items was very extensive, Table 3.7 shows sample results of only one of the 18 items analyzed.

Table 3. 7: Results of Descriptive Statistic of Item 467_EA from District A.

Descriptive Statistics	***Installation of safety end treatments for drainage structures (Item 0467_EA)***					
	EstQty	***ActQty***	***EstDur***	***ActDur***	***EstPr***	***ActPr***
Mean	8.35	8.25	90.47	3.16	0.26	2.22
Standard Error	1.29	1.33	16.56	0.32	0.09	0.17
Median	2.00	3.00	45.00	2.00	0.12	2.00
Standard Deviation	13.58	13.87	68.26	3.37	0.39	1.78
Minimum	0.00	1.00	38.00	1.00	0.02	0.00
Maximum	74.00	87.00	195.00	18.00	1.52	9.00
Sum	919.00	899.75	1,538.00	348.00	4.40	244.40
Count	110.00	109.00	17.00	110.00	17.00	110.00

To statistically compare the estimated values using CTDS and HyPRIS to the as-built (actual) values, a normality test was conducted to determine whether to use parametric or no-parametric statistical analysis. The results showed that only some items follow a normal distribution. However, considering the limited data set available, it was hypothesized that a normal distribution could be achieved with more data available. To validate the study results, both parametric and non-parametric statistical analyses were applied to all work items.

As such, a paired *T*-test was conducted to assess the performance of CTDS and HyPRIS by comparing the mean of the actual values to the ones estimated using the two systems for work items with sample size greater than 30. The null hypothesis (H_0) assumes that the true mean difference (μ_d) between the paired estimated and actual values is zero. Conversely, the alternative hypothesis (H_1) assumes that the true mean difference between the paired estimated and actual values is not equal to zero. In this case, the alternative hypothesis can take one of several forms depending on the descriptive statistics and expected outcome, as shown in Tables 3.4 and 3.5. Paired *T*-tests were performed for work quantity, activity duration and productivity rates.

H_0: $\mu_d = 0$, H_1: $\mu_d \neq 0$

The outputs of the pair-wise comparisons of individual work items of District A showed that for work quantity, the majority of items did not have a significant difference between the means of the estimated and actual quantities. However, only three items showed significant difference in means. There was statistically significant evidence that the average estimated quantity is smaller than the average actual quantity for small roadside sign assemblies (Item 0644_EA), zone pavement markings (Item 0662_LF) and concrete box culverts and drains (Item 0462_LF).

For production rate, there was statistically significant evidence that the average estimated production rates are smaller than the average actual production rates for all the work items analyzed. This indicates that production rates are underestimated in general. For activity duration, there was statistically significant evidence that the average estimated duration is greater than the average actual duration for all items except the installation of safety end treatments for drainage structures (Item 0467_EA). This indicates that the activities durations are overestimated generally.

The summary results for of a sample work items analyzed from District A are provided in Table 3.8. The (*) sign refers to items with p-value less than alpha (0.05) at a confidence interval of 95%. The results support the hypothesized conclusion based on the descriptive statistics that the estimation of unrealistic contract time is attributed to inaccurate production rates rather than an error in estimating the quantities.

Table 3. 8: Results of Pair-wise Comparisons for Items from District A.

Work Item		***Work Quantity***		***Activity Duration***		***Production Rate***	
		H_1	***p-values***	***H_1***	***p-values***	***H_1***	***p-values***
1	0420_CY	$\mu_{EQ} < \mu_{AQ}$	0.44	$\mu_{ED} > \mu_{AD}$	*0.001	$\mu_{Epr} < \mu_{Apr}$	*0.001
2	0432_CY	$\mu_{EQ} < \mu_{AQ}$	0.15	$\mu_{ED} > \mu_{AD}$	*9.14e-5	$\mu_{Epr} < \mu_{Apr}$	*0.001
3	0672_EA	$\mu_{EQ} < \mu_{AQ}$	0.67	$\mu_{ED} > \mu_{AD}$	*0.002	$\mu_{Epr} < \mu_{Apr}$	*4.69e-9
4	0416_LF	$\mu_{EQ} < \mu_{AQ}$	0.71	$\mu_{ED} > \mu_{AD}$	*0.007	$\mu_{Epr} < \mu_{Apr}$	*0.001
5	0462_LF	$\mu_{EQ} < \mu_{AQ}$	*0.05	$\mu_{ED} > \mu_{AD}$	*1.88×10^{-7}	$\mu_{Epr} < \mu_{Apr}$	*4.30×10^{-4}
6	0662_LF	$\mu_{EQ} < \mu_{AQ}$	*0.05	$\mu_{ED} > \mu_{AD}$	*1.45×10^{-5}	$\mu_{Epr} < \mu_{Apr}$	*0.01
7	0666_LF	$\mu_{EQ} > \mu_{AQ}$	0.38	$\mu_{ED} > \mu_{AD}$	*1.47×10^{-14}	$\mu_{Epr} < \mu_{Apr}$	*0.004
8	0467_EA	$\mu_{EQ} > \mu_{AQ}$	0.25	$\mu_{ED} > \mu_{AD}$	1	$\mu_{Epr} < \mu_{Apr}$	*0.001

Wilcoxon Signed Rank Test was used for verification when the sample size was too small to draw a conclusive result that the sample is normally distributed. In analyzing the individual work items. the Wilcoxon signed rank test was used to determine whether there was a difference between the estimated and actual values for work quantity, activity duration and productivity rates. In this test, the null hypothesis (H_0) assumes that there is no difference between the paired estimated and actual values. On the other hand, the alternative hypothesis (H_1) assumes that there is a difference between the paired estimated and actual values.

H_0: $Estimated = Actual$, H_1: $Estimated \neq Actual$

The non-parametric statistical analysis was performed on the estimated and actual work quantities, activity duration and production rates for District A. The output results are in concurrence with the results of the paired T-test, as shown in Tables 3.9.

Table 3. 9: Results of Wilcoxon Signed Rank Test for individual work items of District A.

Work Item		***Work Quantity***	***Activity Duration***	***Productivity Rates***
		p-values	***p-values***	***p-values***
1.000	0420_CY	0.660	*0.001	*0.001
2.000	0432_CY	0.960	*0.002	*0.02
3.000	0672_EA	0.110	*0.002	*0.001
4.000	0416_LF	0.190	*0.002	*0.003
5.000	0462_LF	*0.05	*0.001	*0.001
6.000	0662_LF	*0.02	*0.002	*0.001
7.000	0666_LF	0.450	*0.001	*0.001
8.000	0666_EA	0.810	*0.001	*0.001

3.4 Analysis Summary

The macro-level evaluation of the two systems conducted by grouping all the work items of all the projects together showed significant difference between the estimated values and the actual values of work quantity, activity duration and productivity rates. In general, activity durations were overestimated, and the work quantities and productivity rates were underestimated. Further, the regression analysis showed that errors in estimating the production rates have a higher impact on the duration of an activity than the errors in estimating the quantity.

As previously mentioned, the determination of the activity duration and consequently the project time estimate depends mainly on two estimates: the quantity of work, and the production rates. The errors in estimating the duration (ERDur) can be rooted to either an error in estimating the quantity (ERQty) or errors in estimating production rate (ERPr) or both. A deeper analysis was conducted by statistically assessing the performance of the systems with respect to the nature of work. Four work categories were specified, namely, 1) Earthworks, 2) Finishing Works, 3) Asphalt works, and 4) Concrete works. Results of this analyses revealed no big difference between the estimated and actual work quantities, an overestimation of activity duration and an underestimation of productivity rates for the majority of the types of works. From these results it can be concluded that the cause of the errors in duration were mostly caused by the underestimation of productivity rates. This is due to the fact that the usually difference between the estimated and actual quantity is relatively very small compared to the difference between the estimated and actual production rates.

Finally, a micro-level examination was conducted to provide a comprehensive evaluation of the systems through the analysis of each work item individually. The outputs of the of individual work items of District A showed again that for work quantity, the majority of items did not have a significant difference between the means of the estimated and actual quantities. For production rate, there was statistically significant evidence that the average estimated production rates are smaller than the average actual production rates for all the work items analyzed. This indicates that production rates are underestimated in general. For activity duration, there was statistically significant evidence that the average estimated duration is greater than the average actual duration for the majority of the analyzed items. This indicates that the activities durations are overestimated generally. That is why it is imperative to have a reliable system for estimating the production rates for highway construction projects. Conclusions obtained from statistical analyses are summarized on Table 3.10.

Table 3. 10: Conclusions obtained of Individual Items Statistical analyses.

Individual Items	***Parameter/Variable***	***Conclusion***
0420_CY	ERDur ERQty ERPr	Overestimated No big difference Underestimated
0416_LF	ERDur ERQty ERPr	Overestimated No big difference Underestimated
0666_LF	ERDur ERQty ERPr	Overestimated No big difference Underestimated
0432_CY	ERDur ERQty ERPr	Overestimated No big difference Underestimated
0462_LF	ERDur ERQty ERPr	Overestimated Underestimated Underestimated
0666_EA	ERDur ERQty ERPr	Overestimated No big difference Underestimated
0672_EA	ERDur ERQty ERPr	Overestimated No big difference Underestimated
0662_LF	ERDur ERQty ERPr	Overestimated Underestimated Underestimated

CHAPTER IV

ASSESSMENT OF WEATHER IMPACT ON HIGHWAY PROJECTS CONTRACT TIME

4.1 Introduction

Quantifying the impact of weather conditions on highway construction is a cumbersome task that requires a reliable repository of weather data, and rigorous statistical analysis to build accurate weather models. Confusion about determining weather-related delays is often a basis for disputes between the contractual parties. For instance, TxDOT has noticed that recently more projects seem to be delayed or interrupted by weather events and is questioning whether the source of these delays can be attributed to unforeseen weather conditions when scheduling construction projects (Research Project Statement 17-12, FY 2017 Annual Program: Enhanced Production Rate Establishment to Ascertain Construction Activity Durations, 2016). A thorough analysis of the problem – see Figure 4.1.- revealed that the main factors causing weather-related delays are as follows

a. Temperature variability leads to changes in the productivity rates of construction activities. (Koehn and Brown, 1985). This factor should be considered at two different conditions: when the temperatures are too cold or too hot.
b. Precipitation is regarded as a major uncertainty factor that has adverse impacts on productivity and duration of highway construction activities (Pan, 2005).
c. Wind speed also varies by location; and it can dramatically exacerbate the effects of Temperature and Precipitation. (Dytczak et Al., 2013)

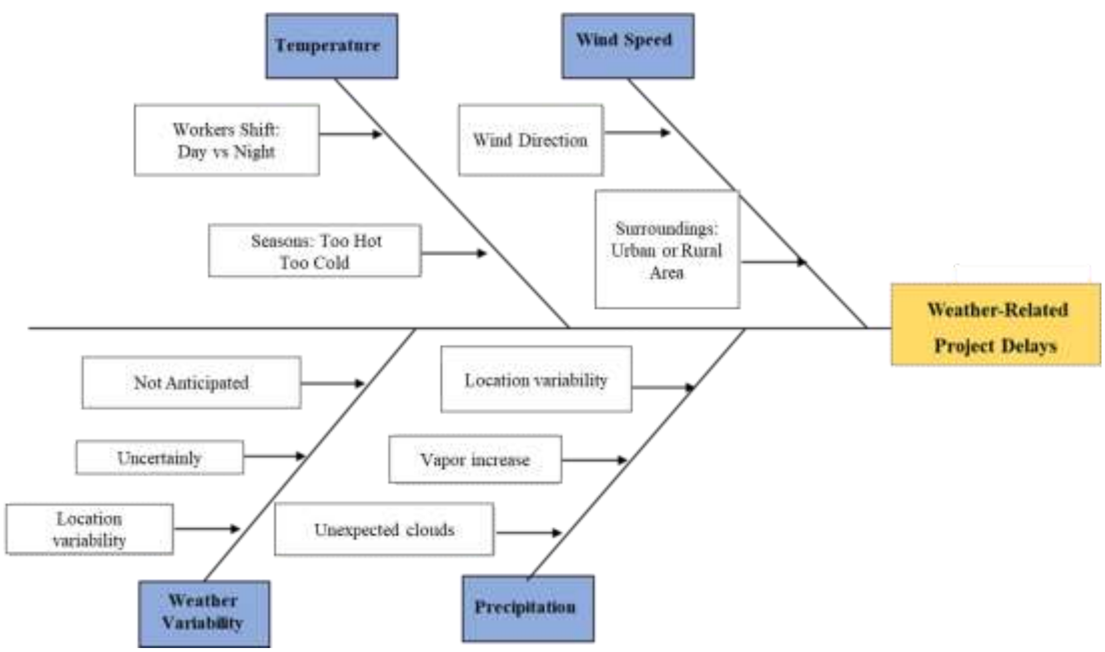


Figure 4. 1: Root-Cause Analysis of the Weather-Related Project Delays.

Fortunately, the literature includes several weather models that can be used to determine the basis of the project delay and the eligibility of the contractor for an extension of time.

However, the applicability of these models to real-life projects and their reliability to obtain true assessment of the weather-related delays need to be further verified.

The objective of this chapter is to provide methods to estimate the impact of weather on highway construction activities by modifying previously developed weather models. Two notable models from the literature were applied to assess the weather delays in highway construction. The first model aims to calculate how long each construction activity may be extended as a function of likely futurere climatic events (Ballesteros-Perez et al. 2017). The second model quantifies and provides a probabilistic forecast of weather events by identifying the attributes causing weather delays and generating synthetic weather sequences using a stochastic weather generator (Apipattanavis et Al. 2010). The modified models were applied to a set of highway projects provided by TxDOT. The modified models were compared by statistically analyzing the assessed outcomes of the weather impacts on the selected highway projects. The modifications introduced in this study further enhances the previously developed weather models and ensures its models their applicability in highway construction.

4.2 Methodology

The work plan devised to investigate weather-related delays is comprised of three main milestones: Data Collection, Weather Modeling, and Data Analysis. A diagram depicting the work plan designed for the investigation of highway construction delays caused by weather is shown in Figure 4.2.

First, an extensive literature review was performed in order to collect information on the effects of weather in highway construction projects. Several models that assessed the impact of weather in project duration were reviewed However, two models were identified and selected for application. Those two models were found to be clear and comprehensive enough to rebuild; and the information provided was enough to facilitate their implementation with real-life data.

The real-life data collection process followed by investigating projects previously developed by TxDOT. Thirty highway projects were selected, and data on the activities performed were extracted. The working dates were matched with the precipitation, wind speed, and temperature information collected from the National Oceanic and Atmospheric Administration (NOAA) database. The data collected from these sources was used for the implementation of each model.

The weather impacts on the 30 TxDOT projects selected were assessed using the two models adopted form the literature. The models focuses primarily on the impact of some weather parameters, such as precipitation, wind speed, and temperature on the construction project activities as well as on the overall project duration. Since the weather varies by region, the original weather thresholds were modified in order to adapt to the South Texas climate, where the 30 TxDOT projects were executed.

Lastly, new parameters were created for different types of durations to compare the results of the models. The first parameter is $S_{AB,}$ which is the as-built duration or actual duration. The second parameter is $S_{TX;}$ this is the duration estimated by TxDOT at the planning stage. The next parameter is the S_{PT}, which is the theoretical planned duration without taking into consideration the impact of weather. The fourth and last parameter is the S_{PH}, this is the duration based on historical weather data, which is supposed to be the most accurate estimate of the duration that schedulers should have come up with taking into consideration the weather impact. The results were then analyzed using paired *T*-tests to compare planned and actual durations. This analysis further helped to provide conclusions about the advantage and limitation of each model in assessing the impact of weather on highway construction activities.

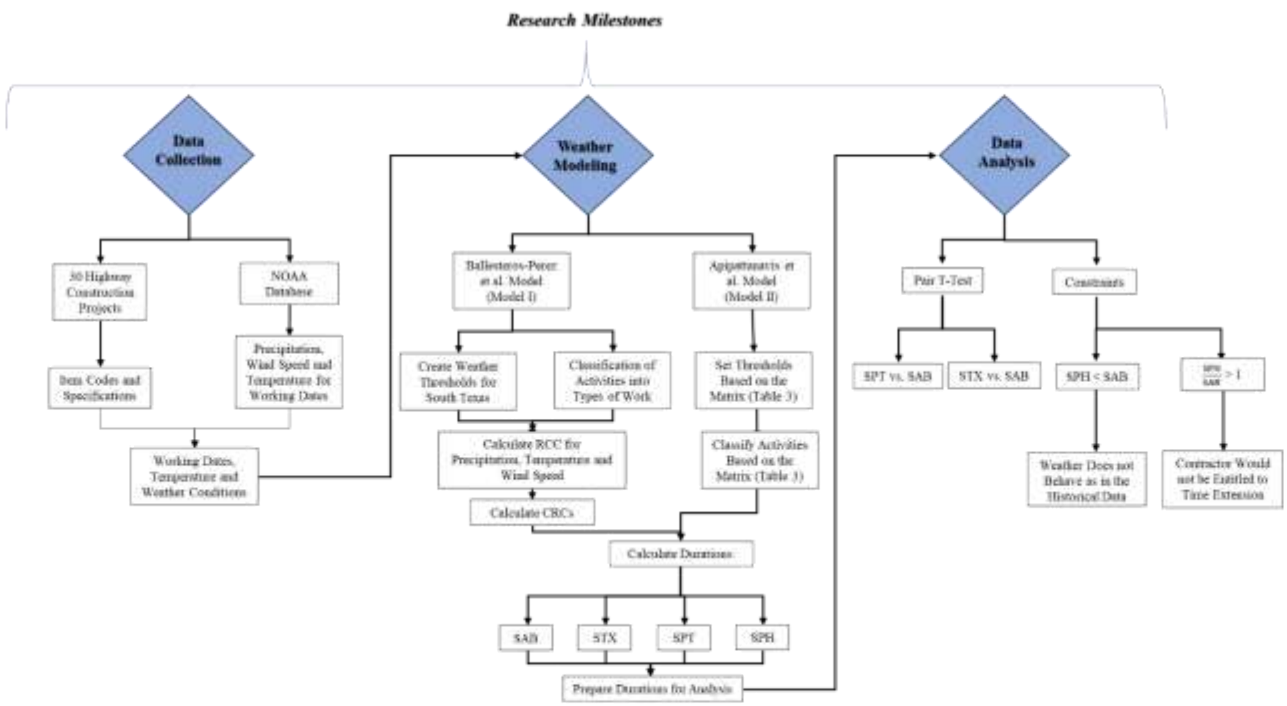


Figure 4. 2: Flow Chart of the Chapter Methodology.

The following subsections discuss in detail the implementation of the three milestones of the research methodology.

4.2.1 Data Collection

To evaluate weather-related delays, historical data on previous projects developed by TxDOT were collected from different sources. The first source is an official summary of the project operations refereed to as the Contract Report Bundles (CRB). As previously mentioned, the CRB contains information about the project activities dates, weather conditions, and many other important specifications. The Standard Specifications for Construction and Maintenance of Highways, Streets and Bridges (Technical Advisory 5080.15, FHWA Guide for Construction Contract Time Determination Procedures, 2002) was also consulted to verify the information provided by the DOT.

However, the CRBs did not contain detailed information about the amount of precipitation or the wind speed at the construction sites. The only information provided in the report was the conditions of the day, expressed as clear, partly cloudy, windy, rain, etc., as well as the lowest and highest temperature. As such, the National Oceanic and Atmospheric Administration (NOAA) website was consulted to get exact measurements of the weather conditions. The dates of the project activities were extracted from the CRBs and were matched to the NOAA database to obtain actual information on precipitation, wind speed, and the temperature. Another piece of information available about the projects was the project timelines (planned schedule) in the form of a Gantt Chart. It provided information about the estimated activities and project duration at the planning stage.

4.2.2 Data Modeling

Two models were applied in order to assess the impact of weather on project durations. Four durations were calculated for the purpose of facilitating the comparison between models, which are: S_{AB}, S_{PT}, S_{PH}, and S_{TX}. Information on the S_{AB} was obtained from the CRBs; the S_{PH} was calculated based on the historical weather data which takes into consideration the weather effect and acknowledges 30 years of historical weather data to determine if the weather delay could have been anticipated. The value of the planned durations (S_{TX}) was obtained from the estimated project timelines provided by the DOT. Finally, the theoretical planned project duration (S_{PT}) is the estimated duration without taking into consideration the weather occurring during the project's time-lapse was derived using information available about the first three parameters, as will be shown in detail in the following sections.

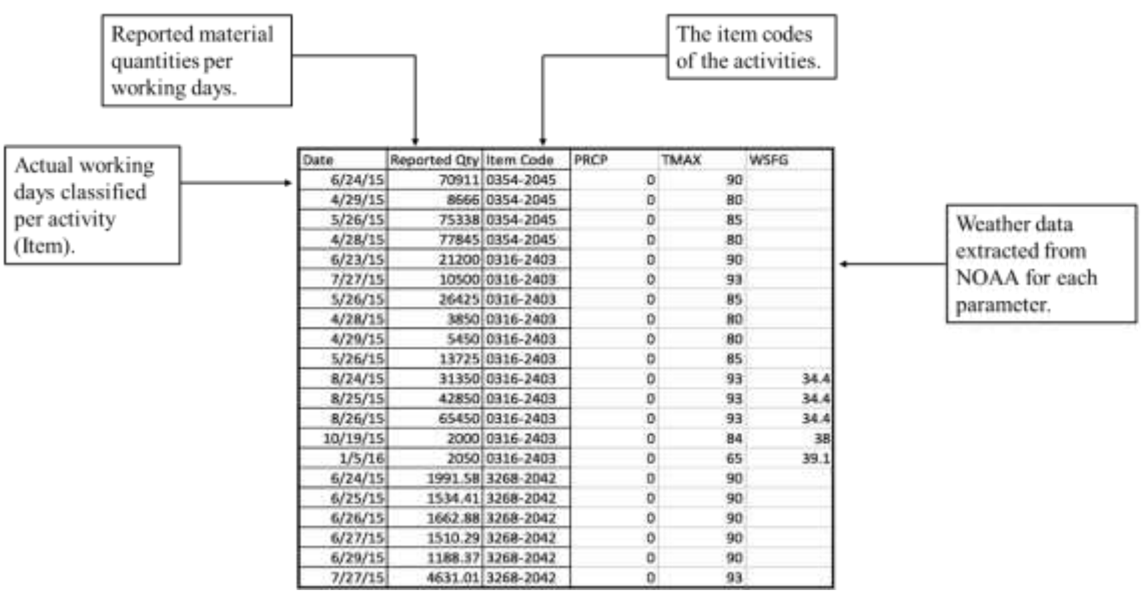
4.2.2.1 Model I. (Ballesteros et Al. 2017). The objective of Ballesteros-Perez et al. (2017) model is to analyze the influence of weather conditions on construction work activities and on the overall project duration by using historical weather data for forecasting these durations. The model was utilized to assess the impact of weather on the previously developed highway projects provided by the DOT; the following five steps were performed:

1. The first step in implementing this model to determine the actual durations of the project activities. Each activity from the project timelines was matched to its equivalent in the CRBs to get the actual working dates and the as-built duration (S_{AB}).
2. The Raw Climatic Coefficients (RCC) are then calculated. The RCC is a reduction coefficient that takes into consideration weather delays by counting the days in which weather parameters, such as precipitation, temperature and wind speed, surpassed certain limits that could cause work stoppage – see Table 4.1. The closer the coefficient is to 1, the less likely the occurrence of the weather phenomenon in a given month will be (Ballesteros-Perez et al. 2017). This means that it is less likely that a weather-sensitive construction activity might suffer a delay. To compute the RCC, the weather data obtained through NOAA was matched with the working dates for each activity in each project, as shown in Figure 4.3.

Thresholds are then determined for each weather parameter in South Texas since weather standards differs between locations. The thresholds consist of precipitation surpassing 1 mm, 10 mm, and 30 mm; wind speed above 34.17 mph, and a maximum temperature higher than 91 F. These limits were determined through an extensive literature review of previous quantitative studies that have measured the impacts of weather variables as indicated in the original study.

Table 4. 1*:* Raw Climatic Coefficient Calculation (Ballesteros et Al. 2017.)

Parameters	***Raw Climatic Coefficients (RCC)***
Precipitation *(1 mm, 10 mm, 30 mm)*	$C_{P1} = 1 - \frac{Days\ per\ month\ with\ precipitation > 1mm}{30\ days}$
	$C_{P10} = 1 - \frac{Days\ per\ month\ with\ precipitation > 10mm}{30\ days}$
	$C_{P10} = 1 - \frac{Days\ per\ month\ with\ precipitation > 10mm}{30\ days}$
Temperature *(32°≥ T ≥ 91°F)*	$C_T = 1 - \frac{Days\ per\ month\ with\ temperatures\ 32º \geq T \geq 91ºF}{30\ days}$
Wind Speed *(34.17 mph)*	$C_W = 1 - \frac{Days\ per\ month\ with\ wind\ speed > 34.17\ mph}{30\ days}$



Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
6/24/15	70911	0354-2045	0	90	
4/29/15	8666	0354-2045	0	80	
5/26/15	75338	0354-2045	0	85	
4/28/15	77845	0354-2045	0	80	
6/23/15	21200	0316-2403	0	90	
7/27/15	10500	0316-2403	0	93	
5/26/15	26425	0316-2403	0	85	
4/28/15	3850	0316-2403	0	80	
4/29/15	5450	0316-2403	0	80	
5/26/15	13725	0316-2403	0	85	
8/24/15	31350	0316-2403	0	93	34.4
8/25/15	42850	0316-2403	0	93	34.4
8/26/15	65450	0316-2403	0	93	34.4
10/19/15	2000	0316-2403	0	84	38
1/5/16	2050	0316-2403	0	65	39.1
6/24/15	1991.58	3268-2042	0	90	
6/25/15	1534.41	3268-2042	0	90	
6/26/15	1662.88	3268-2042	0	90	
6/27/15	1510.29	3268-2042	0	90	
6/29/15	1188.37	3268-2042	0	90	
7/27/15	4631.01	3268-2042	0	93	

Figure 4. 3: Matching the Actual Working Dates with the Weather Data.

Activities were next classified into categories based on the nature of work, namely asphalt, concrete, earthworks, steelworks, and outdoor painting. The weather parameters impacting the activity duration varies from one work category to another, as shown in Table 4.2. The different RCCs affecting the same work category are then multiplied; and the value obtained is called the Climatic Reduction Coefficient Actual (CRC_{Actual}).

Table 4. 2: Influence of Weather on the Type of Work (Ballesteros et Al. 2017)

Influencing Parameters / Type of Work	C_{P1}	C_{P10}	C_{P30}	C_T	C_W	***Reference***
Asphalt Pavement	✓	✓	✓	✓		El-Rayes, Moselhi 2001, Apipattanavis et al. 2010, Chinowsky et al. 2013.
Concrete		✓	✓	✓	✓	Alshebani & Wedawatta 2014.
Earthwork		✓	✓			Thorpe and Karan 2008, Duffy et al. 2012, Ballesteros-Pérez et al. 2017.
Steelworks			✓	✓	✓	Thomas et al. 1999, Li et al. 2016, Shan and Goodrum 2014, David et al. 2010.
Outdoor Painting	✓	✓	✓		✓	Alshebani & Wedawatta 2014

3. The S_{PT} is then calculated by multiplying the CRC_{Actual} by the S_{AB}; this will reduce the actual activity duration and determine how long the original "as-built" schedule would have taken to complete without the weather impacts.
4. The Climatic Reduction Coefficient ($CRC_{Historical}$) is then generated based on historical data; it is computed by multipliying the different historical RCCs by month affecting the same work category. The previous 30 years of historical data made it possible to

calculate how long the original planned theoretical duration would have taken if the weather conditions had been similar to those in the 30 years before. As such, the S_{PH} is then calculated by simply dividing the S_{PT} by the respective $CRC_{Historical}$. The $CRC_{Historical}$ values were determined at an 80% confidence level.

5. The obtained durations are then analyzed and compared to the S_{TX} for conclusions.

4.2.2.2 Model II (Apipattanavis et Al. 2010). The second weather model (Model II) adopted in this research was developed by Apipattanavis et al. in 2010. The objective of this model is to understand how weather affects highway construction, and to develop a framework for predicting a reasonable number of nonwork days as a consequence of adverse weather.

The original model starts with the estimation of the as-built schedule, which should be created with no adjustments for weather delays. Once the activities durations are determined, the project activities are classified into one five construction categories that appear in the matrix shown in Table 4.3. For each critical activity, the pertinent weather conditions that may cause a delay are identified. The three weather types considered are precipitation, temperature, and wind speed. The weather threshold that causes work stoppage are also give in Table 4.3 (Apipattanavis et al. 2010). It should be noted that the basic threshold values should be adjusted to suit the conditions specific to the project site and geographic location. Using historical weather data and a stochastic weather generator, a weather model is applied to estimate the number of days in each month when adverse weather conditions occur. With this prediction, the construction schedule in the original schedule is modified by accounting for the delay days to include the weather effects.

The original model was modified in order to obtain results on the previously established parameters ($S_{AB,}$ $S_{PT,}$ $S_{PH,}$ and S_{TX}.) This model was applied as follows:

1. The first step was to calculate the S_{AB} for each project activity. This procedure is described in the previous sections for Model I, and the same methodology was followed.
2. The activities work dates were then matched with the actual weather retrieved from the NOAA website. The weather data gathered focused on the parameters of precipitation, maximum temperature, and wind speed.
3. The weather thresholds indicated in the original study were used for precipitation, soil temperature and wind velocity. However, temperature limits were adjusted to suit the South Texas region. This threshold limits, were then used to determine the number of days of work stoppage due to the different weather conditions studied.

Table 4. 3: Different Weather Conditions and Thresholds Used in Model II (Apipattanavis et al. 2010)

Type of Work / Weather Condition	Concrete Paving	Asphalt Paving	Structural	Mass Excavation	Grading
Precipitation	Above 0.1 in	No moisture allowed	Between 0.25-0.5 inches	0.25-0.5 inches	0.25-0.5 inches
Temperature	Below 32°F or above 90°F	Below 32°F or above 90°F	Below 32°F and above 90°F	None	Below 32°F or above 90°F
Soil Temperature	Below 22°F	Between 32°F and 50°F	None	Freezing	Freezing
Wind Velocity	Above 25 mph	None	Above 35 mph	None	None

4. The original model used a stochastic weather generator to predict the number of days in which each weather parameter is expected to appear and exceed the pre-established thresholds. To have more accurate results, the model was modified by using historical weather data from the NOAA database. For each weather parameter, data were collected for the previous 30 years. CDFs were generated for each month using the collected data; they were used to get the average number of days in previous years in which each condition occurred. The number of days of work stoppage due to weather delays were determined at 80% probability, as shown in Figure 4.4

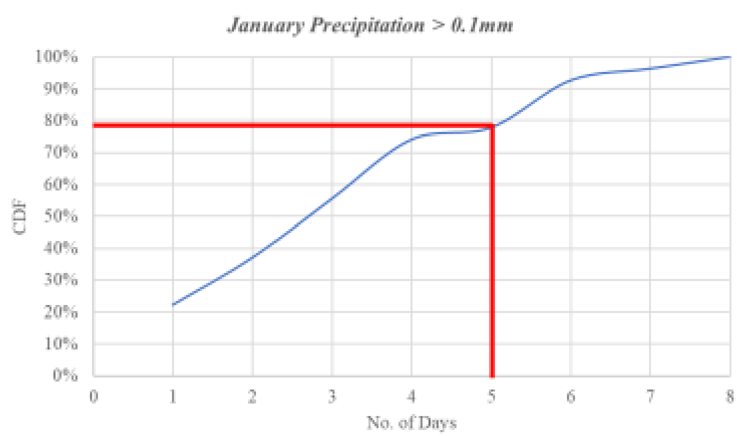


Figure 4. 4: CDF Used to Determine the Number of Days of Weather-Related Delays.

The number of weather days determined using the CDF were used to calculate the number of delay days of an activity. For example, at 80% probability level, Fig. 4 indicates that 5 days in January are expected to have precipitation in excess of 0.1 mm. If a concrete paving activity has a S_{AB} of 9 days, then the number of delay days expected for this activity is 1.5 days calculated as 5/31*9. The delay days are then rounded up to 2 days. The planned theoretical duration (S_{PT}) is then calculated as 7 days by subtracting the delay from the S_{AB}.

5. The last established duration is calculated by using the same method described in the previous model. S_{PT} is divided by the $CRC_{Historical}$ to determine the S_{PH} duration. Finally, results are compared and analyzed for conclusions.

4.2.3 Data Analysis with New Parameters

The new parameters introduced in this study are the $S_{AB}, S_{PT}, S_{PH}, and\ S_{TX}$ durations. The two models were used to determine the values of the 4 parameters ($S_{AB}, S_{PT}, S_{PH}, and\ S_{TX}$) for different types of highway projects for comparison purposes. Summary of the equations used to determine the established durations to compare results from both models is shown in Table 4.4.

Table 4. 4: Established Duration Formulas.

Duration Parameter	***Formula***
As Built (S_{AB})	N.A. (Actual Project Report).
Planned Theoretical (S_{PT})	Model I: $S_{PT} = S_{AB}$ x CRC_{ACTUAL} Model II: $S_{PT}=S_{AB}$ - Delay Days
Planned Historical (S_{PH})	$S_{PH}= S_{PT}/ CRC_{HISTORICAL}$
Estimated by DOT (S_{TX})	N.A. (Planned Project Schedule)

The major difference between the two models is the method used to calculate the planned theoretical duration (S_{PT}). Model I utilize the climatic reduction coefficient while Model II uses the number of delay days. Both methods are based on historical weather data obtained from the NOAA website. However, the method of application is different as previously described. Once the established durations were computed, descriptive and inferential statistical analysis were deployed as follows:

First, four ratios were established S_{PH}/S_{AB}, S_{TX}/S_{AB}, S_{PH}/S_{TX}, and S_{PT}/S_{TX}. These ratios were computed to determine the quantitative relation between the proposed durations, the conclusions for each ratio are:

- S_{PH}/S_{AB}: If the ratio is greater than one, it means that weather is not behaving in the same way as historical data. On the contrary, the contractor has enjoyed better-than average weather conditions. As such, he would not be entitled to time extensions or any kind of compensation.

- S_{PH}/S_{TX}: If the ratio is greater than one, then the project total duration has been underestimated and weather was not taken into consideration in estimating the activities durations.
- S_{PT}/S_{TX}: If the ratio is greater than one, then the project total duration has been underestimated but not necessary because of weather reasons.
- S_{TX}/S_{AB}: If the ratio is greater than one, then the project total duration has been overestimated by the DOT planners and schedulers, and contractor is not entitled to any extension of time because of the weather conditions. Also, there is an indication that the systems used by the TxDOT are not reliable to estimate project duration.

Paired *T*-tests were conducted to assess whether there is a significant difference between the different durations' parameters calculated for the 30 projects studied. The paired *T*-test null hypothesis (H_0) was set to assume that the true mean difference (μ_d) between the studied durations is zero (H_0: μ_d= 0), while the alternative hypothesis (H_1)was set as $\mu_d \neq 0$. The Paired T-tests were performed for S_{PH} vs S_{AB}, S_{PH} vs S_{TX}, S_{PT} vs S_{TX}, and S_{TX} vs $S_{AB.}$ These tests served to verify the conclusions that were based on the values obtained from the ratios.

Lastly, the two models were compared using the 4 durations calculated for each project. Paired T-tests were performed to determine if there is a significant difference in the results obtained from the two models particularly for the planned historical and theoretical durations ($S_{PT\ Model\ I}$ vs. $S_{PT\ Model\ II}$; $S_{PH\ Model\ I}$ vs. $S_{PH\ Model\ II}$)

4.3 Case Study

One projects were selected as case study to demonstrate the applications of the two models and the calculations of the 4 established durations. The results obtained were used to verify the initial hypothesis and further draw final conclusions.

This case study is comprised of a highway project that was completed in South Texas. The project activities, estimated activity durations relationships, and other details are given in Table 4.5. Planners estimated a total duration (S_{TX}) of 167 days for this project. The project had eleven major work items that which were executed between September 2015 and March 2017. As such, distinct types of weather factors and conditions could affect the construction schedule. It took 115 days (S_{AB}) to complete of the project. The Gantt chart shows the actual work days obtained from the CRBs (see Figure 4.6).

Table 4. 5*:* Case Study– Project Time Estimate.

ID NO.	WORK ITEM	UNIT	QUANT.	DURATION DAYS	PRED TASK	LAG (%)	EARLY START	EARLY FINISH
1	SET UP BARRICADES	DAY	2	2			1	2
2	SWEP DEVICES	DAY	5	5	1	100	3	7
3	CEMENT TREAT (EXIST MATL)(DC)(8")	SY	250,023	72	2	100	8	79
4	GEOGRID BASE REINFORCEMENT (TY II)	SY	255,141	57	3	50	44	100
5	FL BS (CMP IN PLC)(TYA GR1-2)(FNAL POS)	CY	69,867	58	4	50	73	130
6	ASPH (AC-15P)	GAL	231,175	21	5	75	117	137
7	BACKFILL (TY A OR B)	STA	720	29	5	75	117	145
8	RE PM W/RET REQ TY I (W)4"(SLD)(100MIL)	LF	216,653	10	6	100	138	147
9	REFL PAV MRKR TY II-A-A	EA	1,429	3	8	100	148	150
10	CELL FBR MLCH SEED(PERM)(RURAL)(CLAY)	SY	154,135	14	9	100	151	164
11	FINAL CLEANUP	DAY	3	3	10	100	165	167

4.3.1 Assessment of the Weather Impacts Using Model I

The first step in the application of Model I was to classify the activities by type of work. The classification was performed based on TxDOT specifications manual (DOT Specifications Manual, 2004) and the CRBs. The activities were then organized chronologically by the month in which they were performed. The number of days in which the established limits were surpassed are shown in Table 4.5. The thresholds for work stoppage for different weather conditions are shown in Table 4.1. For instance, the number of days of delays due to different weather conditions for the Cement Treatment activity is shown in Figure 4.5a. The RCCs were then calculated for each activity for each month of the year using the equations shown in Table 4.1.

Since not all the weather variables (RCC) affect all the construction activities the same, the CRC values were determined by multiplying the RCCs pertaining to a designated work category. For example, the CRC value concrete items is calculated by multiplying the RCCs: $C_{P,}$ C_T and C_w ($CRC = C_{p10} \times C_T \times C_w$) according to Table 4.2, see Figure 4.5b.

Subsequently, the durations of the activities affected by weather were reduced using these CRC values. The planned theortical (S_{PT}) can then be calculated by multiplying the CRC value corresponding to each activity by its as-built duration, see Figure 4.5c. To calculate how long the original planned schedule would have taken to complete (S_{PH},), if the weather conditions had been like those in the previous 30 years, it is only necessary to divide each activity S_{PT} by its respective $CRC_{histroical}$ value obtained from historical weather data.

a)

Activity	Type of Work	No. of Days				
		PRCP (1)	PRCP (10)	PRCP (30)	TMAX	WSFG
Cement Treat. July 2016	Concrete	0.00	0.00	0.00	8.00	0.00
Cement Treat. Sept. 2016	Concrete	2.00	1.00	1.00	5.00	0.00

b)

Activity	RCC Values					CRC Actual	CRC Historical
	C_{P1}	C_{P10}	C_{P30}	C_T	C_W		
Cement Treat. July 2016	1.00	1.00	1.00	0.73	1.00	0.73	0.21
Cement Treat. Sept. 2016	0.93	0.97	0.97	0.83	1.00	0.81	0.40

c)

Activity	No. of Days		
	S_{AB}	S_{PT}	S_{PH}
Cement Treat. July 2016	7.00	5.00	24.00
Cement Treat. Sept. 2016	8.00	6.00	15.00

Figure 4. 5: Model I Application Process. a) No. of Delay Days, b) Calculation of the RCC and CRC values c) Reduction of as-built duration.

The planned historical bar chart schedule for the project is shown in Figure 4.7. The total planned historical project duration calculated was 166 days. Since the as-built duration is smaller than the planned historical, the contractor has enjoyed better-than average weather conditions and would not be entitled to any time-extensions or compensation in case of claims. The illustration of the details of the implementation of Model I is shown in Figure 4.6.

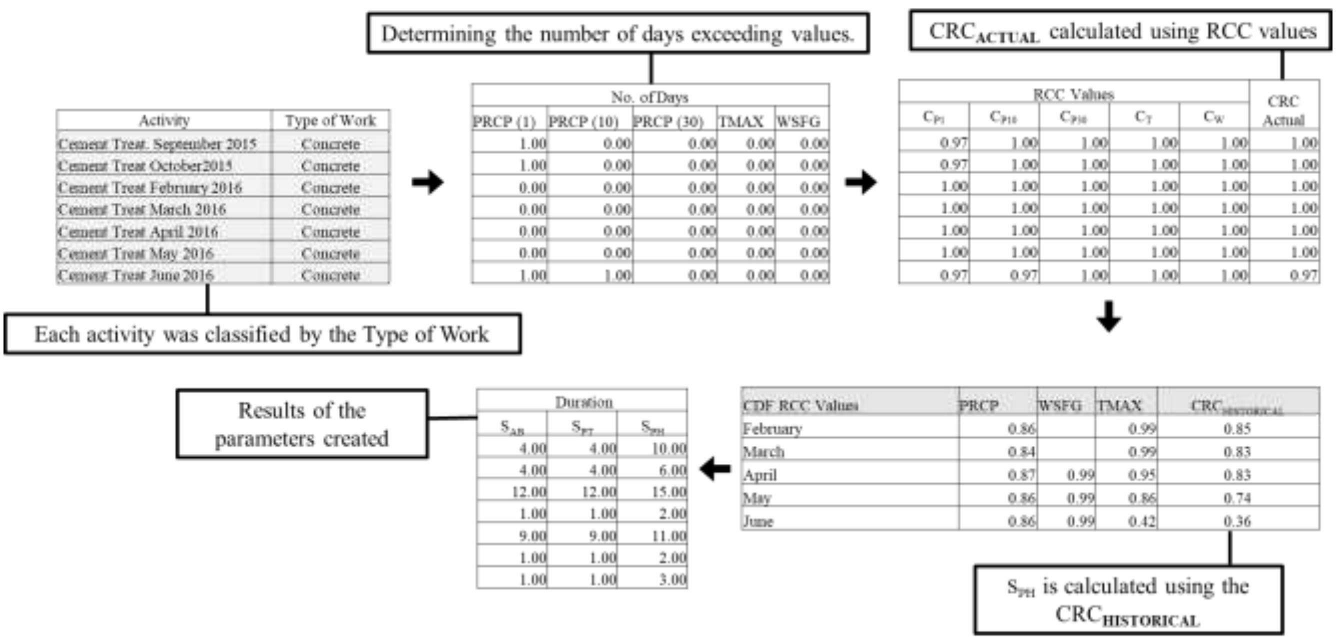


Figure 4. 6: Model I Development Step by Step.

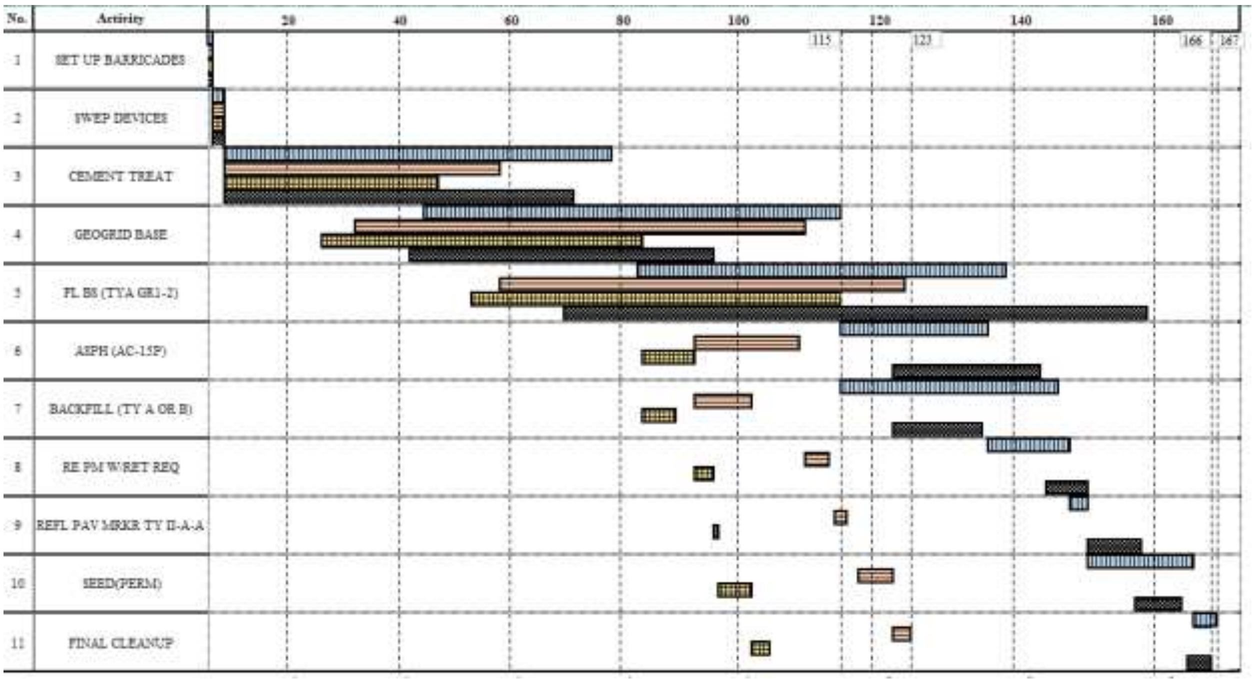


Figure 4. 7: Bar chart schedules for case study**.**

4.3.2 Assessment of Weather Impact using Model II

To Implement Model II, the first step is to determine the number of delay days. The delay days were calculated using the thresholds given in see Table 4.3. The matrix thresholds represent the maximum intensity a weather event can occur before a construction activity stops. Weather events exceeding this threshold constitute reasonable grounds for a work stoppage. The matrix threshold was also used to classify each activity with its own type of work. Due to variations in site conditions and other parameters, the matrix was calibrated to suit the region of south Texas.

Figure 4.8 consists of Part a) the item classification with the matrix parameters and the number of days shown in the CDFs, Part b) reveals the calculation results with respect of delay days, and Part c) shows the as-built duration considering delay days using Model II.

a)

Activity	Type of Work	No. of Days				
		PCP (0.1)	PCP (0.25)	Tmax (91)	WND 25	WND 35
Cement Treat. July 2016	Concrete	6.00	0.00	25.00	18.00	4.00
Cement Treat. Sept. 2016	Concrete	7.00	6.00	16.00	9.00	2.00

↓

b)

Activity	No. of Days					
	S_{AB}	#Days (CDF)	Delay Days	S_{PT}	$CRC_{Historical}$	S_{PH}
Cement Treat- July 2016	7.00	6.00	1.35	5.65	0.21	29.00
Cement Treat- Sept 2016	8.00	7.00	1.81	6.19	0.40	18.00

↓

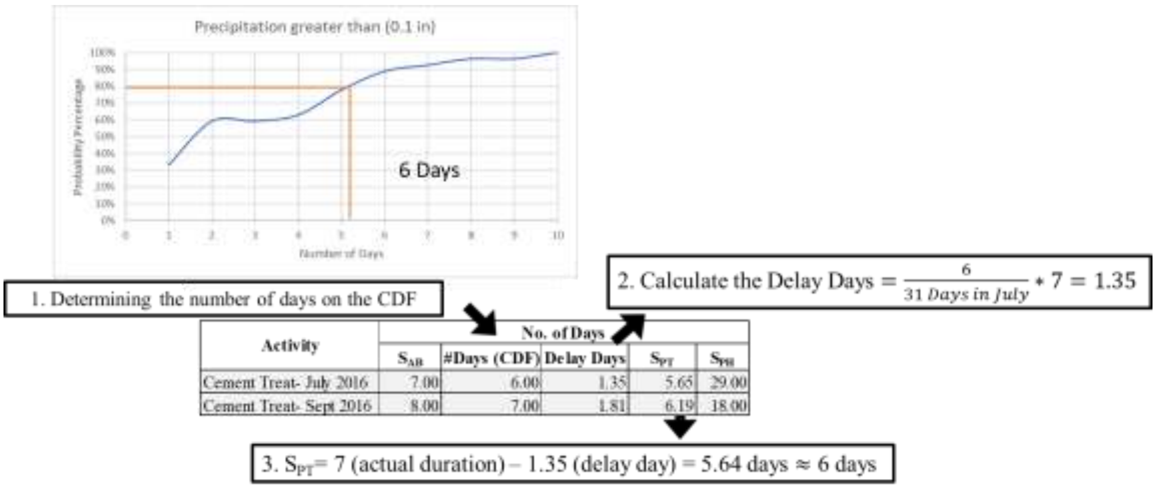
c)

Activity	No. of Days		
	S_{AB}	S_{PT}	S_{PH}
Cement Treat. July 2016	7.00	6.00	29.00
Cement Treat. Sept. 2016	8.00	7.00	18.00

Figure 4. 8: Application Results Model II.

For example, the number of rainy days exceeding the work stoppage threshold for the Cement Treatment activity during the month of July are 6 days. They were determined using the precipitation CDF at 80% probability level, as shown in Figure 8. Since the assumption is that the weather impacts are spread evenly among the days of the month, the number of delay days due to precipitation for the Cement Treatment activity are 1.35 days rounded to 2 days. They were calculated by dividing the total rainy days (6) by the number of days of the month (31) multiplied by the activity duration (7 days).

The S_{PT} was determined by simply subtracting the actual number of delay from the S_{AB}; the project total S_{PT} is 96 days. The S_{PH} durations were determined the same way described in the previous model. The projeect S_{PH} determined using Model II is 150 days is closer to the S_{AB} (115 days) than the S_{PH} determined using Model (166 days). Hence, it can be deduced that Model I tends to exaggerate the weather impacts more than Model II. The demonstration of the details of the implementation of Model II is shown in Figure 4.9.



Activity	Duration Model 2				
	S_{AB}	#Days (CDF)	Delay Days	S_{PT}	S_{PH}
Cement Treat- July 2016	7.00	6.00	1.35	5.65	29.00
Cement Treat- Sept 2016	8.00	7.00	1.81	6.19	18.00

Figure 4. 9: Model II Development Step by Step.

4.4 Analyses and Discussion

The two models were applied to a 30 highway projects executed in Texas. The results of the four durations parameters (S_{AB}, S_{TX}, S_{PT}, S_{PH}) obtained using both models are shown Table 4.6.

Table 4. 6*:* Models Results for all studied projects.

Project	**S_{AB}**	**S_{TX}**	**MODEL I**		**MODEL II**	
			S_{PT}	**S_{PH}**	**S_{PT}**	**S_{PH}**
P1	40.00	238.00	40.00	91.00	37.00	72.00
P2	20.00	34.00	20.00	29.00	16.00	23.00
P3	40.00	51.00	36.00	88.00	20.00	33.00
P4	71.00	85.00	67.00	103.00	54.00	79.00
P5	31.00	102.00	31.00	89.00	29.00	62.00
P6	53.00	42.00	52.00	183.00	35.00	75.00
P7	86.00	69.00	82.00	107.00	73.00	104.00
P8	27.00	119.00	27.00	43.00	26.00	42.00
P9	47.00	88.00	47.00	64.00	45.00	59.00
P10	36.00	42.00	35.00	45.00	30.00	38.00
P11	25.00	51.00	25.00	65.00	18.00	44.00
P12	38.00	61.00	37.00	104.00	30.00	66.00
P13	123.00	167.00	115.00	187.00	103.00	167.00
P14	24.00	59.00	24.00	56.00	22.00	54.00
P15	65.00	48.00	62.00	109.00	48.00	86.00
P16	15.00	59.00	8.00	45.00	8.00	45.00
P17	44.00	61.00	32.00	172.00	17.00	72.00
P18	25.00	66.00	11.00	56.00	7.00	39.00
P19	46.00	60.00	42.00	48.00	33.00	47.00
P20	17.00	18.00	13.00	68.00	6.00	24.00
P21	41.00	65.00	41.00	94.00	29.00	49.00
P22	32.00	28.00	35.00	61.00	33.00	59.00
P23	21.00	51.00	20.00	27.00	17.00	62.00
P24	38.00	96.00	24.00	43.00	24.00	44.00
P25	26.00	119.00	20.00	40.00	20.00	41.00
P26	25.00	102.00	26.00	115.00	21.00	93.00
P27	47.00	102.00	49.00	158.00	44.00	145.00
P28	12.00	51.00	12.00	24.00	12.00	24.00
P29	48.00	148.00	41.00	83.00	37.00	64.00
P30	48.00	68.00	32.00	48.00	37.00	67.00

The analysis conducted is comprised of two main aspects. First, the mathematical comparison of the calculated durations was conducted using four ratios (S_{PH}/S_{AB}, S_{PH}/S_{TX}, S_{PT}/S_{TX}, and S_{TX}/S_{AB}) to assess the performance of the two weather models selected. Second, statistical analysis was deployed to verify the outcome of the analysis of ratios. Paired T-test was used to compare the values of the four duration parameters determined by the same model. Additionally, the performance of the two models was statistically analyzed by comparing the values calculated by each model for a given duration parameter.

4.4.1 Analysis of Ratios

First, the planned historical duration (S_{PH}) was compared to the as-built duration (S_{AB}) - see Table 4.7 - to determine whether the project had experienced inclement weather conditions that could not have been anticipated. The results for the two models - see Figure 4.10a- show that possibly all the projects might have enjoyed better than average weather ($S_{PH}/S_{AB} >1$) except for one project as determined by Model II. In this case, any claim submitted by the contractor for an extension of time on the basis of adverse weather conditions should have been rejected. However, the inspection of the calculated values reveals that in some cases the S_{PH} is almost five times the S_{AB}, which raises a concern about the effectiveness of the two models to assess the impact of weather on the durations of highway projects realistically.

Table 4. 7*:* Different Ratios Used for the Analysis of the Duration Parameters.

Project	S_{PH}/S_{AB}		S_{PH}/S_{TX}		S_{PT}/S_{TX}		S_{TX}/S_{AB}
	Model I	**Model II**	**Model I**	**Model II**	**Model I**	**Model II**	
P1	2.28	1.80	0.38	0.30	0.17	0.16	5.95
P2	1.45	1.15	0.85	0.68	0.59	0.47	1.70
P3	2.20	0.83	1.73	0.65	0.71	0.39	1.28
P4	1.45	1.11	1.21	0.93	0.79	0.64	1.20
P5	2.87	2.00	0.87	0.61	0.30	0.28	3.29
P6	3.45	1.42	4.36	1.79	1.24	0.83	0.79
P7	1.24	1.21	1.55	1.51	1.19	1.06	0.80
P8	1.59	1.56	0.36	0.35	0.23	0.22	4.41
P9	1.36	1.26	0.73	0.67	0.53	0.51	1.87
P10	1.25	1.06	1.07	0.90	0.83	0.71	1.17
P11	2.60	1.76	1.27	0.86	0.49	0.35	2.04
P12	2.74	1.74	1.70	1.08	0.61	0.49	1.61
P13	1.52	1.36	1.12	1.00	0.69	0.62	1.36
P14	2.33	2.25	0.95	0.92	0.41	0.37	2.46
P15	1.68	1.32	2.27	1.79	1.29	1.00	0.74
P16	3.00	3.00	0.76	0.76	0.14	0.14	3.93
P17	3.91	1.64	2.82	1.18	0.52	0.28	1.39
P18	2.24	1.56	0.85	0.59	0.17	0.11	2.64
P19	1.04	1.02	0.80	0.78	0.70	0.55	1.30
P20	4.00	1.41	3.78	1.33	0.72	0.33	1.06
P21	2.29	1.20	1.45	0.75	0.63	0.45	1.59
P22	1.91	1.84	2.18	2.11	1.25	1.18	0.88
P23	1.29	2.95	0.53	1.22	0.39	0.33	2.43
P24	1.13	1.16	0.45	0.46	0.25	0.25	2.53
P25	1.54	1.58	0.34	0.34	0.17	0.17	4.58
P26	4.60	3.72	1.13	0.91	0.25	0.21	4.08
P27	3.36	3.09	1.55	1.42	0.48	0.43	2.17
P28	2.00	2.00	0.47	0.47	0.24	0.24	4.25
P29	1.73	1.33	0.56	0.43	0.28	0.25	3.08
P30	1.00	1.40	0.71	0.99	0.47	0.54	1.42

The planned historical S_{PH} and estimated S_{TX} durations were also compared to assess whether any additional time were allocated to the activities during the schedule planning stage to account for the weather impacts. The results show that 50% of the projects DOT estimated durations

(S_{TX}) were lower than planned historical S_{PH} according to Model I compared to only 30% as determined by Model II. Alternatively, according to both models about 50% the projects estimated S_{TX} exceeded the values of S_{PH} by 20%. Hence, it can be concluded that: the project estimated durations (S_{TX}) were generally overestimated; Model I utilizes a more conservative approach than Model II in assessing the impacts of the weather conditions on the project duration, as evidenced by the higher values of S_{PH} calculated using Model I, as shown in Figure 4.10b.

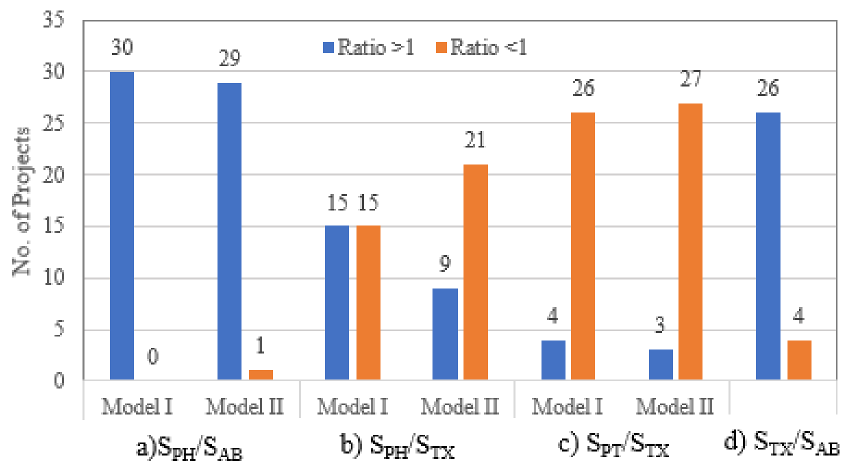


Figure 4. 10: Ratios Results.

The planned theoretical duration (S_{PT}) represents the raw duration of the activity without the incorporation of any additional time to account for weather conditions. The results show that there is no evidence of the incorporation of the weather impacts in the total DOT estimated duration (S_{TX}) of four projects according to Model I, and two projects according to Model II, see Figure 4.10c. Further analysis reveals that the DOT estimated durations had been exaggerated in several occasions. In some cases the S_{TX} was estimated as more than 7 times the $S_{PT.}$ This conclusion was further verified by the analysis of the S_{TX}/S_{AB} ratio; the results show that the project S_{TX} are generally overestimated – see Figure 4.10d - and was overly exaggerated in some cases. For example, the S_{TX} for the first project is more than five times the actual project duration (S_{AB}), see Table 4.7.

By inspecting the four ratios, it can be deduced that the project estimated durations (S_{TX}) are generally higher than the rest of the durations. The fact that the project estimated durations (S_{TX}) are generally overestimated compared to the planned historical duration (S_{PH}) suggests that the exaggeration in the S_{TX} can be rooted to other causes such as, the utilization of low production rates.

4.4.2 Statistical Analyses of Models Results

Inferential parametric statistical analysis was used assuming a normal distribution – based on the normality test conducted - to investigate the significance of the differences between the true means of the four duration parameters, and to verify the findings concluded using the ratios analysis. The S_{PH} and S_{AB} values were statistically compared using a paired t-test. The results showed that there is a significant difference between the true mean values of S_{PH} and S_{AB} calculated using both models, see Table 8. The t Stat, t Critical, and P-Value were 6.38, 2.05, and 5.62×10^{-7} for Model I, and 5.88, 2.05, and 2.23×10^{-6} for Model II at a confidence interval (CI) of 95%. The results further support the previous conclusions regarding the ineligibility of the contractors to weather-based time extensions, and the concern raised about the accuracy of the two weather models due to the inflated values of S_{PH}.

Table 4. 8*:* Paired t-Test of Models Results.

T-test: Paired Two Sample for Means	Model I		Model II		Model I		Model II	
	S_{PH}	S_{AB}	S_{PH}	S_{AB}	S_{PH}	S_{TX}	S_{PH}	S_{TX}
Mean	81.50	40.37	62.63	40.37	81.50	78.33	78.33	62.63
Variance	2,083.78	524.10	1,052.24	524.10	2,083.78	2,087.68	2,087.68	1,052.24
Observations	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00
t Stat	6.38		5.88		0.31		1.99	
P(T<=t) two-tail	5.62*10-7		2.23E*10-6		0.76		0.06	
t Critical two-tail	2.05		2.05		2.05		2.05	

Although the analysis of the ratios showed that the estimated S_{TX} durations exceed the S_{PH} for the most part, the statistical analysis using a paired t-test showed that there is no significant difference between the true means of the S_{TX} and S_{PH} durations using both models. In fact, these results support previous findings using the ratio analysis since half of the S_{TX} values were greater than S_{PH} durations while the other half was lower, see Figure 4.11.

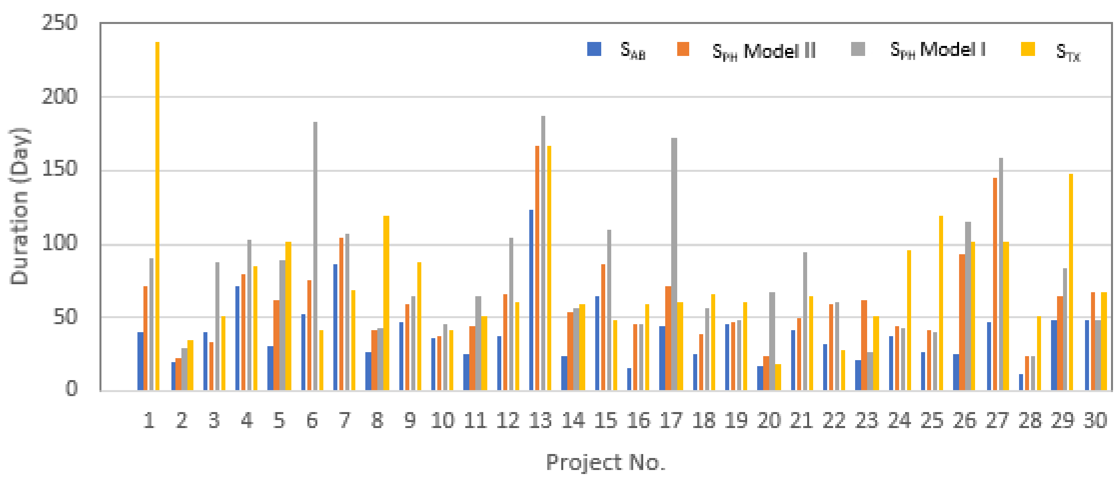


Figure 4. 11: Comparison between the DOT estimated duration ($\mathbf{S_{TX}}$) and planned historical duration ($\mathbf{S_{PH}}$)

The statistical comparison between S_{TX} and S_{AB} show a significant difference in the true means, see Table 4.9. This result support the fact that the S_{TX} are overestimated as shown using the ratio analysis.

Table 4. 9*:* Paired t-Test for estimated and actual durations.

***T*-test: Paired Two Sample for Means**	S_{TX}	S_{AB}
Mean	78.33	40.36
Variance	2,087.67	524.10
Observations	30.00	30.00
t Stat	4.76	
P(T<=t) two-tail	$4.87*10^{-5}$	
t Critical two-tail	2.04	

4.4.3 Comparison of Models Results

The statistical analysis conducted by comparing the mean of the values of the S_{PH} values and S_{AB} suggests that the two models do not reflect what happens in reality. Further analysis was compared to investigate whether there is any significant difference in the performance of the two models. A paired t-test conducted to compare the true mean values of the S_{PH} and S_{PT} obtained using both models the results – see Table 4.10 - showed that there is no significant difference in the means.

Table 4. 10*:* Paired T-test Results for comparisons of planned historical and planned theoretical durations.

***T*-test: Paired Two Sample for Means**	S_{PT} ***Model I***	S_{PT} ***Model II***	S_{PH} ***Model I***	S_{PH} ***Model II***
Mean	36.87	31.03	81.50	62.63
Variance	501.77	401.62	2,083.78	1,052.24
Observations	30.00	30.00	30.00	30.00
t Stat	5.75		3.49	
P(T<=t) two-tail	$3.13*10^{-6}$		$1.58*10^{-3}$	
t Critical two-tail	2.05		2.05	

CHAPTER V

EFFECT OF LOCATION, WORKERS SHIFT, TYPE OF WEATHER AND TEMPERATURE ON PRODUCTION

5.1. Introduction

Managing unexpected and unavoidable factors is one of the most difficult, yet important aspects of the planning process of any highway construction project. Anticipating the effect of these factors can have a huge impact in terms of completing the project on time and on budget. Better yet, including the adverse influence of these factors when scheduling projects, enables to better organize the execution of construction projects more reliably. The incompletion of the project in the scheduled time and budget causes legal conflicts between the investor and the contractor. Contractor's claims, in respect to delays caused by external factors, are validated if proof is shown that the delay was beyond his control. However, proving the negative effects of external factors is a difficult task that is yet to be completely solved. Quantifying the effects of these factors can facilitate or avoid the contractual disputes between both parties. TxDOT has noticed that recently more projects seem to be delayed or interrupted by: (1) Conflicting Weather Conditions (2) Temperature, (3) Project's location, and (4) Workers' shifts. The DOT is questioning whether the source of these delays can be attributed to unforeseen impact of these factors when scheduling construction projects.

The primary objective of this chapter is to evaluate how (1) Conflicting Weather Conditions (2) Temperature, (3) Project's location, and (4) Work shifts, affect the productivity rates of highway construction activities. This includes the assessment of the accuracy of the construction production rates used for determining contract time. To accomplish this objective, historical data from previous projects were collected and analyzed to compare productivity rates under different conditions and determine if there was any significant difference between them.

5.2. Methodology

The methodology designed to investigate the scheduling delays in the Highway projects is comprised of the following main milestones: Data Collection, Data Modeling and Data Analysis- see Figure 5.1. In order to develop a realistic contract time, TxDOT schedulers need to understand how these external factors can affect project duration. First, an extensive literature review was performed in order to collect information on the impact of these factors on the productivity rates. Also, it deemed essential to identify the common factors reported by previous studies that affect the production rates. The second step was to collect historical data from different district offices. The data collected were modeled and statistically analyzed to evaluate how the different factors affect productivity rates. The obtained results assisted to draw final conclusions on how these factors affect the overall project duration.

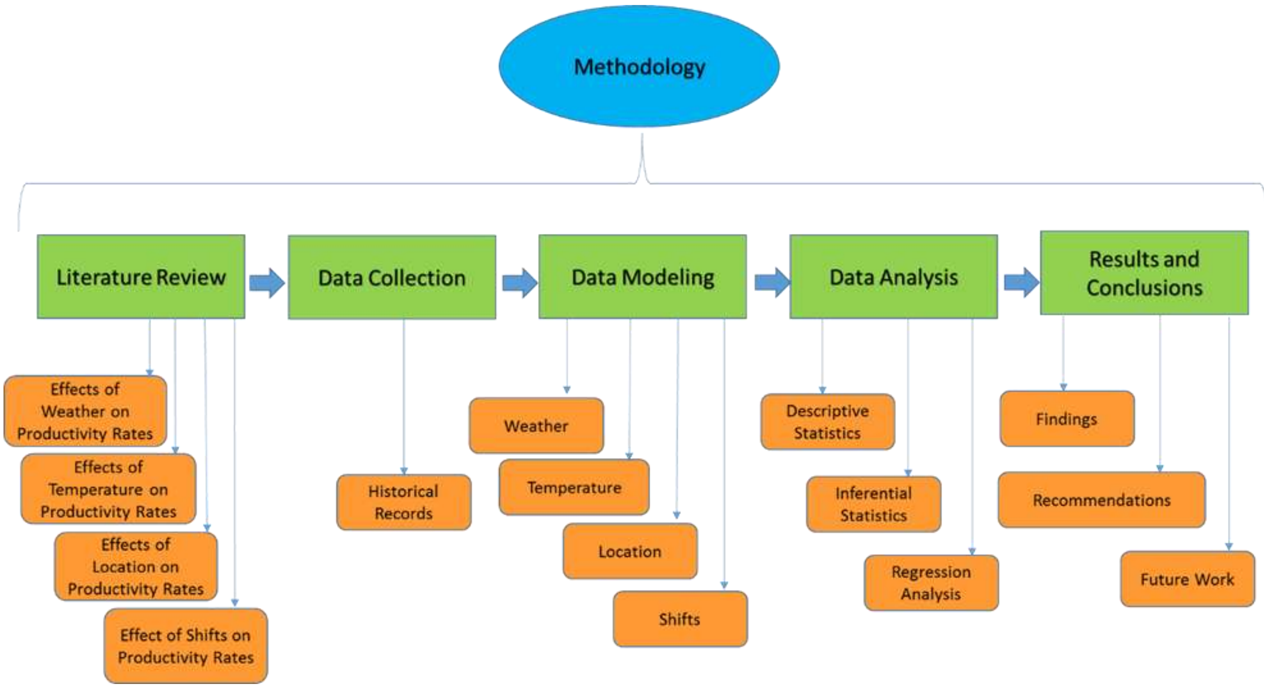


Figure 5. 1: Chapter Methodology Flow chart.

5.3 Implementation

Following the work plan shown in Figure 5.1., the implementation of these three main milestones is described below:

5.3.1 Data Collection and Factors Evaluated.

The first step in evaluating the previously mentioned factors was to collect data on different work items of previous projects developed by TxDOT. The data collected was for the work items production rates and the studied conditions to which the projects were exposed.

The conditions studied were also found in the Contract Report Bundles (CRB) provided by TxDOT. The CRB contains the daily temperatures, weather conditions (Clear, Cloudy, Drizzle, Heavy Rain, Partly Cloudy, Rain, Stormy, Windy, or Hazy), the location of the project (Urban or Rural area) and the time in which activities were developed (Day or Night Shifts).

The information was extracted using the spreadsheet-based software designed by team to automate the process, ensure consistency, and minimize the chances of error.

5.3.2 Data Modeling

The data collected were then analyzed to assess the impact of the studied conditions on the productivity rates. Each condition was modeled in order to perform the statistical analyses, the modeling of each condition is described in the following sections:

5.3.2.1 Evaluation on Weather Effect. Weather conditions were compared between projects to determine the effect conditions on the productivity of the workers in the South Texas Region. Twelve (12) different types of weather conditions were found in the report bundles, which included: clear, cloudy, partly cloudy, fog, hazy, windy, drizzle, rain, heavy rain, stormy, icy, snow. Two different assumptions were made to ease the analysis process: First, the windy and drizzle conditions were divided into two categories. Windy-1 and Drizzle-1 if work was performed during these conditions and Windy-2 and Drizzle-2 if no work was performed due to strong wind or rain. Second, all conditions were classified into four main categories: 1). Clear - considered a perfect work condition. 2) Cloudy (i.e., Cloudy, Partly Cloudy) - good work conditions (effect of sunlight) 3) Mild weather (Fog, Hazy, Drizzle 1, Windy 1) -considered uncomfortable work condition, sometimes work slowed down, activities were delayed, or stopped work early due to safety concern. 4) Severe weather (Drizzle 2, Windy 2, Rain, Heavy Rain, Icy, Snow, Stormy) – does not allow work.

The previously mentioned four conditions were used in the statistical analysis. Due to consideration of valid sample size, the analysis was made according to the following three different situations: -If the valid sample sizes for mild and severe conditions were equal or greater than 10, all four groups clear, cloudy, mild, severe were used. -If the valid sample sizes for mild or severe conditions were less than 10, a new group called mild/severe was formed from the combination of these two. Afterward, the analysis was performed with three groups: clear, cloudy, and mild/severe. -If the combined valid sample size of mild/severe resulted in less than 10, the data was ignored, and analysis was performed with two groups: clear and cloudy. -The raw records provided AM condition and PM condition for a day. By merging the 1703 working items together, it was found that there were 16341 (79%) days had same AM and PM conditions, and 4735 (21%) days had different AM and PM conditions. In cases were the conditions were different, the worse condition was used for the analysis. Due to the sample size limitation, statistical analysis could only be performed on 39 items for the weather conditions analysis.

5.3.2.2 Evaluation on Temperature Effect. Although it may seem that temperature has a lower effect on productivity when compared to weather conditions, it can have an equal or even more significant impact on the productivity rates. For this reason, it was important to consider the impact temperature has on productivity rates. Two types of temperatures were provided in the CRB: High and Low-temperature readings by date. The temperatures were defined as follows: 1) If work was executed during the daytime, the highest temperature reading was recorded. 2) If work was executed at night, the lowest temperature reading was used. If work was completed at Day/Night (207 cases, less than 1%), that day's temperature was assigned a value NA (i.e., missing) therefore, that case was excluded from further analysis.

Due to the existence of many outliers in the data provided and the sample size limitation, only 40 items were studied for this part of the investigation.

5.3.2.3 Evaluation on Location Effect. One of the factors not commonly studied in the literature is the location of the project, specifically whether a project is located in an urban or rural area. To conduct a meaningful evaluation, it was essential to analyze the collected data statistically from three different perspectives, and the location is one. According to the project's address provided in the CRB, projects were simply classified as urban or rural projects. The productivity rates were then analyzed to determine if there is a change based on the location of the project. Due to the sample size limitation, the location was examined on 26 items only.

5.3.2.4 Evaluation on Shift Effect. Worker's shift (Day or Night), has not been investigated as often as the other factors. This factor is related to traffic and location and consequently affects production rates. The investigation of shift impact on productivity rates can help engineers determine if nighttime operations have an advantage over daytime in terms of productivity. Similar to location, the types of shifts were simply classified in Day or Night. Due to sample size limitation, only three items were considered for workers shifts.

5.3.3 Data Analysis

The factors collected were then analyzed to assess the effect of the studied conditions on the productivity rates. A total of 1703 working items were retrieved from all the projects provided by the DOT. As a result of further data exploration, the existence of many outliers was discovered in almost all items, and statistical analysis could only be performed on some of these items. To evaluate the impact of external factors on the productivity rates, descriptive statistics, comparisons on the averages (or median) of production rates, and regression analyses were applied.

In order to conduct a meaningful evaluation of productivity rates, it was essential to analyze the collected data statistically from three different perspectives. First, descriptive statistical analysis was conducted to provide a comprehensive evaluation of the productivity rates through the analysis of each work item individually. Every work item was listed in a separate sheet; data on the temperature, weather conditions, location, shifts and production rates of the specific item were collected from all the projects provided by the DOT, see Table 2. Second, the analysis was conducted using inferential statistics. These analyses helped determine if there was a significant difference between production rates under the different conditions studied. Finally, items were classified into four work categories, namely, 1) Earthworks, 2) Finishing Works, 3) Asphalt works, and 4) Concrete works. Items of the same nature were grouped together, and their data were statistically analyzed to evaluate the effect of each condition on the productivity rates with respect to the designated work categories. In order to obtain significant statistical results only items with a sample size greater than 60 were considered for the evaluation.

5.4. Statistical Analyses Results

To evaluate the effect of weather conditions, temperature, location, and workers shift on the production rates of construction activities, a series of statistical analyses were performed on each factor. The primary objectives of the analyses are to determine if there is significant difference between production rates under the different conditions studied. A significance level of 0.05 was used for all tests.

5.4.1 Weather Conditions

For each of the factors studied (Clear, Cloudy, Mild/Severe), only work items with a sample size bigger than 60 were considered for the analyses. First, the use of descriptive statistics was essential to determine the general characteristics of each factor. Based on this exploration, the existence of many outliers (some extreme) was found in all items studied. This means that distribution of work items could not be assumed to be normal.

When data was not available for one of the weather conditions, the non-parametric two-sample Wilcoxon signed rank test was used for the analysis. When items presented all three weather conditions the non-parametric Kruskal Wallis test was performed.

The Wilcoxon signed rank test helped determine if the median average of production rates of one of the weather conditions was significantly less or greater than the other condition studied. (Ex. $m_{clear}<m_{cloudy}$).

On the other hand, the Kruskal Wallis Test, which is a non-parametric alternative to the one-way Anova, was used to determine whether there was or not a difference in the productivity rates among all of the weather condition studied. The null hypothesis (H_0) assumes that there is no difference in the distribution of productivity rates Conversely, the alternative hypothesis (H_1) assumes that there is difference in the distribution of productivity.

Additionally, a Post Hoc test is necessary when the null hypothesis is rejected and a difference in the distribution is found. The Post-Hoc test was needed to discover where the three weather conditions were different. Finally, a regression analysis was performed to obtain a more robust conclusion, and to determine if there was a relationship between the different weather conditions.

From the items analyzed, 10 out of 39 items yielded significant results. Summary of descriptive statistics of all the items that showed significant results, are illustrated in Table 5.1.

Table 5. 1*:* Summary Statistics of Weather Conditions.

Weather Condition	Item Code	Valid N	Descriptive Statistics				
			Mean	Median	SD	Min	Max
Clear	432	92	101	51	213	2	1107
	644	61	25	11	27	1	101
	420	77	54	19	75	2	314
	467	89	4	2	5	1	23
	672	56	117	60	17	8	687
	316	80	104	42	217	7	1078
	316	82	2056	1350	1733	20	6000
	316	59	333	256	254	25	931
	247	75	946	584	1320	31	7124
	275	88	60	50	20	25	144
Cloudy	432	92	31	15	44	0	174
	644	61	13	7	20	1	111
	420	77	23	18	16	5	66
	467	89	7	4	9	1	62
	672	56	170	111	165	14	681
	316	80	172	39	261	3	1121
	316	82	5617	2310	7822	4	327
	316	59	217	141	259	3	1204
	247	75	1335	810	1532	37	5636
	275	88	97	75	92	12	466
Mild/Severe	432	92	75	20	91	6	246
	644	61					
	420	77	16	12	16	3	57
	467	89	10	6	10	2	23
	672	56					
	316	80					
	316	82					
	316	59					
	247	75					
	275	88	60	50	38	15	165

First, the plots for descriptive statistics were analyzed. Plots for item number 0420, which is the operation of constructing concrete substructures is shown below for illustration purposes. Figure 5.2 shows the plots of production rates for the different weather conditions analyzed:

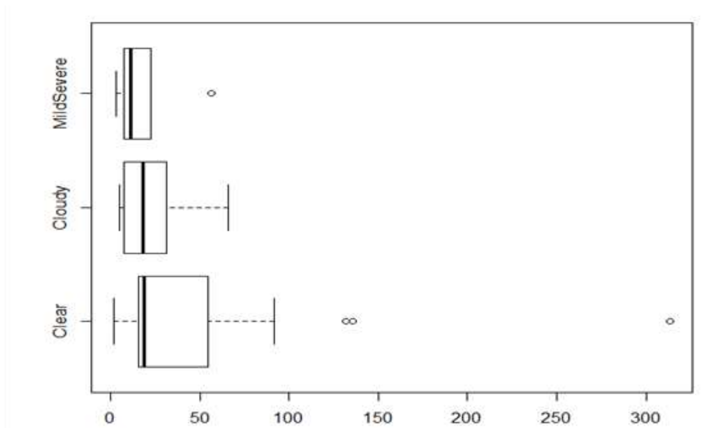


Figure 5. 2: Production Rates Comparison for different Weathers for Item 0420.

As seen in the figure above, there is statistically significant evidence that the medians of production rates are not equal among Clear, Cloudy and Mild/Severe days. With further Post Hoc Tests, it was determined that the median of production rates on Mild/Severe days is significantly less than that on Clear and Cloudy days. According to the regression analysis results, the average production rate on Cloudy days is 16.2 units less than the average of production rate on Clear days. In other words, Cloudy days led to 41.4% of production rate reduction for this item. Table 5.2. shows results for all the previous mentioned items.

Table 5. 2: Results on other Statistical tests for estimating the relationships among Weather Condition.

Work Item		**Non-Parametric Comparison Tests**				**Post Hoc**		**Regression**	
		Wilcoxon Signed Rank		**Kruskal_Wallis**					
		H_1	**p-values**	**H_1**	**p-values**	**H_1**	**p-values**	**H_1**	**p-values**
1	432	N.A.		md ≠ 0	0.02*	$\mu_{Clear} > \mu_{Cloudy}$ $\mu_{Cloudy} < \mu_{Mild}$	0.0009* 0.02*	md ≠ 0	0.02*
2	644	$\mu_{Clear} > \mu_{Cloudy}$	0.01*	N.A.		N.A.		$\beta_{cloudy} \neq 0$	0.03*
3	420	N.A.		md ≠ 0	0.1	N.A.		$\beta_{cloudy} \neq 0$	0.03*
4	467	N.A.		md ≠ 0	0.004*	$\mu_{Clear} > \mu_{Cloudy}$ $\mu_{Cloudy} < \mu_{Mild}$	0.002* 0.003*	$\beta_{cloudy} \neq 0$	0.1
5	672	$\mu_{Clear} < \mu_{Cloudy}$	0.02*	N.A.		N.A.		$\beta_{cloudy} \neq 0$	0.01*
6	316	$\mu_{Clear} < \mu_{Cloudy}$	0.02*	N.A.		N.A.		$\beta_{cloudy} \neq 0$	0.07*
7	316	$\mu_{Clear} < \mu_{Cloudy}$	0.004*	N.A.		N.A.		$\beta_{cloudy} \neq 0$	0.03*
8	316	$\mu_{Clear} > \mu_{Cloudy}$	0.02*	N.A.		N.A.		$\beta_{cloudy} \neq 0$	0.002*
9	247	$\mu_{Clear} < \mu_{Cloudy}$	0.3	N.A.		N.A.		$\beta_{cloudy} \neq 0$	0.03*
10	275	NA		md ≠ 0	0.08	N.A.		$\beta_{cloudy} \neq 0$	0.02*

*P-value<0.05, **p-value<0.01, ***p-value<0.001

N.A. indicates that the statistical analysis was not feasible.

Further analysis showed that the nature of work of items with significant results were of concrete, drainage structures, finishing and asphalt works. Figure 5.3 shows that 6 out of the 10 items found to have significant results were concrete related activities.

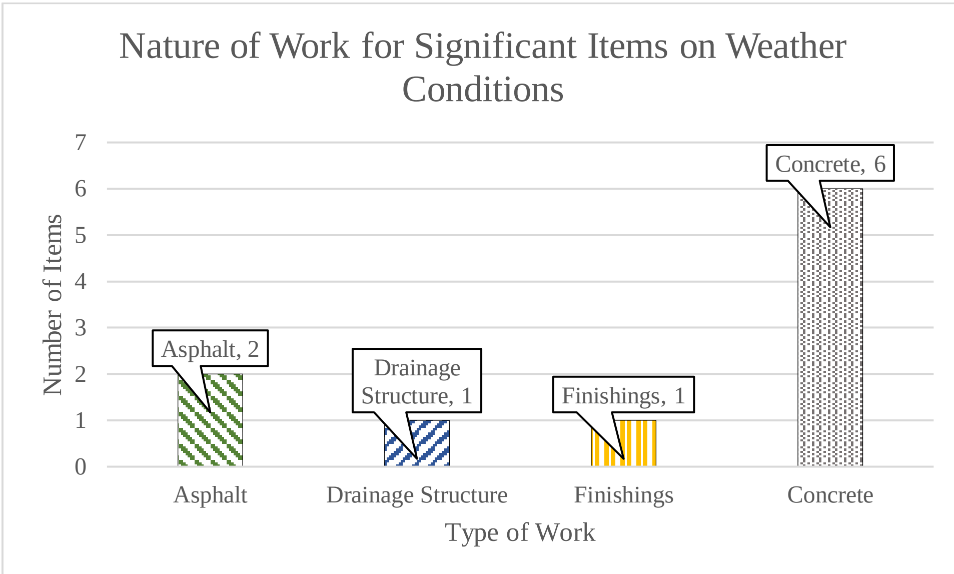


Figure 5. 3: Nature of Work for Significant Items of Weather Conditions.

These findings indicate that concrete works are more susceptible to be affected by unusual weather conditions. Statistical analysis results can be found in Appendix 5.1.

5.4.2 Temperature

First, descriptive statistics were used to understand the features of temperatures on the items studied. Once a general insight was drawn, the items were studied separately by performing a Pearson correlation test and regression analysis.

The Pearson correlation test helped evaluate the strength of the relationship between the productivity rates and temperatures of the different work items studied. Correlation values range between -1.0 and 1.0, this value is used to quantify the association between these two variables. The data exploration revealed significant linear correlation between productivity rates and temperatures (see Table 5) for some items. Additionally, a regression analysis was needed to determine the variation in productivity rates based on the variation in temperatures. Table 5 lists the results of correlation analysis, and regression analysis for temperature effect. Out of the 40 analyzed items, 7 yielded significant results. Table 5.3 summarizes the outcomes obtained with descriptive statistics:

Table 5. 3*:* Summary Statistics for Temperature.

Item Code	N	Productivity rate					Temperature				
		Mean	**Median**	**SD**	**Min**	**Max**	**Mean**	**Median**	**SD**	**Min**	**Max**
432	71	67.55	16.4	141.27	0.15	1107	78.45	78	13.72	46	101
420	59	34.25	22.48	45.02	2	313.57	86.41	88	13.54	57	106
662	62	1870.52	725	2429.4	50	10220	75.35	75	13.73	29	103
3268	17	567.71	388.43	539.99	20.69	1607.85	80.71	86	11.52	59	97
341	68	1130.48	1074.31	1204.27	30.53	9249.8	79.96	80	10.86	57	100
316	79	129.26	6	223.78	3	1120.5	73.89	71	10.48	54	94
316	84	3659.99	1900	5700.9	4	32656	73	71	10.76	48	100

Results for item 0432, which is furnishing and placing concrete, stone, cement-stabilized, or special riprap, are shown in Figure 5.4 for illustration purposes. For item 432 there is statistically significant evidence that the temperature has an influence on production rates. The image on the left shows all the provided data and the figure on the right shows the "clean" data without any outliers. The regression analysis showed that one degree of temperature increase (in Fahrenheit) led to a decrease of 1.9 unit in production rate. Another 6 items from 40 analyzed yielded similar results, Table 5.4. shows the correlation test and regression analysis results for all items with significant findings:

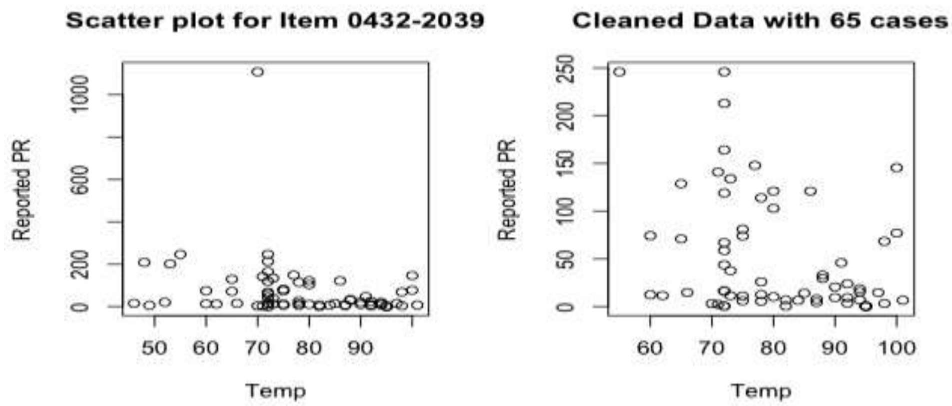


Figure 5. 4: Scatterplots for Temperature vs Reported PR for Item 0432.

Table 5. 4: Correlation Test and Regression Analysis Results for Temperature.

Item Code	**Correlation Test**		**Regression**	
	Cor	**p-value**	**H_1**	**p-values**
432	-0.35	0.004*	$\beta \neq 0$	0.004*
420	0.32	0.01*	$\beta \neq 0$	0.002*
662	0.48	<0.001*	$\beta \neq 0$	<0.001*
268	-0.63	0.006*	$\beta \neq 0$	0.04*
341	0.34	0.005*	$\beta \neq 0$	0.005*
316	0.46	<0.001*	$\beta \neq 0$	0.003*
316	0.46	<0.001*	$\beta \neq 0$	<0.001*

*p-value<0.05, **p-value<0.01, ***p-value<0.001

Further exploration showed that the nature of work of significant items were of concrete, finishing and asphalt works. Figure 5.5. shows that 4 out of the 7 items found to have significant results were asphalt related activities.

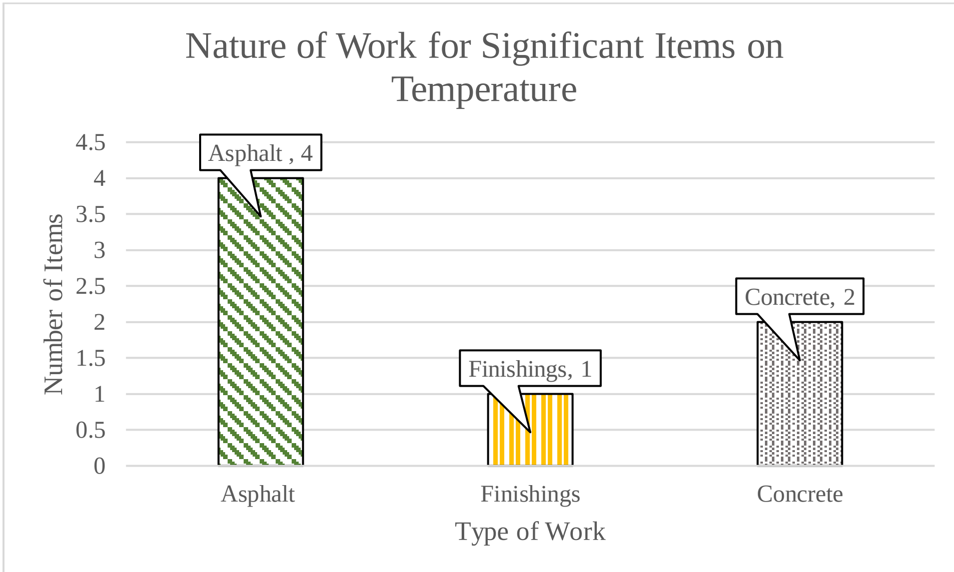


Figure 5. 5: Nature of Work for Significant Items on Temperature.

These findings indicate that asphalt works are more susceptible to be affected by high temperatures. Statistical analysis results can be found in Appendix 5.2.

5.4.3 Location

Statistical analyzes to study the effect of location on productivity rates consisted of: first, descriptive statistical analysis was conducted on the productivity rates to get an initial evaluation of the performance of workers on urban and rural areas. Second, the non-parametric one-sample Wilcoxon signed rank test was performed. The test was used to determine whether the median of differemce between productivity rates in urban areas and productivity rates in rural is greater or less than 0. Lastly, multiple linear regression was used to explain the relationship between one continuous dependent variable (Productivity rates) and two or more independent variables (urban or rural areas) by fitting a linear equation to the observed data.

Out of the 26 items analyzed 16 yielded significant results- see Tables 5.5.

Table 5. 5: Summary Statistics Results for Location.

Item Code	Valid N	Rural						Urban					
		N	Mean	Median	SD	Min	Max	N	Mean	Median	SD	Min	Max
496	91	60	80.56	32.00	153.72	4.00	984.00	31	197.61	97.00	274.36	20.00	1,259.00
677	81	55	3,742.93	1,214.00	6,656.75	50.00	42,432.00	26	7,997.23	4,493.00	14,329.59	4.00	69,490.00
668	77	53	5.91	4.00	6.60	1.00	39.00	24	8.21	5.00	6.58	1.00	20.00
160	72	42	11,948.71	3,321.00	16,862.98	8.01	66,870.75	30	88,774.84	22,390.98	199,995.90	138.89	1,061,656.00
310	67	20	1,053.60	650.00	928.24	150.00	2,875.00	47	3,716.20	1,800.00	11,139.68	0.00	7,766.16
420	80	32	13.46	7.80	11.77	0.46	46.30	48	39.23	22.48	49.35	4.98	313.57
467	91	30	11.07	6.00	11.62	1.00	62.00	61	4.72	4.00	4.02	1.00	22.00
618	65	33	243.55	64.50	352.90	10.00	1,200.00	32	893.88	687.50	945.35	18.00	4,112.00
662	95	43	2,835.77	1,633.75	2,930.79	130.00	11,080.00	52	1,010.71	585.00	1,210.78	50.00	6,550.00
432	94	44	13.38	6.80	19.74	0.42	97.71	50	78.49	56.27	92.44	0.68	534.81
3268	92	39	410.27	388.43	380.43	4.99	1,554.86	53	1,152.19	1,203.68	782.05	59.35	2,995.84
465	63	45	1.27	0.75	1.58	0.25	8.00	18	3.50	3.75	2.11	0.50	9.00
316	93	57	250.38	120.00	305.33	14.00	1,120.50	36	39.47	42.00	18.69	3.00	70.00
316	92	58	5,658.86	3,940.00	7,224.87	4.00	32,656.00	34	1,277.35	1,325.00	491.19	300.00	1,950.00
247	67	50	2,674.84	1,322.60	6,810.71	38.86	47,909.00	17	836.75	508.08	900.17	62.69	3,722.45
530	65	38	2,487.93	2,071.00	1,987.13	17.33	7,889.65	27	580.43	334.83	633.38	45.00	2,335.84

According to comparison test results, there is statistically significant evidence that the median of production rates in rural areas is different from that in urban areas for 16 items. Plots for item number 496 which is the operation of removing and dispose or salvage structures are shown in Figure 5.6. The figure above shows that there is statistically significant evidence that the median of production rates in rural areas is less than that in urban areas. Regression analysis results showed that the average of production rates in Urban areas is 75.42 unit greater than the average of production rates in Rural areas. In another word, Urban areas led to 115.6% of production rate increase for this item.

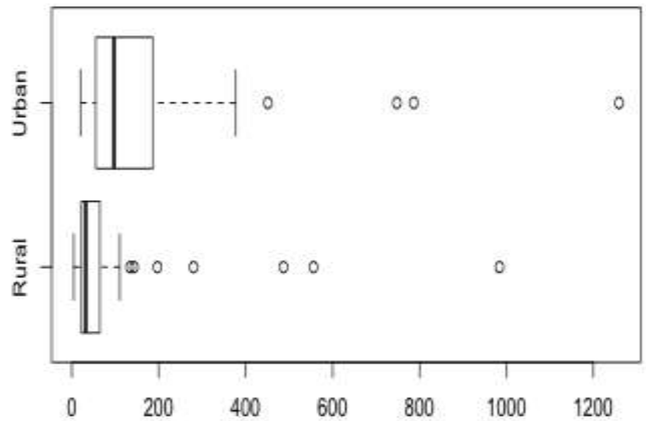


Figure 5. 6: Production Rates Comparison for Rural and Urban Areas for Item 0496.

Table 5. 6*:* Correlation Test and Regression Analysis.

Item Code	**Non-Parametric Comparison test**		**Regression**	
	H_1	**p-values**	**H_1**	**p-values**
496	$m_{rural} < m_{urban}$	<0.001*	$\beta_{urban} \neq 0$	0.007*
677	$m_{rural} > m_{urban}$	0.03*	$\beta_{urban} \neq 0$	0.040
668	$m_{rural} < m_{urban}$	0.060	$\beta_{urban} \neq 0$	0.03*
160	$m_{rural} < m_{urban}$	<0.001*	$\beta_{urban} \neq 0$	0.001*
310	$m_{rural} < m_{urban}$	0.002*	$\beta_{urban} \neq 0$	0.009*
420	$m_{rural} < m_{urban}$	<0.001*	$\beta_{urban} \neq 0$	<0.001*
467	$m_{rural} > m_{urban}$	0.002*	$\beta_{urban} \neq 0$	<0.001*
618	$m_{rural} < m_{urban}$	<0.001*	$\beta_{urban} \neq 0$	<0.001*
662	$m_{rural} > m_{urban}$	<0.001*	$\beta_{urban} \neq 0$	<0.001*
432	$m_{rural} < m_{urban}$	<0.001*	$\beta_{urban} \neq 0$	<0.001*
3,268	$m_{rural} < m_{urban}$	<0.001*	$\beta_{urban} \neq 0$	<0.001*
465	$m_{rural} < m_{urban}$	<0.001*	$\beta_{urban} \neq 0$	<0.001*
316	$m_{rural} > m_{urban}$	<0.001*	$\beta_{urban} \neq 0$	<0.001*
316	$m_{rural} > m_{urban}$	<0.001*	$\beta_{urban} \neq 0$	<0.001*
247	$m_{rural} > m_{urban}$	0.02*	$\beta_{urban} \neq 0$	0.070
530	$m_{rural} > m_{urban}$	<0.001*	$\beta_{urban} \neq 0$	<0.001*

*P-value<0.05, **p-value<0.01, ***p-value<0.001

Further exploration showed that the nature of work of significant items were of concrete, finishing, drainage structures and asphalt works. Figure 5.7 shows that 5 out of the 16 items found to have significant results were asphalt related activities. Statistical analysis results can be found in Appendix 5.3.

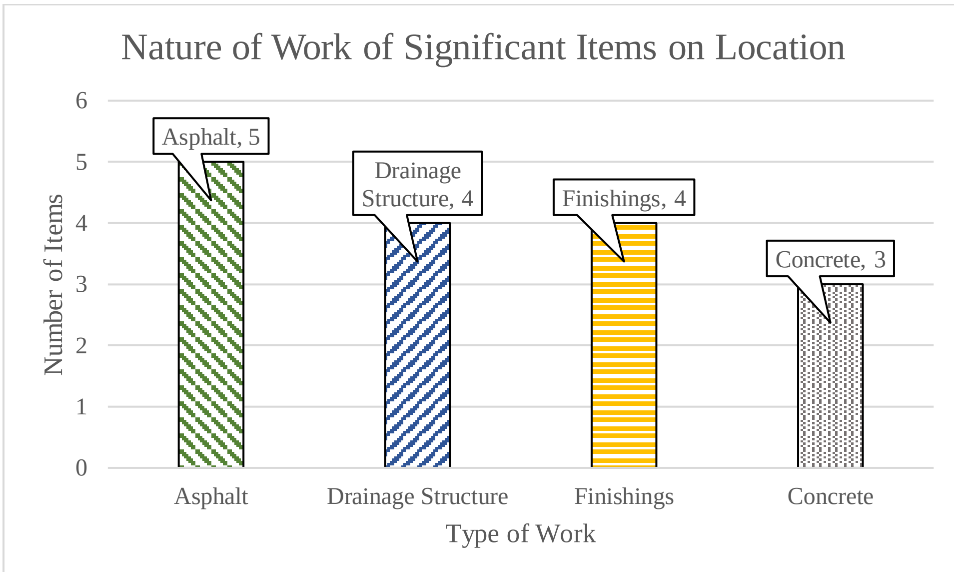


Figure 5. 7: Nature of Work for Significant Items on Location.

5.4.4 Workers Shift

The same statistical analyses utilized for location were used to study the workers shift. These analyses could only be performed on 3 items with a large enough sample size. All 3 items yielded significant results. The analysis discovered that there is statistically significant evidence that the median of production rates during nighttime is less than daytime for all 3 items. Results are compiled in Table 5.7.

Table 5. 7: Summary Statistics Results for Workers Shift.

Item Code	Valid N	Night						Day					
		N	Mean	Median	SD	Min	Max	N	Mean	Median	SD	Min	Max
662	62	29	894.00	540.00	1,228.42	180.00	7,096.00	33	228.67	1,580.00	2,882.12	50.00	10,220.00
316	83	35	4,049.00	42.00	170.93	3.00	70.00	48	228.60	110.25	296.88	14.00	1,120.50
316	85	37	1,200.00	1,250.00	539.52	250.00	1,950.00	48	5,561.23	4,050.00	6,979.73	4.00	32,656.00

Results for item 0662 (Furnish, place, and maintain work zone pavement markings) are shown in Figure 5.8:

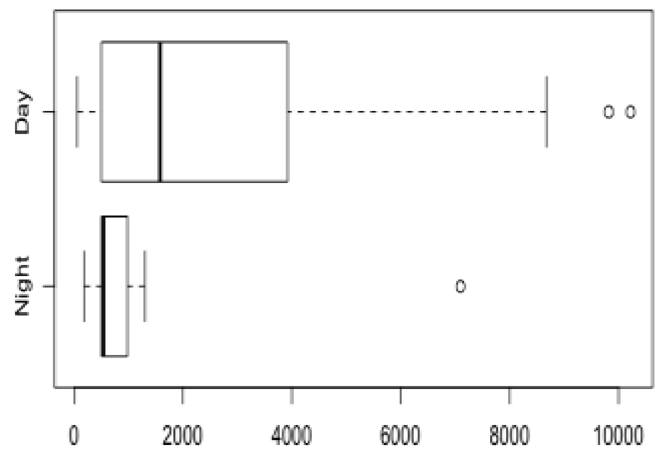


Figure 5. 8: Production Rates Comparison of Day and Night for Item 0662.

The figure above shows this difference in the productivity rates. Regression analysis results also showed that for item 662, the average of production rates in Day is 1364.2 unit (95% CI: 416.57, 2311.77) more than the average of production rates at Night. In other words, day led to 152.6% of production rate increase (95% CI: 46.6%, 258.6%) for this item. Similarly, the two other items analyzed yielded significant results.

Table 5. 8: Correlation Test and Regression Analysis Results for Workers Shift

Item Code	Non-Parametric Comparison test		Regression	
	H_1	p-values	H_1	p-values
662	$m_{night} < m_{day}$	0.01*	$\beta_{day} \neq 0$	0.005*
316	$m_{night} < m_{day}$	<0.001*	$\beta_{day} \neq 0$	<0.001*
316	$m_{night} < m_{day}$	<0.001*	$\beta_{day} \neq 0$	<0.001*

*P-value<0.05, **p-value<0.01, ***p-value<0.001

NA indicate no statistical analysis was feasible.

Further exploration revealed that the nature of work of significant items were of finishing, and asphalt works. Figure 5.9 shows that 2 out of the 3 items found to have significant results were asphalt related activities. Statistical analysis results can be found in Appendix 5.4.

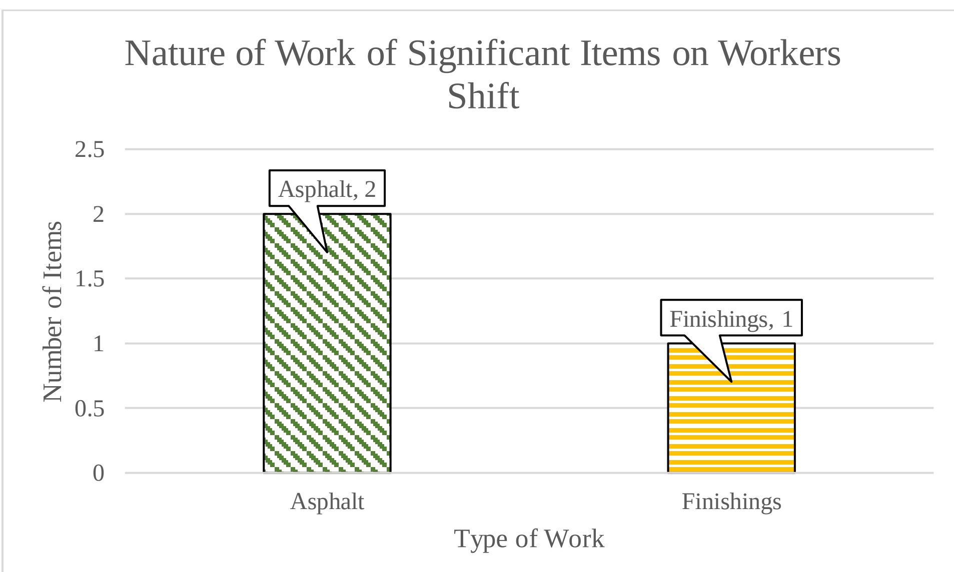


Figure 5. 9: Nature of Work for Significant Items on Workers Shift.

CHAPTER VI

SUMMARY AND CONCLUSIONS

6.1 Introduction

This study was conducted to have a greater understanding of how the productivity rates of highway construction projects are affected by certain factors. Through a comprehensive literature review and an extensive statistical analysis, the research identified the significant production rates drivers and determined how each of the drivers affected the production so that schedulers can make good use of this information.

6.2 Summary and Conclusions

This study has investigated the impact of the common cause variation represented by the contract time determination systems used by TxDOT on estimating the project time. The results obtained from the statistical analyses conducted indicate that the CTDS and HyPRIS systems are outdated. Both systems have not been updated since their creation. This finding is clearly illustrated by the fact that most production rates are underestimated which implies that the CTDS and HyPRIS are based on old technological methods. The results also showed that the negative impact of inaccurate production rates on estimating a reasonable contract time is higher than the impact of the inaccuracy in estimating work quantities. Both CTDS and HyPRIS systems utilize deterministic production rates. As such, the impact of special cause variabilities on the production rates are not accurately considered. The study also revealed the need for consistent and accurate documentations of the project progress and the work executed on daily bases to be able to properly assess the performance of the contract time determination systems used to estimate the project time.

The application of the weather models found in the literature review, also revealed that the projects planned durations are overestimated in general. There is a need for further investigation to determine the root cause of the inflation in estimating the project duration. Although there is a concern about the reliability of the two models studied to assess the impacts of weather accurately, there is a potential to improve the accuracy of the output durations by using new thresholds specific to the region of the project. Projects delays can be mitigated by understanding the weather patterns and impacts in the region and reflecting them in the activity's duration using reliable models. Proper planning is the key; project critical weather-dependent activities should be scheduled during clear days based on historical data. Weather models can be of great assistance to DOTs in order to minimize delays, disputes and cost, and to maximize the value.

The methodology described in this paper has the potential to enable schedulers to better evaluate the effect of the factors studied on the duration of construction projects. It was found that weather, temperature, location, and workers shift all have a significant impact on production rates for some work activivties.

It was also noticed that for many activities, the number of cases on mild or severe weather conditions were much smaller than for clear and cloudy; Further, all the production rates on mild or severe weather were identified as outliers during the regression analysis. This indicates that weather has impact on production rates but more data is needed to fully evaluate the mild and severe weather's effect.

Not only for the weather analysis, was the lack of data an issue; from the 1703 items extracted less than 3% had a sample size big enough for analysis and more data will be needed to draw more specific conclusions that. In addition, it was determined that the nature of work played a big role in the analysis. It was discovered that of the items that showed significant results, were either concrete or asphalt works. This indicates that these two types of work are more susceptible to be affected by the conditions studied.

6.3 Recommendations and Future Work

Further research is required to evaluate and refine the methodology described in this paper; it is argued that it represents an important step in better predicting the likely duration of a construction projects given historical weather conditions. The next step will be the determination of more realistic production rates, now that it has been proven that the database of production rates available for TxDOT schedulers is not reliable.

The scope of this study is limited and the issue of how to improve production rates and/or productivity was not studied. However, the results obtained from these study call into question the accuracy of the data provided by the DOT. This accuracy of the data depends on the inspector who filled such reports. It was mentioned that the inspectors are supposed to fill the reports especially the daily work report on a daily basis, but in some cases it was found that the inspectors did not fill properly the reports, since some lines in the report where created to adjust quantities that needed to be paid.

Now that it has been proven that the factors studied have a significant effect on the productivity rates, the next step will be to quantify the impact they have on the schedule. Such quantification has the potential to help the DOT and contractors to make a better estimate of project time, minimize disputes resulting from delays, and deliver cost savings as a result of less uncertainty with respect to duration of the project as a result of weather conditions, temperature, location, and work shift. The main goal being the creation of a more accurate Model that applies to the South Texas Region.

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APPENDIX

APPENDIX 3.1.

SURVEY FOR SELECTING DISTRICTS FOR STUDY

Survey on TxDOT Contract Time Determination System (CTDS) and the Highway Production Rate Information System (HyPRIS)

Dear District Engineers:

TxDOT has used the Contract Time Determination System (CTDS) and the Highway Production Rate Information System (HyPRIS) to determine the project contract time. The CTDS and HyPRIS include production rates and adjustment factors that can be used to determine the durations of selected work activities. However, there is a concern about the reliability and the accuracy of these tools in determining the contract time.
A research team at the University of Texas Rio Grande Valley (UTRGV) is currently investigating the effectiveness of Texas CTDS and the HyPRIS in determining the project contract time (Project 0-6924). This survey aims at assessing the utilization of these tools by different TxDOT District Offices to determine the contract times for different types of projects. Your cooperation is highly appreciated

On behalf of the University of Texas Rio Grande Valley Research Team:

Mohamed Abdel-Raheem, PhD, PMP, LEED GA, CM-BIM, CM-Lean
Assistant Professor
Civil Engineering Department
Ph.: (956) 665-2050
Email: Mohamed.Abdelraheem@UTRGV.edu

1. Do you currently use the Texas CTDS to determine the productivity rates for different work items? *

◯ Yes

◯ No

2. Have you ever used the CTDS? *

◯ Yes

◯ No

2.1. If yes: when was the last time you used the CTDS to determine the contract time of a project? Please indicate the year only.

Your answer

2.2. If yes: On a scale from 0 (least) to 5 (highest), please rate the effectiveness and accuracy of the CTDS in determining the activity duration.

	1	2	3	4	5	
Ineffective	◯	◯	◯	◯	◯	Extremely Effective

2.3. If not: please type N/A

Your answer

3. Do you currently use the HyPRIS to determine the productivity rates for different work items? *

◯ Yes

◯ No

4. Have you ever used the HyPRIS? *

◯ Yes

◯ No

4.1. If yes: when was the last time you used HyPRIS to determine the contract time of a project? Please indicate the year only.

Your answer

4.2. If yes: On a scale from 0 (least) to 5(highest), please rate the effectiveness and accuracy of HyPRIS in determining the activity duration.

	1	2	3	4	5	
Ineffective	◯	◯	◯	◯	◯	Extremely Effective

4.3. If not: please type N/A

Your answer

5. Do you use other tools to determine the productivity rates for different work items? *

- Yes
- No

5.1. If yes: please describe what tools do you use

Your answer

5.2 If not: please type N/A

Your answer

APPENDIX 3.2.

RESULTS OF THE SURVEY FOR SELECTING DISTRICTS TO BE TRACKED.

		Questions				
Timestamp	***District Office***	***1***	***2***	***2.1.***	***2.2.***	***2.3.***
2016/10/13 10:19:17 AM CDT	BWD	Yes	Yes	2016	3	
2016/10/13 10:34:17 AM CDT	Atlanta	No	No			N/A
2016/10/13 2:41:04 PM CDT	Abilene	No	No			
2016/10/13 3:53:00 PM CDT	San Antonio	No	No			n/a
2016/10/13 5:07:16 PM CDT	Brownwood	No	No			N/A
2016/10/13 8:41:55 PM CDT	Odessa	No	No			N/A
2016/10/14 7:34:36 AM CDT	Amarillo	No	No			N/A
2016/10/14 7:37:43 AM CDT	Amarillo	No	No			N/A
2016/10/14 10:41:17 AM CDT	ODA	No	No	N/A		N/A
2016/10/14 3:25:04 PM CDT	San Antonio	Yes	Yes	2016	2	
2016/10/16 3:43:45 PM CDT	Paris District	No	No			N/A
2016/10/17 10:10:13 AM CDT	Lufkin	No	No			N/A
2016/10/17 10:55:06 AM CDT	Lufkin	No	No			
2016/10/18 9:33:52 AM CDT	FTW	No	No			n/a
2016/11/17 10:57:04 AM CST	Austin	Yes	Yes	2016	4	
2016/11/17 11:11:35 AM CST	Yoakum	No	No			N/A

2016/11/17 11:12:37 AM CST	El Paso District	No	No			
2016/11/17 11:16:29 AM CST	Wichita Falls	No	No			N/A
2016/11/17 11:31:57 AM CST	Pharr	No	No			N/A
2016/11/17 11:55:45 AM CST	TP&D	Yes	Yes	2016	3	
2016/11/17 11:57:31 AM CST	Beaumont	No	No			N/A
		Questions				
Timestamp	***District Office***	***1***	***2***	***2.1.***	***2.2***	***2.3.***
2016/11/17 12:00:29 PM CST	Yoakum	No	No		1	N/A
2016/11/17 12:34:08 PM CST	Yoakum	No	No			N/A
2016/11/17 12:55:10 PM CST	Brownwood	Yes	Yes	2016	3	
2016/11/17 1:04:48 PM CST	Beaumont	No	No			N/A
2016/11/17 1:05:27 PM CST	Fort Worth	No	No			N/A
2016/11/17 1:14:20 PM CST	ODA	No	No	NA		NA
2016/11/17 1:14:52 PM CST	BMT-TP&D	No	No			N/A
2016/11/17 1:18:34 PM CST	Beaumont	No	No			N/A
2016/11/17 3:39:20 PM CST	Lufkin	Yes	Yes	2014	3	
2016/11/17 9:32:33 PM CST	Lufkin	No	No			N/A
2016/11/18 7:28:14 AM CST	Beaumont	No	No			N/A
2016/11/18 7:37:12 AM CST	Austin - District Design	No	No			
2016/11/18 7:56:26 AM CST	Beaumont	No	No			N/A
2016/11/18 12:59:33 PM CST	Lufkin	No	No			na

2016/11/18 3:27:24 PM CST	Waco	No	No			N/A
2016/11/21 7:37:26 AM CST	Beaumont TP&D	Yes	Yes	2015	2	
2016/11/21 7:40:13 AM CST	TYLER	No	No			N/A
2016/11/21 8:19:25 AM CST	Lufkin	No	No			N/A
2016/11/21 10:08:29 AM CST	Beaumont	No	Yes	Unknow n	3	----------
2016/11/22 10:15:26 AM CST	Bryan	No	No			N/A
2016/11/22 3:33:35 PM CST	Bryan	No	No			
2016/11/28 7:58:21 AM CST	Bryan	No	No			What is CTDS? Where can it be found?
		Questions				
Timestamp	***District Office***	***1***	***2***	***2.1.***	***2.2***	***2.3.***
2016/11/28 7:58:49 AM CST	Beaumont	No	No	N/A		N/A
2016/12/01 10:25:44 AM CST	Tyler	No	No			n/a
2016/12/03 12:26:46 PM CST	Corpus Christi	No	No			N/A
2016/11/17 11:58:17 AM CST	Austin	No	No			N/A

Questions About HYPRIS:

		Questions				
Timestamp	***District Office***	***4***	***4.1***	***4.2***	***4.3***	***5***
2016/10/13 10:19:17 AM CDT	BWD	Yes	2016	3		No
2016/10/13 10:34:17 AM CDT	Atlanta	No			N/A	Yes
2016/10/13 2:41:04 PM CDT	Abilene	No				No

2016/10/13 3:53:00 PM CDT	San Antonio	No			n/a	Yes
2016/10/13 5:07:16 PM CDT	Brownwood	No			N/A	Yes
2016/10/13 8:41:55 PM CDT	Odessa	No			N/A	No
2016/10/14 7:34:36 AM CDT	Amarillo	Yes	2016	3		Yes
2016/10/14 7:37:43 AM CDT	Amarillo	No			N/A	No
2016/10/14 10:41:17 AM CDT	ODA	No	N/A		N/A	Yes
2016/10/14 3:25:04 PM CDT	San Antonio	Yes	2016	2		Yes
2016/10/16 3:43:45 PM CDT	Paris District	No			N/A	Yes
2016/10/17 10:10:13 AM CDT	Lufkin	Yes	2014	3		Yes
2016/10/17 10:55:06 AM CDT	Lufkin	No				Yes
2016/10/18 9:33:52 AM CDT	FTW	No			n/a	No
2016/11/17 10:57:04 AM CST	Austin	Yes	2002	1		No
		Questions				
Timestamp	***District Office***	***4***	***4.1***	***4.2***	***4.3***	***5***
2016/11/17 11:11:35 AM CST	Yoakum	No			N/A	Yes

2016/11/17 11:12:37 AM CST	El Paso Distract	No				Yes
2016/11/17 11:16:29 AM CST	Wichita Falls	No			N/A	No
2016/11/17 11:31:57 AM CST	Pharr	No			N/A	Yes
2016/11/17 11:55:45 AM CST	TP&D	No			NA	Yes
2016/11/17 11:57:31 AM CST	Beaumont	Yes	2015	3		Yes
2016/11/17 12:00:29 PM CST	Yoakum	No			N/A	No
2016/11/17 12:34:08 PM CST	Yoakum	No			N/A	No
2016/11/17 12:55:10 PM CST	Brownwood	Yes	2016	3		No
2016/11/17 1:04:48 PM CST	Beaumont	No			N/A	No
2016/11/17 1:05:27 PM CST	Fort Worth	No			N/A	No
2016/11/17 1:14:20 PM CST	ODA	No	NA		NA	No
2016/11/17 1:14:52 PM CST	BMT-TP&D	No			N/A	Yes
2016/11/17 1:18:34 PM CST	Beaumont	No			N/A	Yes
2016/11/17 3:39:20 PM CST	Lufkin	No			N/A	No

2016/11/17 9:32:33 PM CST	Lufkin	No			N/A	Yes
2016/11/18 7:28:14 AM CST	Beaumont	No				Yes
2016/11/18 7:37:12 AM CST	Austin - District Design	No				Yes
2016/11/18 7:56:26 AM CST	Beaumont	No			N/A	No
2016/11/18 12:59:33 PM CST	Lufkin	Yes	2010		N/A	No
2016/11/18 3:27:24 PM CST	Waco	Yes	prior to 2010	1		Yes
				Questions		
Timestamp	***District Office***	***4***	***4.1***	***4.2***	***4.3***	***5***
2016/11/21 7:40:13 AM CST	TYLER	No			N/A	No
2016/11/21 8:19:25 AM CST	Lufkin	Yes	1999	3		Yes
2016/11/21 10:08:29 AM CST	Beaumont	Yes	Unknown	3	----------	Yes
2016/11/22 10:15:26 AM CST	Bryan	No			N/A	Yes
2016/11/22 3:33:35 PM CST	Bryan	No				Yes
2016/11/28 7:58:21 AM CST	Bryan	Yes	Looked at it but never really	1		Yes

			used it. It does not have enough data to determine contract time.			
2016/11/28 7:58:49 AM CST	Beaumont	No	N/A		N/A	No
2016/12/01 10:25:44 AM CST	Tyler	Yes	2015	2		Yes
2016/12/03 12:26:46 PM CST	Corpus Christi	No			N/A	Yes
2016/11/17 11:58:17 AM CST	Austin	Yes	2015	3		No
2016/11/21 7:37:26 AM CST	Beaumont TP&D	No			N/A	No

APPENDIX 3.3

DATA COLLECTION TEMPLATE

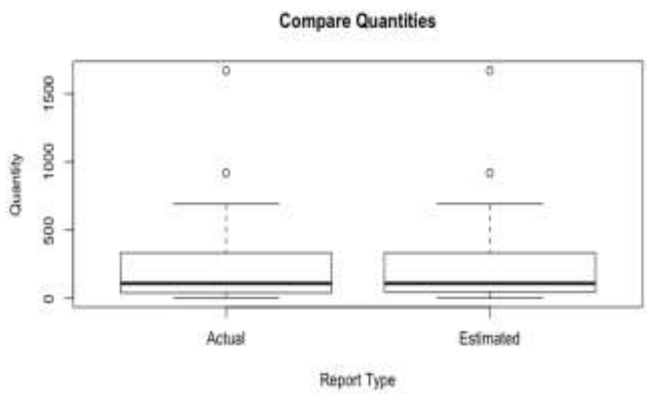
Item Information			Quantities			Duration		Timeline
Item Code	Item Description	Date	Unit	Estimated Quantity	Actual Quantity	Estimated Duration	Actual Duration	Contracto r or TxDOT?

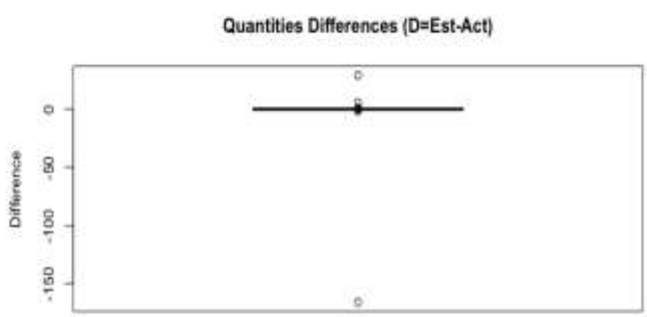
APPENDIX 3.4

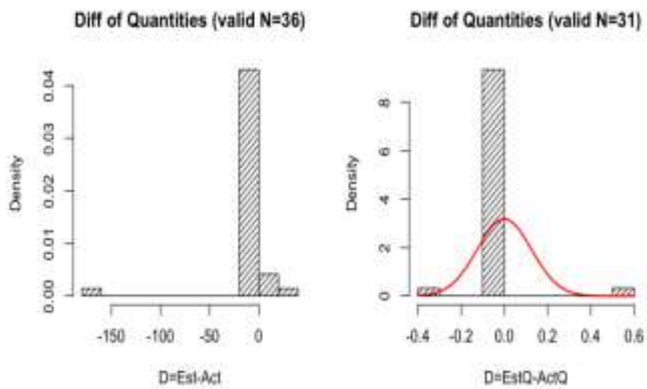
RESULTS OF STATISTICAL ANALYSIS OF ITEMS WITH SAMPLE SIZE GREATER THAN 30 FOR THE DISTRICT A

Item 0420_CY

1) Qty: (N=36)



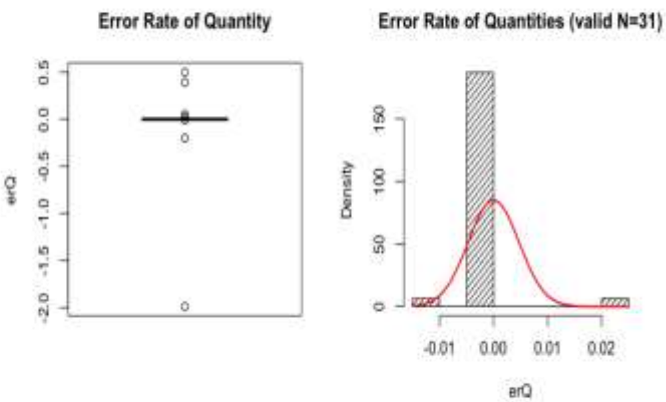





```
newAQ=ActQty[ActQty<918.2&EstQty<918.2]
newEQ=EstQty[ActQty<918.2&EstQty<918.2]

                Paired t-test

data:  newEQ and newAQ
t = -0.77654, df = 33, p-value = 0.2215
alternative hypothesis: true difference in means is less than 0


t = -0.77654, df = 33, p-value = 0.443
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -14.02630   6.27689
sample estimates:
mean of the differences
              -3.874706


        Wilcoxon signed rank test with continuity correction

data:  EstQty and ActQty
V = 16, p-value = 0.6637
alternative hypothesis: true location shift is less than 0
```

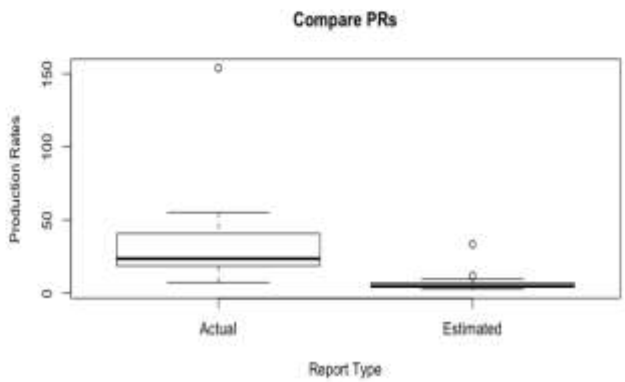
Consider the error rate of Q:

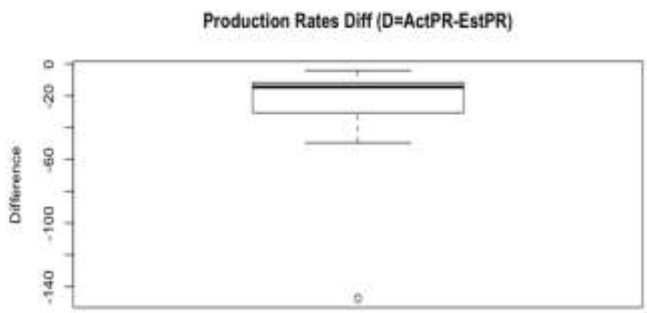
```
> describeBy(erQ)
   vars  n  mean   sd median trimmed mad   min max range  skew kurtosis   se
X1    1 36 -0.03 0.35      0       0   0 -1.99 0.5  2.49 -4.58    23.37 0.06
```

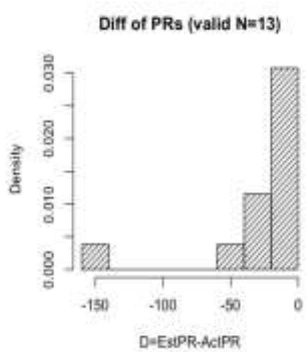


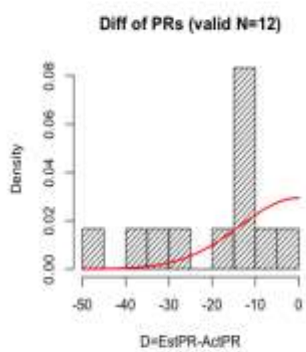

```
newER=erQ[erQ>-0.01001391&erQ<0.02382979]

                One Sample t-test

data:  newER
t = 0.52825, df = 30, p-value = 0.3006
alternative hypothesis: true mean is greater than 0


t = 0.52825, df = 30, p-value = 0.6012
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.001277363  0.002168710
sample estimates:
   mean of x
0.0004456735

        Wilcoxon signed rank test with continuity correction

data:  erQ
V = 16, p-value = 0.6637
alternative hypothesis: true location is less than 0


V = 16, p-value = 0.7998
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 -1.0946906  0.4441107
sample estimates:
(pseudo)median
    0.02193165
```

2) PRs: (N=36, valid n=13)







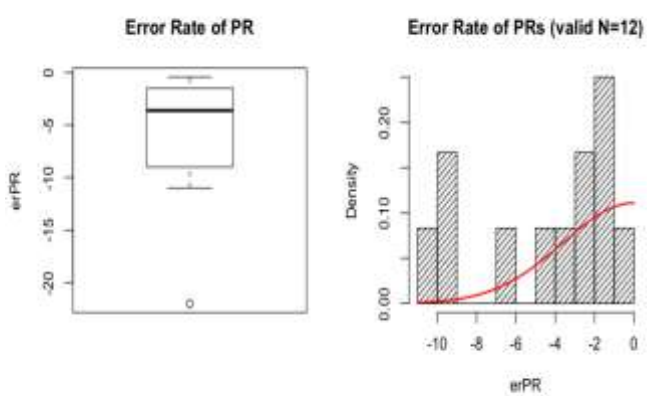



```
newEPR=EstPR[ActPR<154&EstPR<11.63333]
newAPR=ActPR[ActPR<154&EstPR<11.63333]


        Paired t-test

data:  newEPR and newAPR
t = -4.6275, df = 9, p-value = 0.0006206
```

```
alternative hypothesis: true difference in means is less than 0

t = -4.6275, df = 9, p-value = 0.001241
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -31.69319 -10.88073
sample estimates:
mean of the differences
              -21.28696


        Wilcoxon signed rank test

data:  EstPR and ActPR
V = 0, p-value = 0.0001221
alternative hypothesis: true location shift is less than 0
```

Consider the error rate of PR:

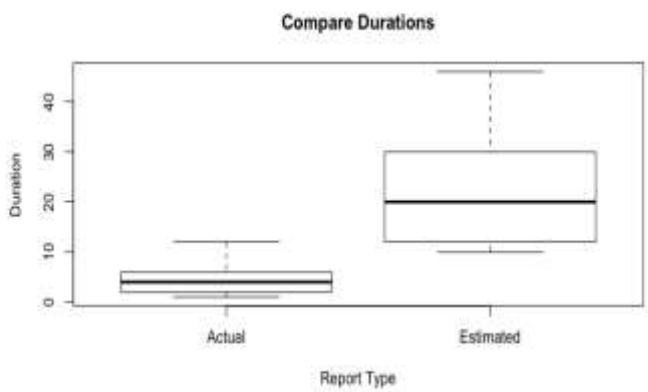
```
> describeBy(erPR)
   vars  n  mean   sd median trimmed  mad min   max range  skew kurtosis   se
X1    1 13 -5.77 5.97  -3.63   -4.78 3.89 -22 -0.43 21.57 -1.44      1.4 1.66
```

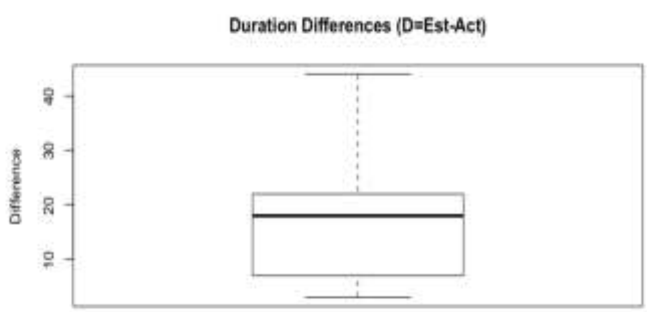


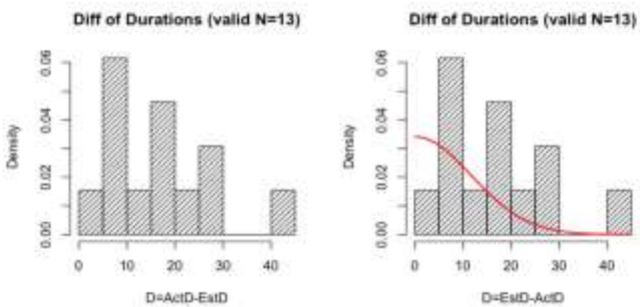

```
newER=erPR[erPR>-22]

                One Sample t-test

data:  newER
t = -4.261, df = 11, p-value = 0.0006704
alternative hypothesis: true mean is less than 0


t = -4.261, df = 11, p-value = 0.001341
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -6.702742 -2.136742
sample estimates:
mean of x
-4.419742


        Wilcoxon signed rank test
```

```
data:  erPR
V = 0, p-value = 0.0001221
alternative hypothesis: true location is less than 0


V = 0, p-value = 0.0002441
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 -9.000 -2.075
sample estimates:
(pseudo)median
            -5
```

3) Durations: (N=36, valid n=13)



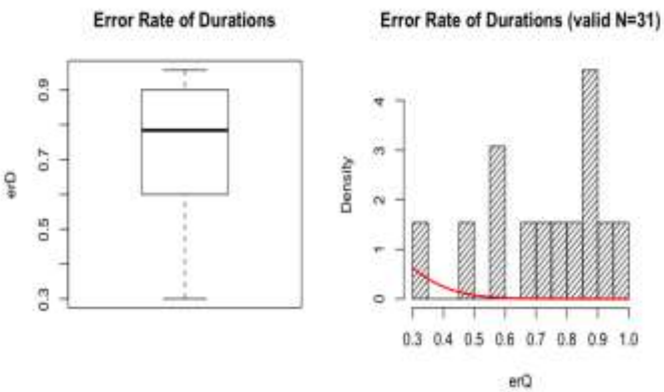





```
newAD=DurDays
newED=EstDur

        Paired t-test

data:  newED and newAD
t = 5.2399, df = 12, p-value = 0.0001039
alternative hypothesis: true difference in means is greater than 0


t = 5.2399, df = 12, p-value = 0.0002078
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
  9.931224 24.068776
sample estimates:
mean of the differences
                     17


        Wilcoxon signed rank test with continuity correction

data:  EstDur and DurDays
V = 91, p-value = 0.0008254
alternative hypothesis: true location shift is greater than 0
```

Consider the error rate of erD:

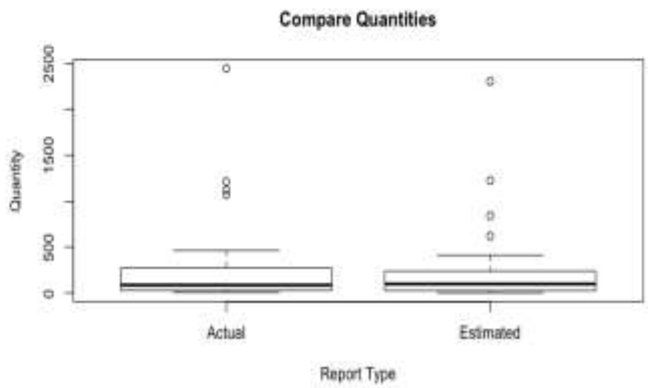
```
> describeBy(erD)
   vars  n mean   sd median trimmed  mad min  max range  skew kurtosis   se
X1    1 13 0.74 0.19   0.78    0.75 0.17 0.3 0.96  0.66 -0.77    -0.53 0.05
```

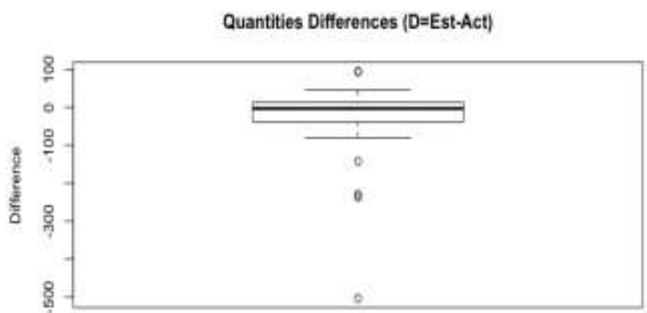


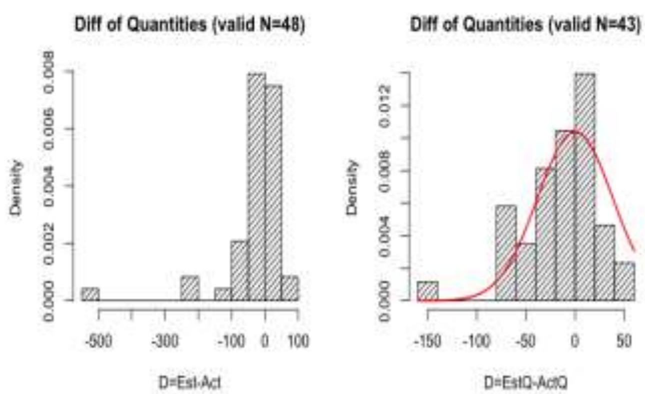

```
newED=erD

        One Sample t-test

data:  newED
t = 13.69, df = 12, p-value = 5.498e-09
alternative hypothesis: true mean is greater than 0


t = 13.69, df = 12, p-value = 1.1e-08
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 0.6184005 0.8524925
sample estimates:
mean of x
0.7354465


        Wilcoxon signed rank test with continuity correction

data:  erD
V = 91, p-value = 0.0008281
alternative hypothesis: true location is greater than 0


V = 91, p-value = 0.001656
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 0.6000310 0.8700966
sample estimates:
(pseudo)median
     0.7500485
```

Item 0432_CY

1) Qty: (N=48)





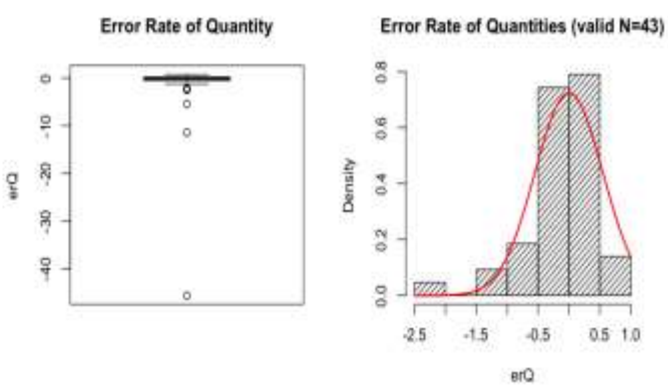



```
newAQ=ActQty[ActQty<1070.29&EstQty<621.30]
newEQ=EstQty[ActQty<1070.29&EstQty<621.30]

                Paired t-test

data:  newEQ and newAQ
```

```
t = -1.4466, df = 43, p-value = 0.07763
alternative hypothesis: true difference in means is less than 0


t = -1.4466, df = 43, p-value = 0.1553
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -27.363268   4.504177
sample estimates:
mean of the differences
              -11.42955


        Wilcoxon signed rank test with continuity correction

data:  EstQty and ActQty
V = 400, p-value = 0.9591
alternative hypothesis: true location shift is greater than 0
```

Consider the error rate of Q:

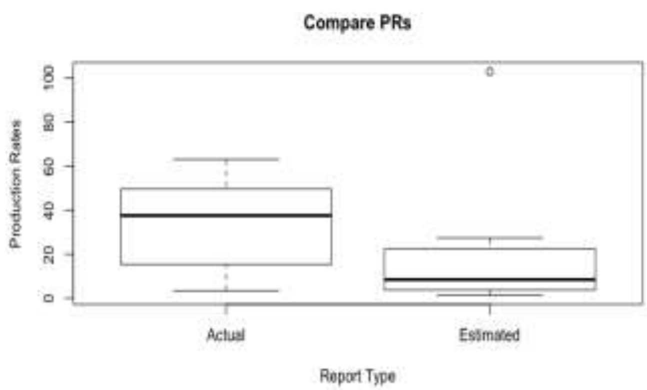
```
> describeBy(erQ)
   vars  n  mean   sd median trimmed  mad    min  max range  skew kurtosis
X1    1 48 -1.48 6.78  -0.02   -0.22 0.35 -45.64 0.77 46.41 -5.81    34.53
     se
X1 0.98
```

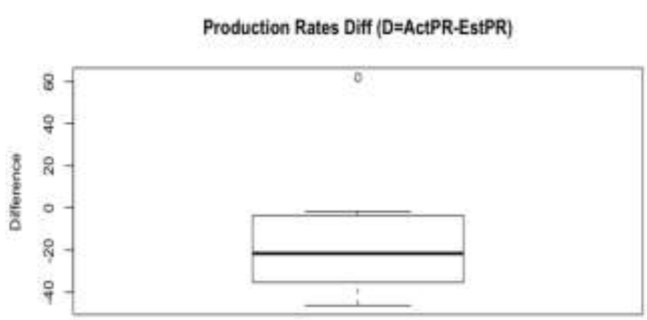


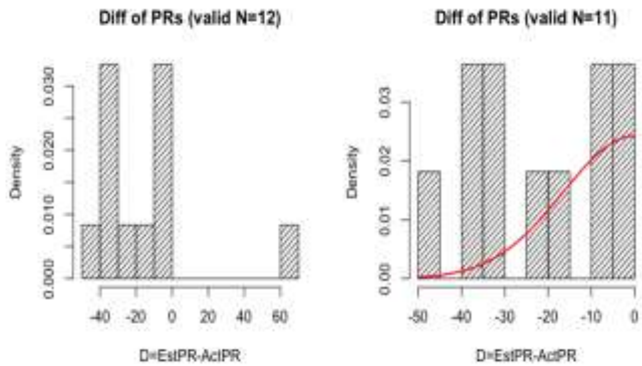

```
newER=erQ[erQ>-2.141364]

        One Sample t-test

data:  newER
t = -1.0937, df = 42, p-value = 0.1402
alternative hypothesis: true mean is less than 0


t = -1.0937, df = 42, p-value = 0.2803
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.2614665  0.0776721
sample estimates:
```

```
  mean of x
-0.09189718


        Wilcoxon signed rank test with continuity correction

data:  erQ
V = 412, p-value = 0.05444
alternative hypothesis: true location is less than 0


V = 412, p-value = 0.1089
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 -0.42815972  0.02959926
sample estimates:
(pseudo)median
     -0.124868
```

2) PRs: (N=48, valid n=12)



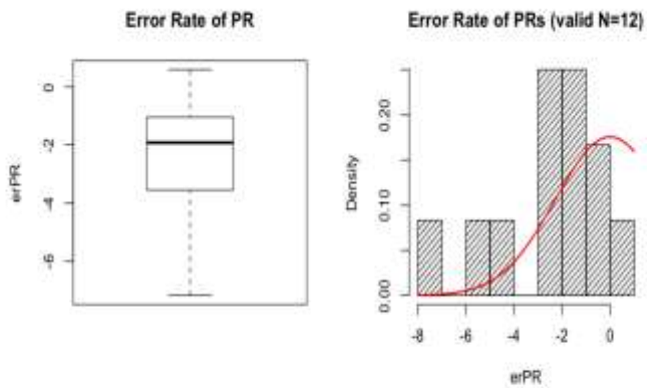





```
newEPR=EstPR[EstPR<103]
newAPR=ActPR[EstPR<103]

                Paired t-test

data:  newEPR and newAPR
t = -4.5211, df = 10, p-value = 0.0005532
alternative hypothesis: true difference in means is less than 0


t = -4.5211, df = 10, p-value = 0.001106
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -33.49129 -11.37821
sample estimates:
mean of the differences
              -22.43475

        Wilcoxon signed rank test

data:  EstPR and ActPR
V = 12, p-value = 0.01709
alternative hypothesis: true location shift is less than 0
```

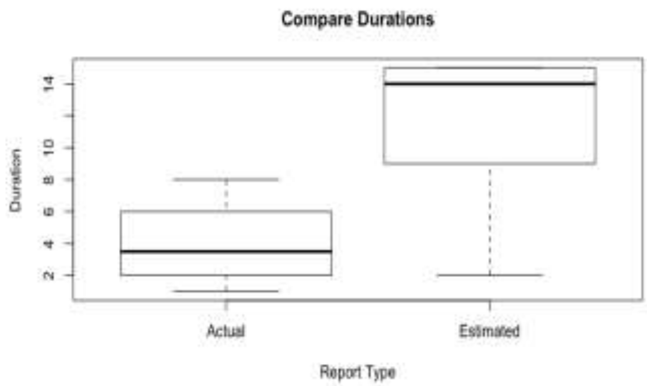
Consider the error rate of Q:

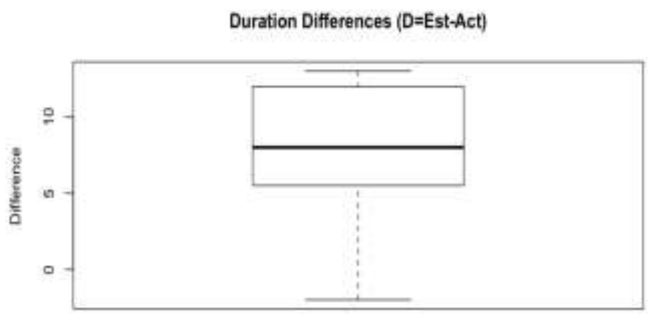
```
> describeBy(erPR)
   vars  n  mean   sd median trimmed  mad   min max range  skew kurtosis   se
X1    1 12 -2.45 2.27  -1.92   -2.29 1.41 -7.18 0.6  7.78 -0.73    -0.65 0.66
```

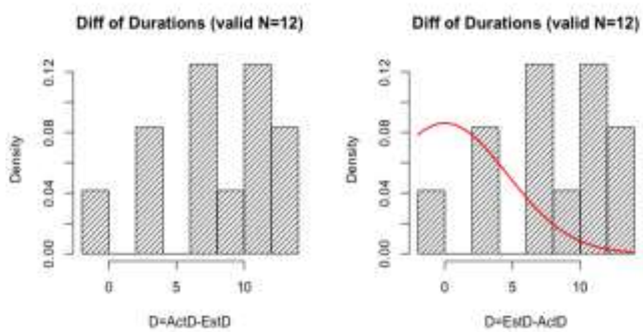



```
newER=erQ

        One Sample t-test

data:  newER
t = -3.7374, df = 11, p-value = 0.00164
alternative hypothesis: true mean is less than 0


t = -3.7374, df = 11, p-value = 0.003281
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -3.896944 -1.008241
sample estimates:
mean of x
-2.452592

        Wilcoxon signed rank test

data:  erPR
V = 2, p-value = 0.0007324
alternative hypothesis: true location is less than 0


V = 2, p-value = 0.001465
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 -4.0912500 -0.9862169
sample estimates:
(pseudo)median
     -2.129555
```

3) Durations: (N=48, valid n=12)





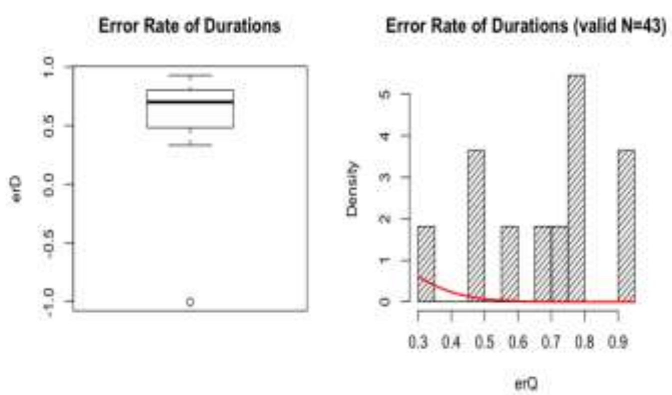



```
newAD=DurDays
newED=EstDur
              Paired t-test

data:  newED and newAD
t = 5.983, df = 11, p-value = 4.573e-05
alternative hypothesis: true difference in means is greater than 0
```

```
t = 5.983, df = 11, p-value = 9.147e-05
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
  5.057028 10.942972
sample estimates:
mean of the differences
                      8


        Wilcoxon signed rank test with continuity correction

data:  EstDur and DurDays
V = 77, p-value = 0.001596
alternative hypothesis: true location shift is greater than 0
```

Consider the error rate of Q:

```
> describeBy(erD)
   vars  n mean   sd median trimmed  mad min  max range  skew kurtosis   se
X1    1 12 0.54 0.52    0.7    0.66 0.22  -1 0.93  1.93 -2.09     3.57 0.15
```

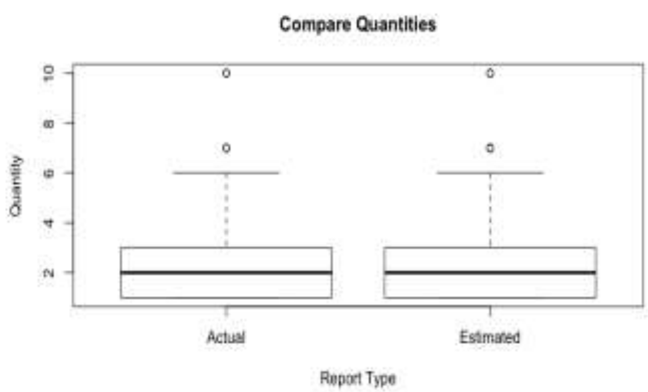


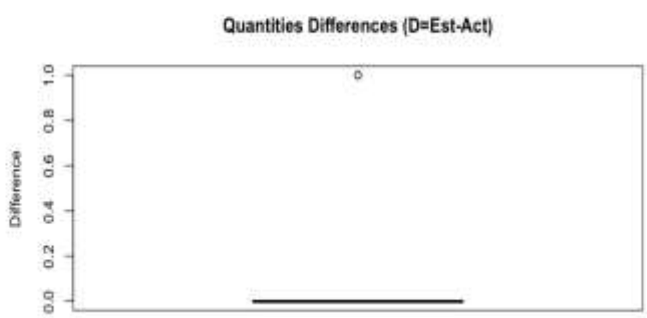

```
newER=erQ[erQ>-1]

        One Sample t-test

data:  newED
t = 11.824, df = 10, p-value = 1.678e-07
alternative hypothesis: true mean is greater than 0


t = 11.824, df = 10, p-value = 3.356e-07
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 0.5559122 0.8140733
sample estimates:
mean of x
0.6849928

        Wilcoxon signed rank test with continuity correction
```

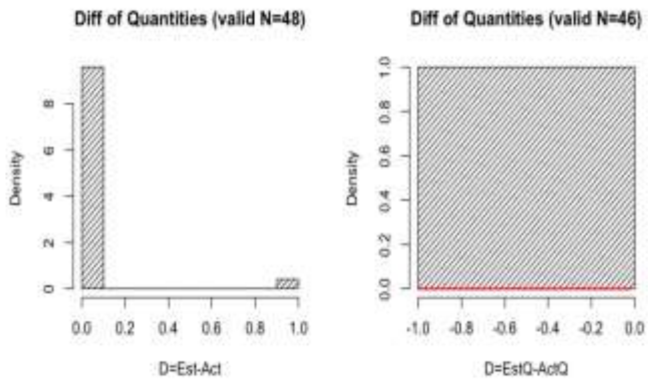
```
data:  erD
V = 66, p-value = 0.01874
alternative hypothesis: true location is greater than 0


V = 66, p-value = 0.03749
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 0.4000198 0.7999351
sample estimates:
(pseudo)median
     0.6499845
```

Item 0466_EA

1) Qty: (N=48)



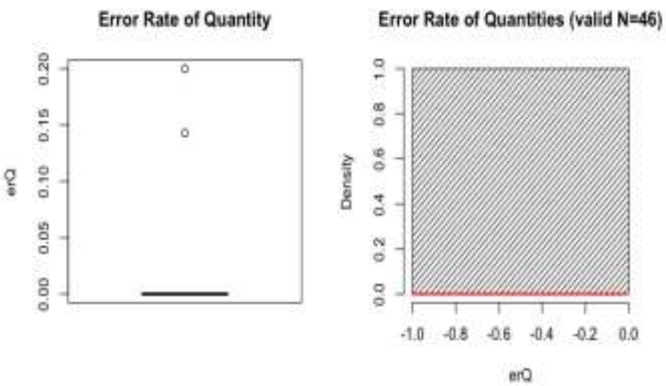





```
newAQ=ActQty[ActQty<7&EstQty<7]
newEQ=EstQty[ActQty<7&EstQty<7]

                Paired t-test

data:  newEQ and newAQ
t = 1, df = 42, p-value = 0.1615
alternative hypothesis: true difference in means is greater than 0

t = 1, df = 42, p-value = 0.323
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -0.02367632  0.07018795
sample estimates:
mean of the differences
             0.02325581


        Wilcoxon signed rank test with continuity correction

data:  EstQty and ActQty
V = 3, p-value = 0.1729
alternative hypothesis: true location shift is greater than 0
```

Consider the error rate of Q:

```
> describeBy(erQ)
   vars  n mean   sd median trimmed mad min max range skew kurtosis   se
X1    1 48 0.01 0.04      0       0   0   0 0.2   0.2 4.65     20.6 0.01
```




```
newER=erQ[erQ<0.1428571]

        One Sample t-test

data:  newER
t = NaN, df = 45, p-value = NA
alternative hypothesis: true mean is less than 0


t = NaN, df = 45, p-value = NA
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 NaN NaN
sample estimates:
mean of x
        0

        Wilcoxon signed rank test with continuity correction

data:  erQ
V = 3, p-value = 0.9632
alternative hypothesis: true location is less than 0
```

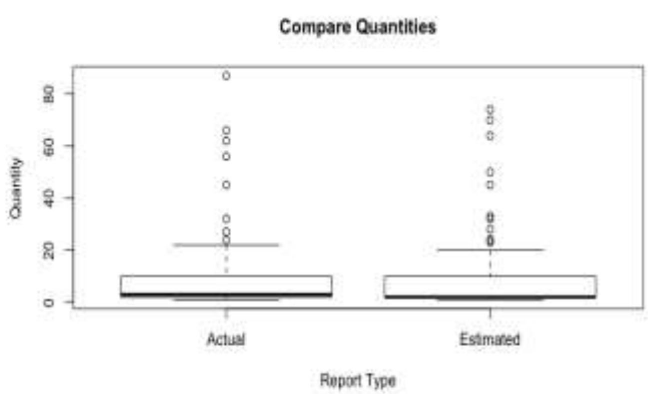
2) PRs: (N=48, valid n=9)
3) Durations: (N=48, valid n=9)

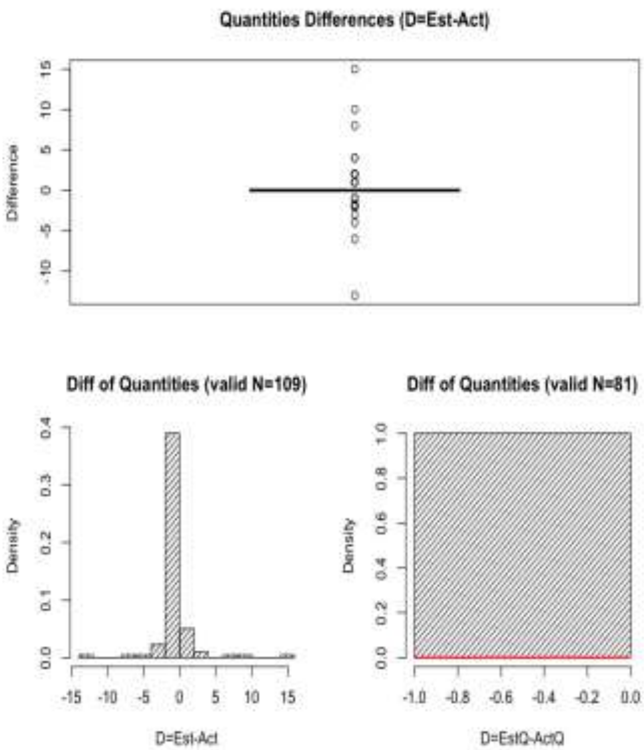
Quantity			Duration			Production Rate		
Actual	Estimated	erQ	Actual	Estimated	erD	Actual	Estimated	erPR
3	3	0.00	4	15	0.73	0.20	0.75	-2.75
1	1	0.00	2	15	0.87	0.07	0.5	-6.50
6	7	0.14	3	144	0.98	0.05	2	-40.14

1	1	0.00	1	144	0.99	0.01	1	-143.00
10	10	0.00	3	144	0.98	0.07	3.333333333	-47.00
2	2	0.00	1	144	0.99	0.01	2	-143.00
4	4	0.00	1	144	0.99	0.03	4	-143.00
5	5	0.00	3	144	0.98	0.03	1.666666667	-47.00
1	1	0.00	1	144	0.99	0.01	1	-143.00

Item 0467_EA

1) Qty: (N=110 valid N=109)

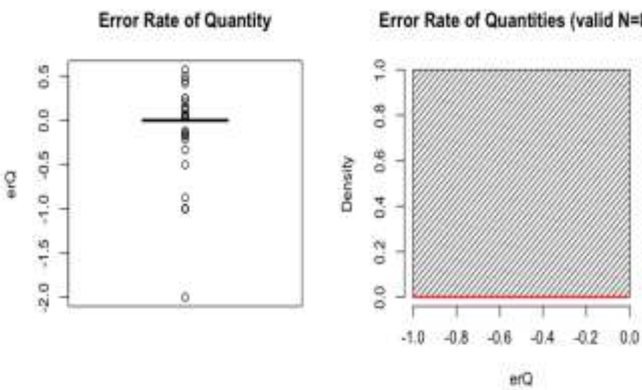





```
newAQ=ActQty[ActQty<24&EstQty<24]
newEQ=EstQty[ActQty<24&EstQty<24]

                Paired t-test

data:  newEQ and newAQ
t = 0.5066, df = 98, p-value = 0.3068
alternative hypothesis: true difference in means is greater than 0


t = 0.5066, df = 98, p-value = 0.6136
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -0.1841685  0.3104311
sample estimates:
mean of the differences
             0.06313131


        Wilcoxon signed rank test with continuity correction

data:  EstQty and ActQty
V = 232.5, p-value = 0.2528
alternative hypothesis: true location shift is greater than 0
```

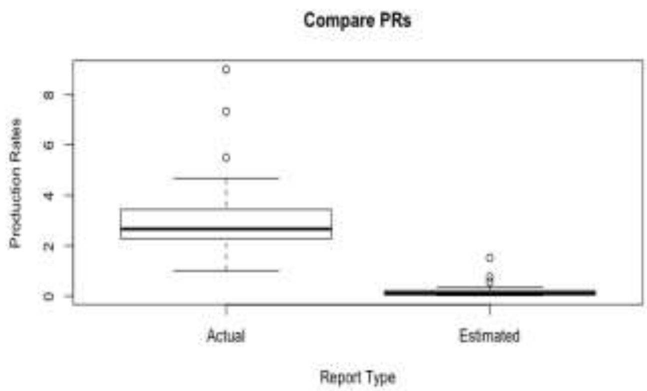
Consider the error rate of Q:

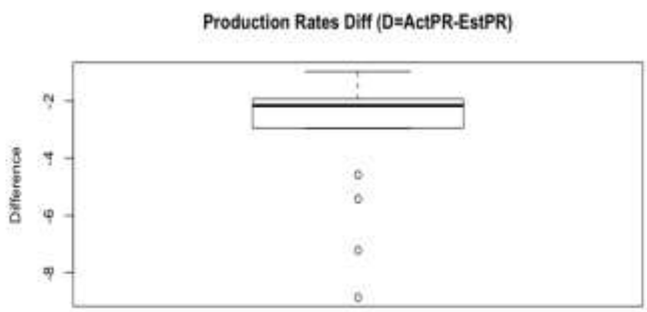
```
> describeBy(erQ)
   vars   n  mean   sd median trimmed mad min  max range  skew kurtosis   se
X1    1 109 -0.04 0.29      0       0   0  -2 0.57  2.57 -3.72    19.59 0.03
```

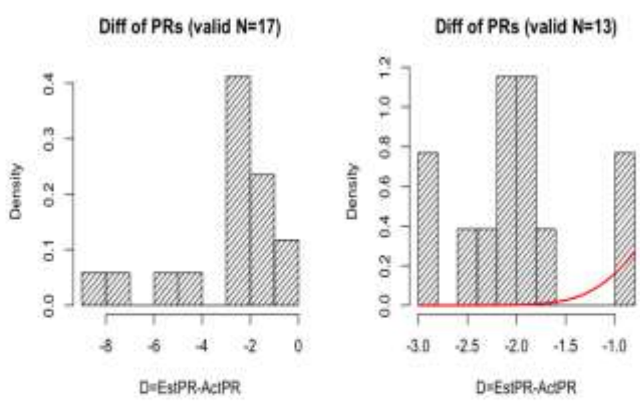



```
newER=erQ[erQ>-0.12&erQ<0.03125000]

                One Sample t-test

data:  newER
t = NaN, df = 80, p-value = NA
alternative hypothesis: true mean is less than 0


t = NaN, df = 80, p-value = NA
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 NaN NaN
sample estimates:
mean of x
        0


        Wilcoxon signed rank test with continuity correction

data:  erQ
V = 179.5, p-value = 0.3002
alternative hypothesis: true location is less than 0

V = 179.5, p-value = 0.6003
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 -0.3333699  0.1156267
sample estimates:
(pseudo)median
   -0.04401563
```

2) PRs: (N=110, valid n=17)





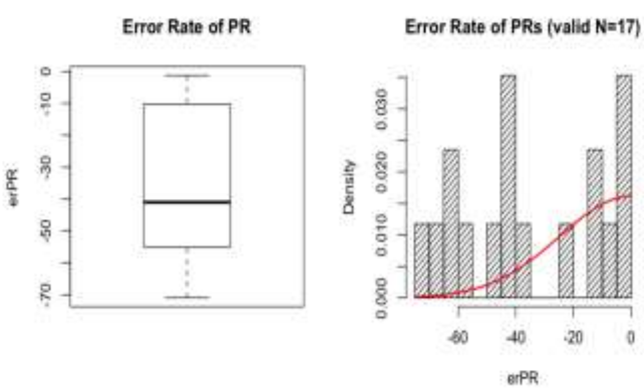



```
newEPR=EstPR[ActPR<5.5&EstPR<0.5714286]
newAPR=ActPR[ActPR<5.5&EstPR<0.5714286]
```

```
        Paired t-test

data:  newEPR and newAPR
t = -8.1071, df = 11, p-value = 2.877e-06
alternative hypothesis: true difference in means is less than 0


t = -8.1071, df = 11, p-value = 5.755e-06
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -2.853156 -1.634745
sample estimates:
mean of the differences
              -2.243951

        Wilcoxon signed rank test

data:  EstPR and ActPR
V = 0, p-value = 7.629e-06
alternative hypothesis: true location shift is less than 0
```

Consider the error rate of PR:

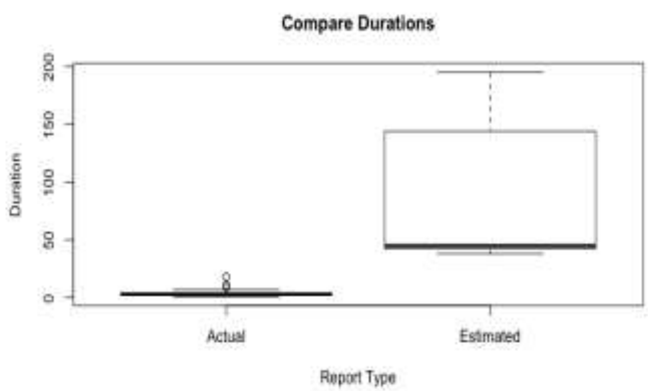
```
> describeBy(erPR)
   vars  n  mean    sd median trimmed   mad min   max range skew kurtosis   se
X1    1 17 -34.3 24.69    -41  -34.06 31.13 -71 -1.26 69.74 0.04    -1.65 5.99
```

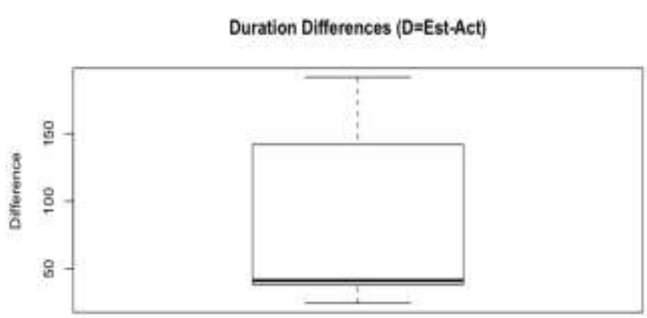


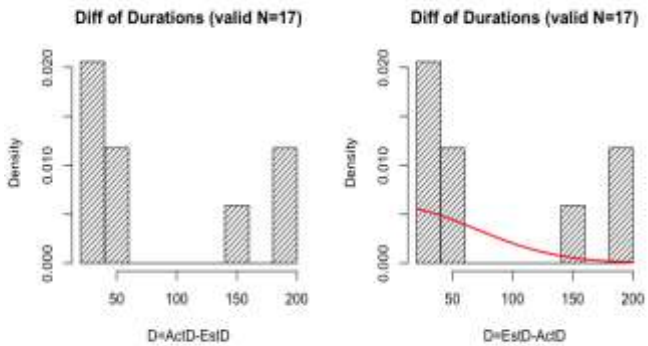

```
newER=erPR

                One Sample t-test

data:  newER
t = -5.7279, df = 16, p-value = 1.557e-05
alternative hypothesis: true mean is less than 0


t = -5.7279, df = 16, p-value = 3.113e-05
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -47.00125 -21.60846
sample estimates:
```

```
mean of x
-34.30486


        Wilcoxon signed rank test

data:  erPR
V = 0, p-value = 7.629e-06
alternative hypothesis: true location is less than 0


V = 0, p-value = 1.526e-05
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 -49.50000 -21.90909
sample estimates:
(pseudo)median
     -33.88021
```

3) Durations: (N=110, valid n=17)



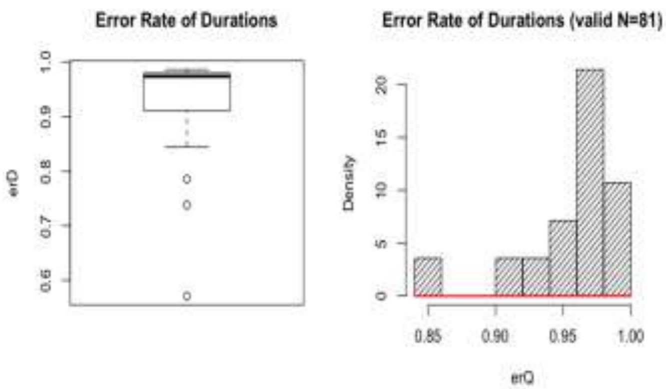





```
newAD=DurDays
newED=EstDur

        Paired t-test

data:  newED and newAD
t = 5.1026, df = 16, p-value = 5.323e-05
alternative hypothesis: true difference in means is greater than 0


t = 5.1026, df = 16, p-value = 0.0001065
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
  50.20202 121.56269
sample estimates:
mean of the differences
               85.88235


        Wilcoxon signed rank test with continuity correction

data:  EstDur and DurDays
V = 153, p-value = 0.0001596
alternative hypothesis: true location shift is greater than 0
```

Consider the error rate of erD:

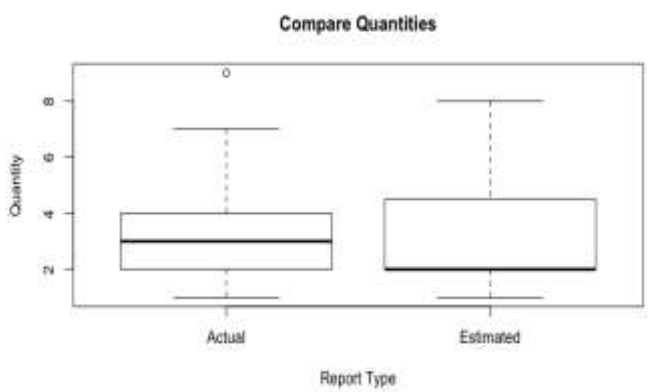
```
> describeBy(erD)
   vars  n mean   sd median trimmed  mad  min  max range skew kurtosis   se
X1    1 17 0.91 0.12   0.97    0.93 0.02 0.57 0.99  0.41 -1.7     1.97 0.03
```

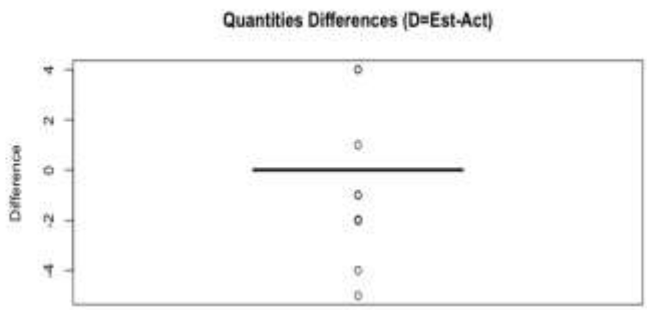


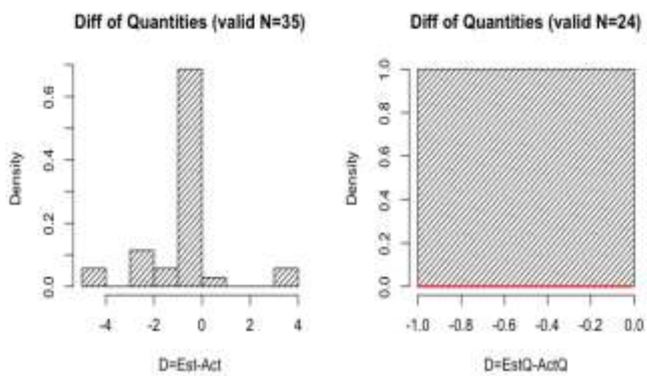

```
newED=erD  newED=erD[erD>0.7857143]

        One Sample t-test

data:  newED
t = 90.179, df = 13, p-value < 2.2e-16
alternative hypothesis: true mean is greater than 0


t = 90.179, df = 13, p-value < 2.2e-16
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 0.9351332 0.9810380
sample estimates:
mean of x
0.9580856

        Wilcoxon signed rank test with continuity correction

data:  erD
V = 153, p-value = 0.0001599
alternative hypothesis: true location is greater than 0


V = 153, p-value = 0.0003198
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 0.8588031 0.9777909
sample estimates:
(pseudo)median
     0.9478654
```

Item 0545_EA

1) Qty: (N=35)



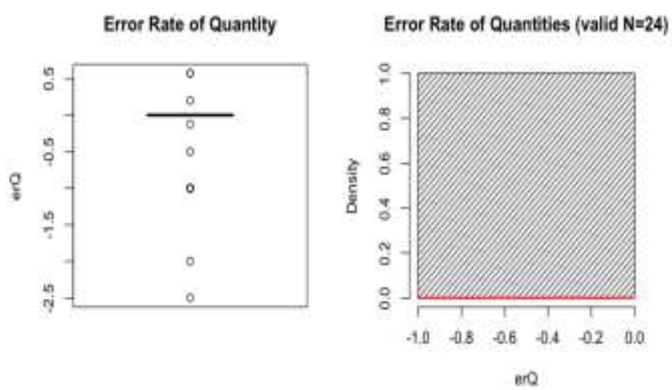





```
newAQ=ActQty[ActQty<9]
newEQ=EstQty[ActQty<9]

                Paired t-test

data:  newEQ and newAQ
t = -0.94189, df = 33, p-value = 0.1765
alternative hypothesis: true difference in means is less than 0

t = -0.94189, df = 33, p-value = 0.3531
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -0.8364802  0.3070684
sample estimates:
mean of the differences
             -0.2647059


        Wilcoxon signed rank test with continuity correction

data:  EstQty and ActQty
V = 20, p-value = 0.1311
alternative hypothesis: true location shift is less than 0
```

Consider the error rate of Q:

```
> describeBy(erQ)
   vars  n  mean   sd median trimmed mad  min  max range  skew kurtosis   se
X1    1 35 -0.22 0.63      0   -0.12   0 -2.5 0.57  3.07 -2.06     4.14 0.11
```



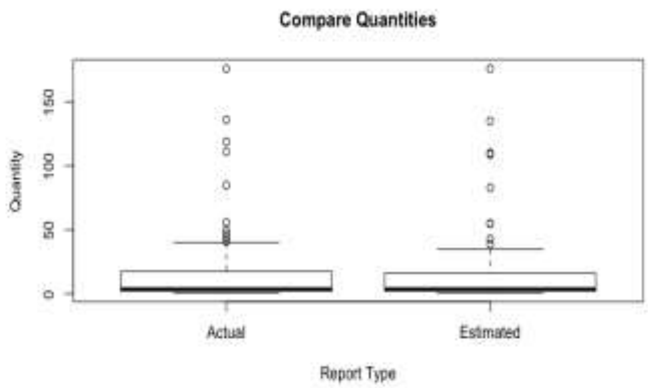

```
newER=erQ[erQ>-0.125&erQ<0.2]

                One Sample t-test

data:  newER
t = NaN, df = 23, p-value = NA
alternative hypothesis: true mean is less than 0


t = NaN, df = 23, p-value = NA
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 NaN NaN
sample estimates:
mean of x
        0

        Wilcoxon signed rank test with continuity correction

data:  erQ
V = 11, p-value = 0.0273
alternative hypothesis: true location is less than 0


V = 11, p-value = 0.0546
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 -1.49998537  0.03566383
sample estimates:
(pseudo)median
    -0.7337307
```

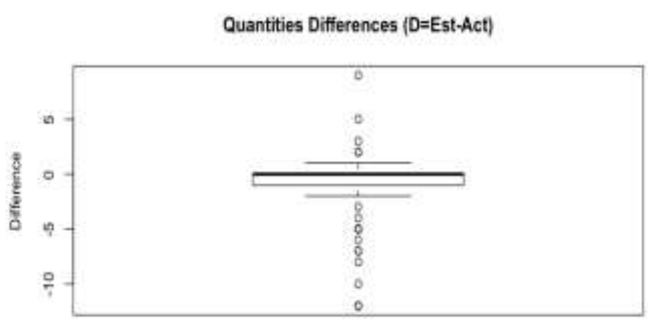
2) PRs: (N=35, valid n=0)

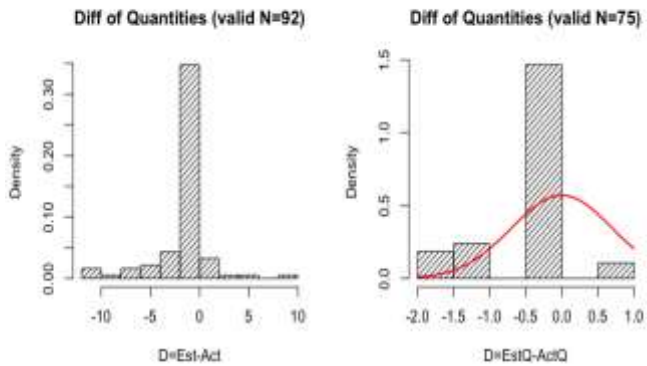
3) Durations: (N=35, valid n=0)

Item 0644_EA

1) Qty: (N=92)



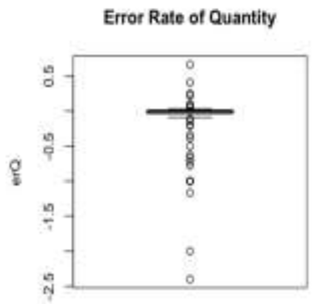


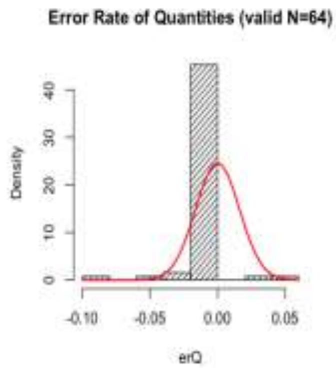



```
newAQ=ActQty[EstQty<41&ActQty<43]
newEQ=EstQty[EstQty<41&ActQty<43]

                Paired t-test

data:  newEQ and newAQ
t = -2.5448, df = 82, p-value = 0.006405
alternative hypothesis: true difference in means is less than 0


t = -2.5448, df = 82, p-value = 0.01281
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -1.2665304 -0.1551563
sample estimates:
mean of the differences
             -0.7108434


        Wilcoxon signed rank test with continuity correction

data:  EstQty and ActQty
V = 149, p-value = 0.001073
alternative hypothesis: true location shift is less than 0
```

Consider the error rate of Q:

```
> describeBy(erQ)
   vars  n  mean   sd median trimmed mad  min  max range  skew kurtosis   se
X1    1 92 -0.17 0.46      0   -0.08   0 -2.4 0.67  3.07 -2.49     7.49 0.05
```





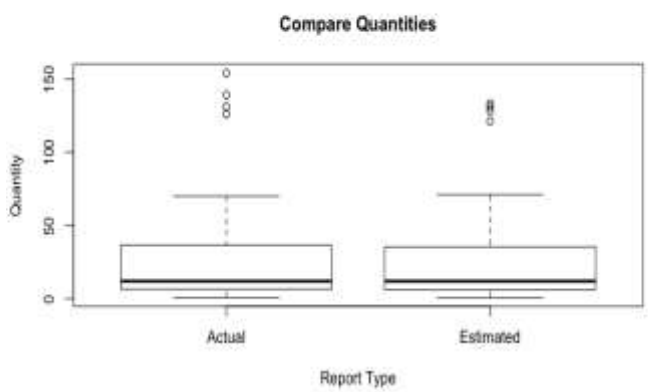

```
newER=erQ[erQ>-0.11111111&erQ<0.05882353]

        One Sample t-test

data:  newER
t = -1.0596, df = 63, p-value = 0.1467
alternative hypothesis: true mean is less than 0


t = -1.0596, df = 63, p-value = 0.2934
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.006207751  0.001905796
sample estimates:
   mean of x
-0.002150977

        Wilcoxon signed rank test with continuity correction

data:  erQ
V = 125.5, p-value = 0.0003312
alternative hypothesis: true location is less than 0

V = 125.5, p-value = 0.0006623
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 -0.5554754 -0.1420101
sample estimates:
(pseudo)median
    -0.3838841
```

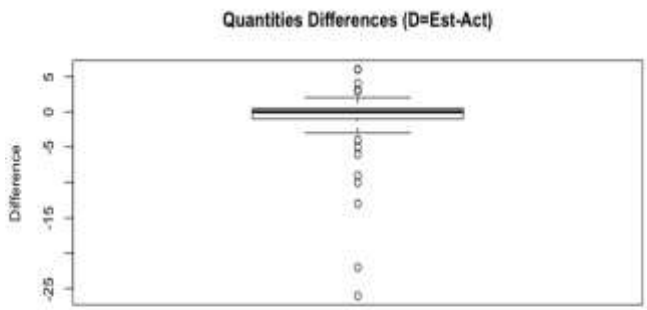
2) PRs: (N=92, valid n=4)
3) Durations: (N=92, valid n=4)

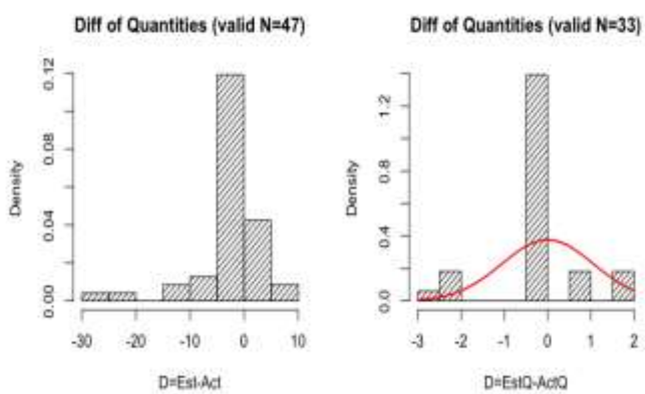
Quantity			Duration			Production Rate		
Actual	Estimated	erQ	Actual	Estimated	erD	Actual	Estimated	erPR
85	83	-0.02	1	112	0.99	85	0.74	-113.70
22	22	0.00	1	112	0.99	22	0.20	-111.00
4	4	0.00	1	112	0.99	4	0.04	-111.00
111	110	-0.01	1	112	0.99	111	0.98	-112.02

Item 0658_EA

1) Qty: (N=47)





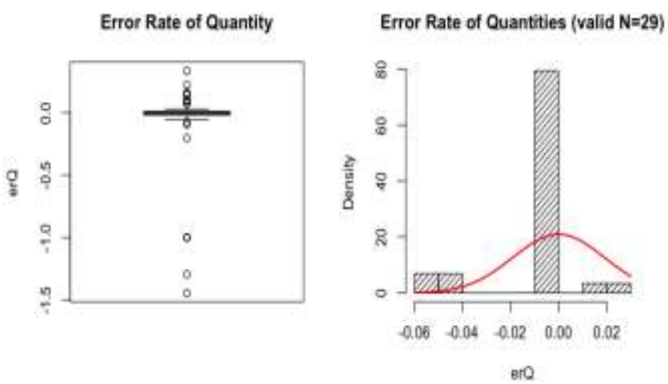



```
newAQ=ActQty[EstQty<126&ActQty<121]
newEQ=EstQty[EstQty<126&ActQty<121]

                Paired t-test

data:  newEQ and newAQ
t = -1.0441, df = 42, p-value = 0.1512
alternative hypothesis: true difference in means is less than 0


t = -1.0441, df = 42, p-value = 0.3024
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -2.2507532  0.7158695
sample estimates:
mean of the differences
             -0.7674419


        Wilcoxon signed rank test with continuity correction

data:  EstQty and ActQty
V = 110.5, p-value = 0.1319
```

```
alternative hypothesis: true location shift is less than 0
```

Consider the error rate of Q:

```
> describeBy(erQ)
   vars  n mean   sd median trimmed  mad   min  max range  skew kurtosis   se
X1    1 47 -0.1 0.38      0   -0.02 0.02 -1.44 0.33  1.78 -2.37     4.52 0.06
```




```
newER=erQ[erQ>-0.075&erQ<0.07142857]

        One Sample t-test

data:  newER
t = -1.5503, df = 28, p-value = 0.06615
alternative hypothesis: true mean is less than 0


t = -1.5503, df = 28, p-value = 0.1323
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.012720110  0.001760635
sample estimates:
   mean of x
-0.005479737

        Wilcoxon signed rank test with continuity correction

data:  erQ
V = 135, p-value = 0.3393
alternative hypothesis: true location is less than 0

V = 135, p-value = 0.6786
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 -0.46435462  0.05856342
sample estimates:
(pseudo)median
   -0.02560966
```

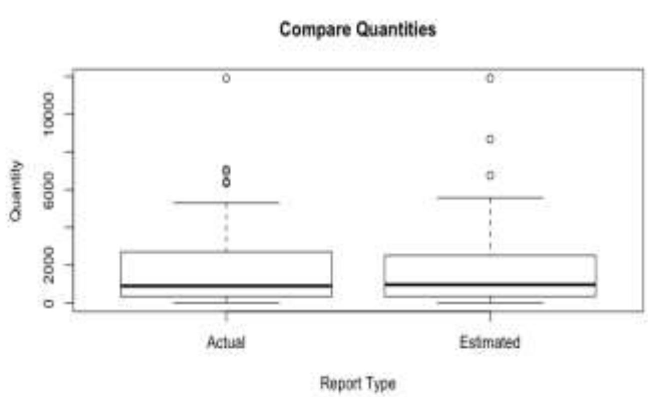
2) PRs: (N=47, valid n=4)

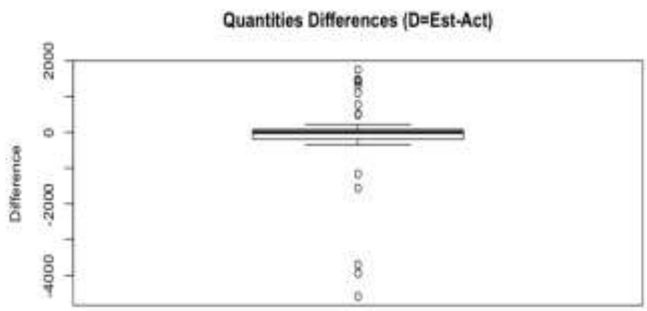
3) Durations: (N=47, valid n=4)

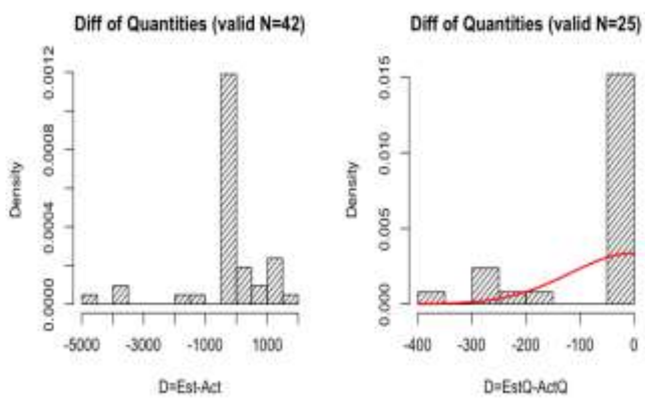
Quantity			Duration			Production Rate		
Actual	Estimated	erQ	Actual	Estimated	erD	Actual	Estimated	erPR
22	9	-1.44	2	2	0.00	11	4.50	-1.44
5	5	0.00	2	2	0.00	2.5	2.50	0.00
12	12	0.00	1	1	0.00	12	12.00	0.00
2	2	0.00	1	1	0.00	2	2.00	0.00

Item 0662_EA

1) Qty: (N=42)



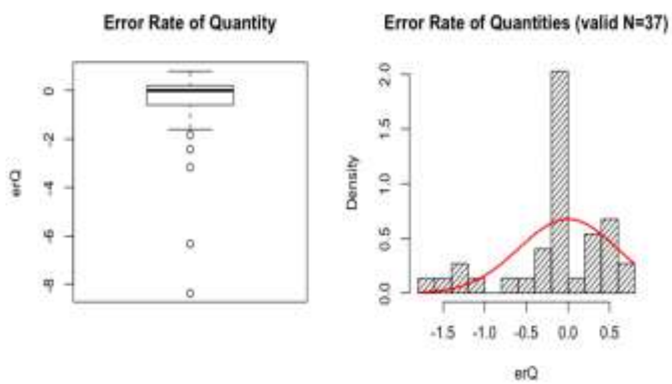





```
newAQ=ActQty[EstQty<6342&ActQty<6757]
newEQ=EstQty[EstQty<6342&ActQty<6757]

                Paired t-test

data:  newEQ and newAQ
t = -0.70434, df = 37, p-value = 0.2428
alternative hypothesis: true difference in means is less than 0


t = -0.70434, df = 37, p-value = 0.4856
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -466.5334  225.8491
sample estimates:
mean of the differences
              -120.3421


        Wilcoxon signed rank test with continuity correction

data:  EstQty and ActQty
V = 211, p-value = 0.5602
alternative hypothesis: true location shift is greater than 0
```

Consider the error rate of Q:

```
> describeBy(erQ)
   vars  n  mean   sd median trimmed  mad   min  max range  skew kurtosis   se
X1    1 42 -0.63 1.75      0   -0.26 0.39 -8.36 0.79  9.15 -2.91     8.93 0.27
```




```
newER=erQ[erQ>-1.8308]

        One Sample t-test

data:  newER
t = -1.2367, df = 36, p-value = 0.1121
alternative hypothesis: true mean is less than 0


t = -1.2367, df = 36, p-value = 0.2242
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.31644966  0.07670322
sample estimates:
 mean of x
-0.1198732


        Wilcoxon signed rank test with continuity correction

data:  erQ
V = 128, p-value = 0.02714
alternative hypothesis: true location is less than 0

V = 128, p-value = 0.05429
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 -1.08872202  0.01042979
sample estimates:
(pseudo)median
    -0.5122785
```

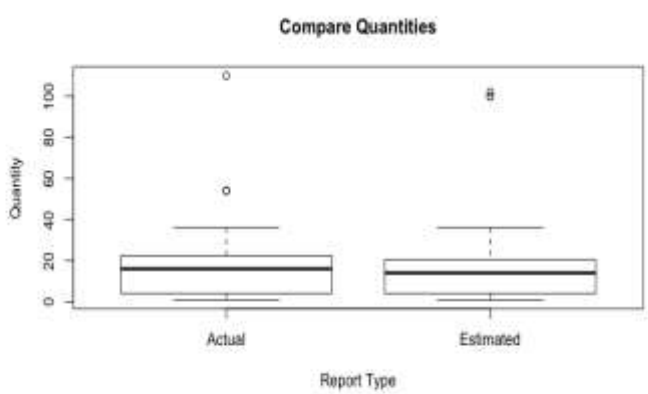
2) PRs: (N=42, valid n=1)

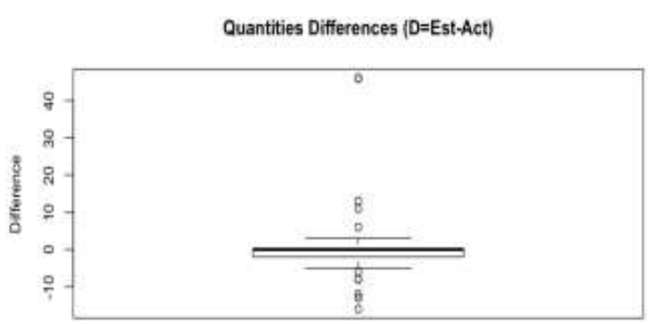
3) Durations: (N=42, valid n=1)

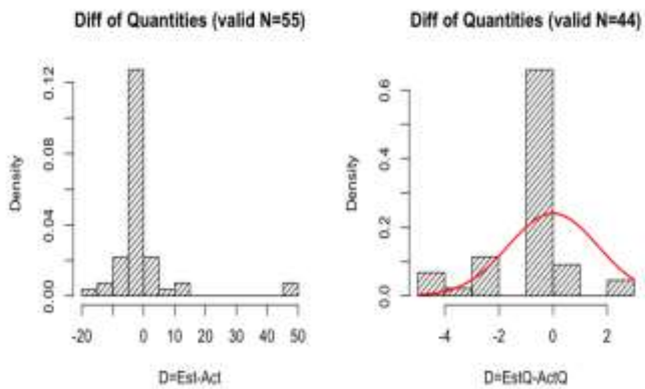
Quantity			Duration			Production Rate		
Actual	Estimated	erQ	Actual	Estimated	erD	Actual	Estimated	erPR
852	1072	0.21	1	2	0.50	85.2	536	-0.59

Item 0666_EA

1) Qty: (N=55)



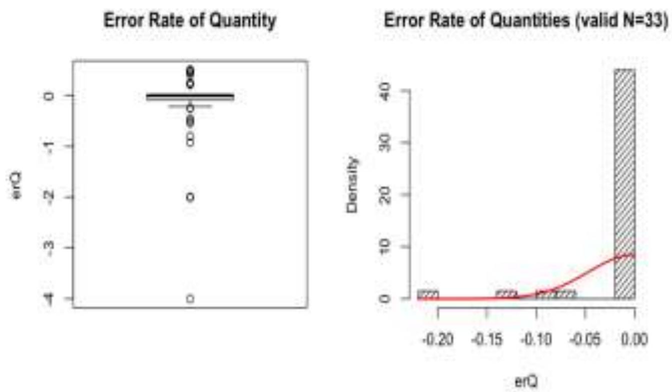





```
newAQ=ActQty[EstQty<54&ActQty<54]
newEQ=EstQty[EstQty<54&ActQty<54]

                Paired t-test

data:  newEQ and newAQ
t = -1.2926, df = 51, p-value = 0.101
alternative hypothesis: true difference in means is less than 0


t = -1.2926, df = 51, p-value = 0.202
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -2.1112935  0.4574473
sample estimates:
mean of the differences
             -0.8269231

        Wilcoxon signed rank test with continuity correction

data:  EstQty and ActQty
V = 142, p-value = 0.8065
alternative hypothesis: true location shift is greater than 0
0
```

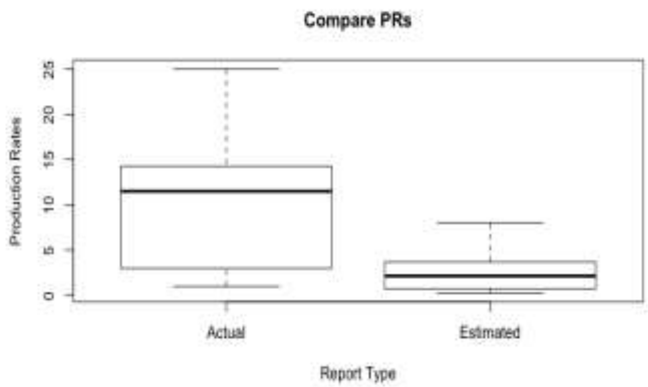
Consider the error rate of Q:

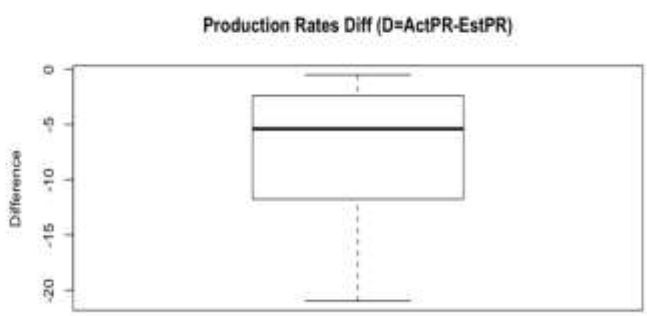
```
> describeBy(erQ)
   vars  n  mean   sd median trimmed mad min max range skew kurtosis  se
X1    1 55 -0.18 0.75      0   -0.03   0  -4 0.5   4.5 -3.1    11.18 0.1
```

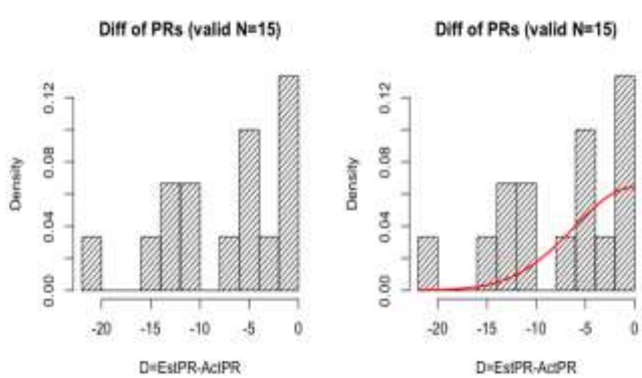



```
newER=erQ[erQ<0.2142857&erQ>-0.25]

                One Sample t-test

data:  newER
t = -1.9308, df = 32, p-value = 0.0312
alternative hypothesis: true mean is less than 0


t = -1.9308, df = 32, p-value = 0.06241
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.0324615456  0.0008683023
sample estimates:
  mean of x
-0.01579662

        Wilcoxon signed rank test with continuity correction

data:  erQ
V = 132, p-value = 0.1372
alternative hypothesis: true location is less than 0


V = 132, p-value = 0.2744
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 -0.7499657  0.1228374
sample estimates:
(pseudo)median
    -0.1641739
```

2) PRs: (N=55, valid n=15)





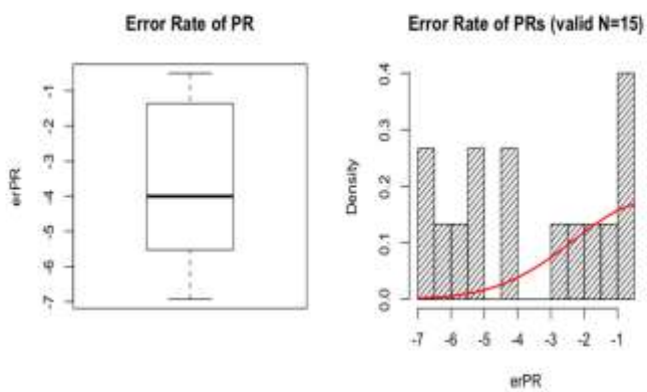



```
        Paired t-test

data:  EstPR and ActPR
t = -4.7298, df = 14, p-value = 0.0001613
alternative hypothesis: true difference in means is less than 0
```

```
t = -4.7298, df = 14, p-value = 0.0003225
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -11.01632  -4.14241
sample estimates:
mean of the differences
              -7.579365

        Wilcoxon signed rank test with continuity correction

data:  EstPR and ActPR
V = 0, p-value = 0.0003624
alternative hypothesis: true location shift is less than 0
```

Consider the error rate of PR:

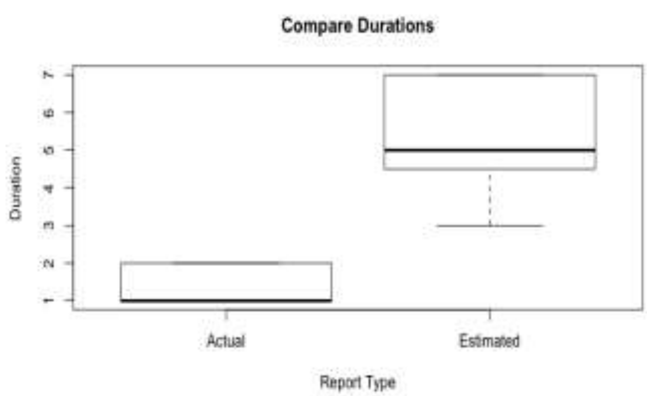
```
> describeBy(erPR)
   vars  n  mean   sd median trimmed  mad   min  max range  skew kurtosis  se
X1    1 15 -3.54 2.32     -4   -3.51 2.97 -6.93 -0.5  6.43 -0.03    -1.73 0.6
```

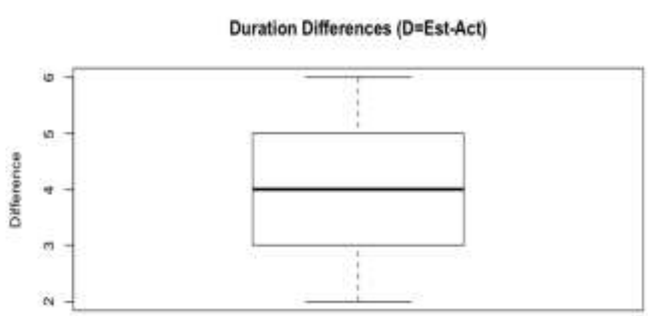


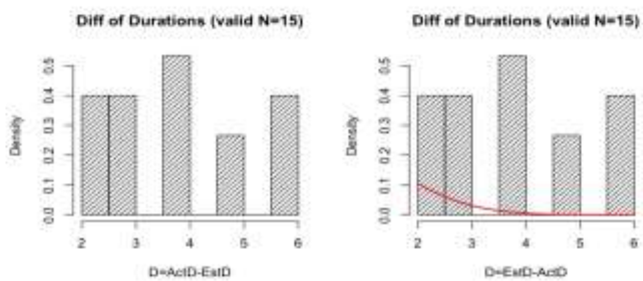

```
newER=erPR

                One Sample t-test

data:  newER
t = -5.912, df = 14, p-value = 1.894e-05
alternative hypothesis: true mean is less than 0


t = -5.912, df = 14, p-value = 3.788e-05
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -4.820687 -2.254075
sample estimates:
mean of x
-3.537381
```

```
        Wilcoxon signed rank test with continuity correction

data:  erPR
V = 0, p-value = 0.0003624
alternative hypothesis: true location is less than 0


V = 0, p-value = 0.0007247
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 -5.249989 -2.000028
sample estimates:
(pseudo)median
     -3.512917
```

3) Durations: (N=55, valid n=15)



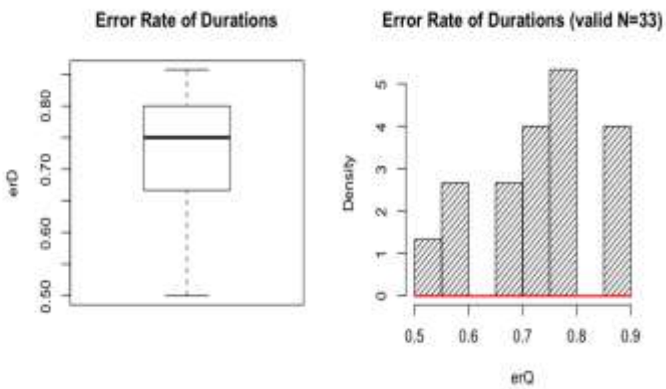





```
newAD=DurDays
newED=EstDur

        Paired t-test

data:  newED and newAD
t = 10.597, df = 14, p-value = 2.268e-08
alternative hypothesis: true difference in means is greater than 0


t = 10.597, df = 14, p-value = 4.535e-08
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 3.137222 4.729444
sample estimates:
mean of the differences
               3.933333

        Wilcoxon signed rank test with continuity correction

data:  EstDur and DurDays
V = 120, p-value = 0.000343
alternative hypothesis: true location shift is greater than 0
```

Consider the error rate of erD:

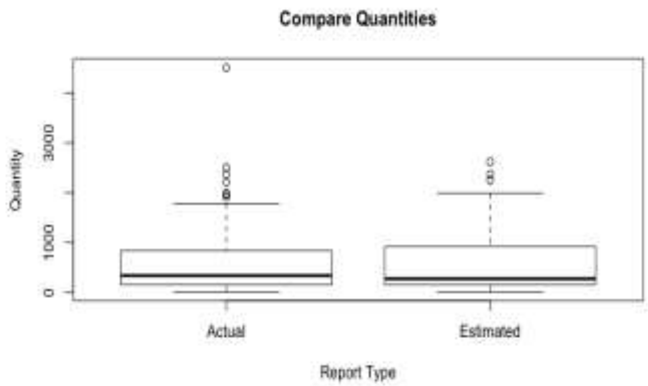
```
> describeBy(erD)
   vars  n mean   sd median trimmed  mad min  max range  skew kurtosis   se
X1    1 15 0.73 0.11   0.75    0.74 0.12 0.5 0.86  0.36 -0.56    -0.87 0.03
```

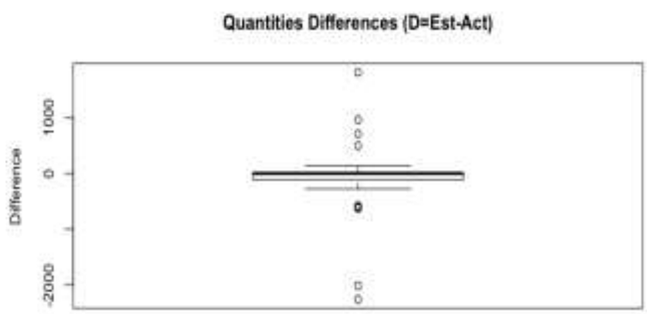


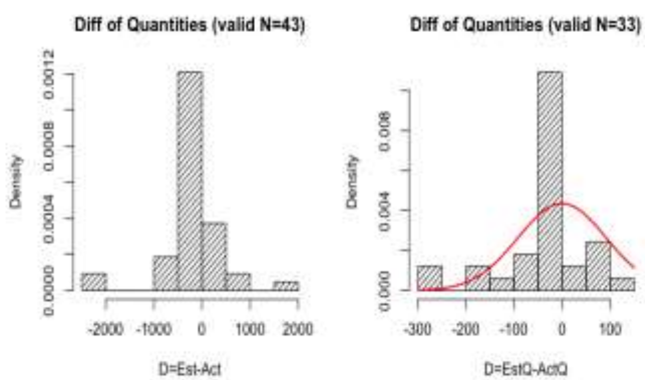

```
newED=erD

        One Sample t-test

data:  newED
t = 26.231, df = 14, p-value = 1.325e-13
alternative hypothesis: true mean is greater than 0


t = 26.231, df = 14, p-value = 2.65e-13
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 0.6723512 0.7920932
sample estimates:
mean of x
0.7322222

        Wilcoxon signed rank test with continuity correction

data:  erD
V = 120, p-value = 0.0003482
alternative hypothesis: true location is greater than 0


V = 120, p-value = 0.0006963
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 0.6666906 0.8000359
sample estimates:
(pseudo)median
     0.7333766
```

Item 0672_EA

1) Qty: (N=43)





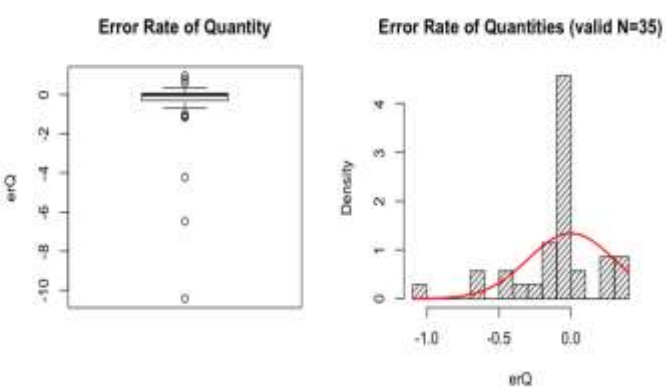



```
newAQ=ActQty[EstQty<1911&ActQty<2250]
newEQ=EstQty[EstQty<1911&ActQty<2250]

            Paired t-test
```

```
data:  newEQ and newAQ
t = -0.4209, df = 37, p-value = 0.3381
alternative hypothesis: true difference in means is less than 0


t = -0.4209, df = 37, p-value = 0.6763
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -204.5591  134.1907
sample estimates:
mean of the differences
              -35.18421


        Wilcoxon signed rank test with continuity correction

data:  EstQty and ActQty
V = 159.5, p-value = 0.1069
alternative hypothesis: true location shift is less than 0

0
```

Consider the error rate of Q:

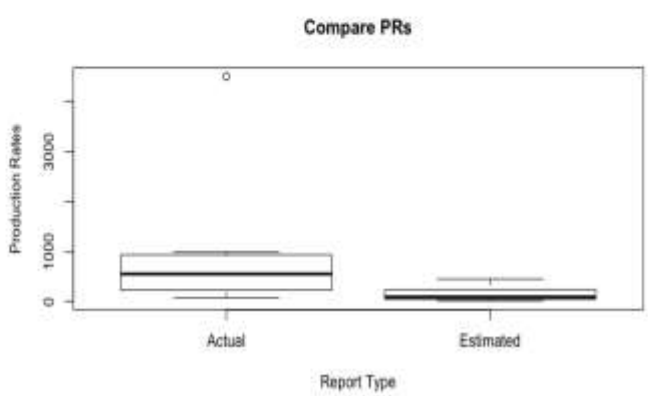
```
> describeBy(erQ)
   vars  n  mean   sd median trimmed  mad    min  max range  skew kurtosis  se
X1    1 43 -0.56 1.97      0   -0.12 0.28 -10.44 0.96  11.4 -3.67    13.87 0.3
```

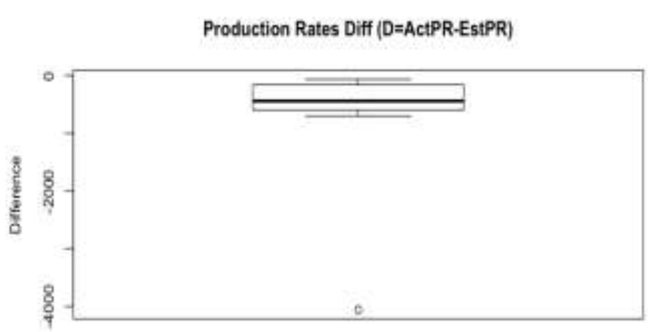


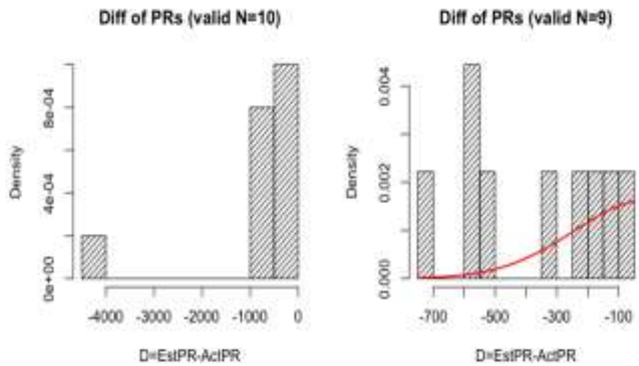

```
newER=erQ[erQ<0.5802171&erQ>-1.0035556]

                One Sample t-test

data:  newER
t = -1.6216, df = 34, p-value = 0.05706
alternative hypothesis: true mean is less than 0


t = -1.6216, df = 34, p-value = 0.1141
alternative hypothesis: true mean is not equal to 0
```

```
95 percent confidence interval:
 -0.1836166  0.0206361
sample estimates:
  mean of x
-0.08149027


        Wilcoxon signed rank test with continuity correction

data:  erQ
V = 142, p-value = 0.05243
alternative hypothesis: true location is less than 0

V = 142, p-value = 0.1049
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 -0.58191382  0.05479067
sample estimates:
(pseudo)median
    -0.2035111
```

2) PRs: (N=43, valid n=10)



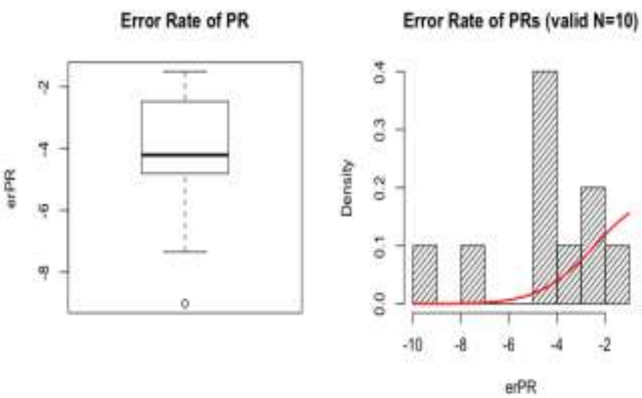





```
newEPR=EstPR[ActPR<4508]
newAPR=ActPR[ActPR<4508]

        Paired t-test

data:  newEPR and newAPR
t = -4.5332, df = 8, p-value = 0.0009581
alternative hypothesis: true difference in means is less than 0


t = -4.5332, df = 8, p-value = 0.001916
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -552.8760 -180.0462
sample estimates:
mean of the differences
              -366.4611

        Wilcoxon signed rank test

data:  EstPR and ActPR
V = 0, p-value = 0.0009766
alternative hypothesis: true location shift is less than 0
```

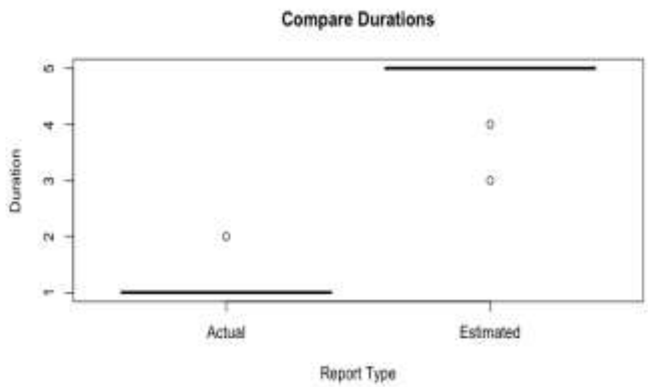
Consider the error rate of PR:

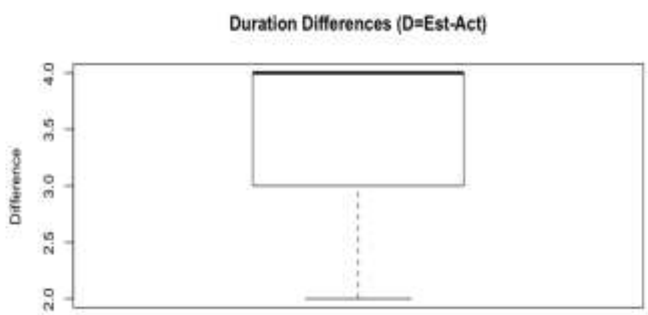
```
> describeBy(erPR)
   vars  n  mean   sd median trimmed  mad   min  max range  skew kurtosis   se
X1    1 10 -4.35 2.34  -4.21   -4.12 2.18 -9.02 -1.5  7.52 -0.68     -0.8 0.74
```

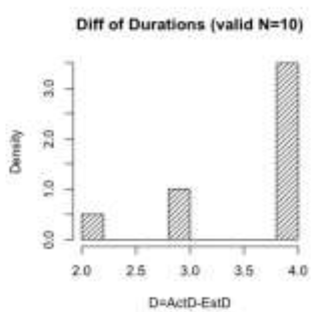


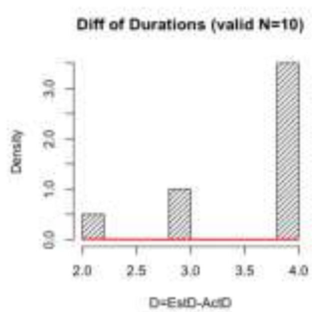

```
newER=erPR[erPR>-9.017778]

                One Sample t-test

data:  newER
t = -5.8848, df = 9, p-value = 0.0001167
alternative hypothesis: true mean is less than 0


t = -5.8848, df = 9, p-value = 0.0002334
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -6.021255 -2.677407
sample estimates:
mean of x
-4.349331

        Wilcoxon signed rank test

data:  erPR
V = 0, p-value = 0.0009766
alternative hypothesis: true location is less than 0


V = 0, p-value = 0.001953
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 -6.030528 -2.738462
sample estimates:
(pseudo)median
     -4.205479
```

3) Durations: (N=43, valid n=10)







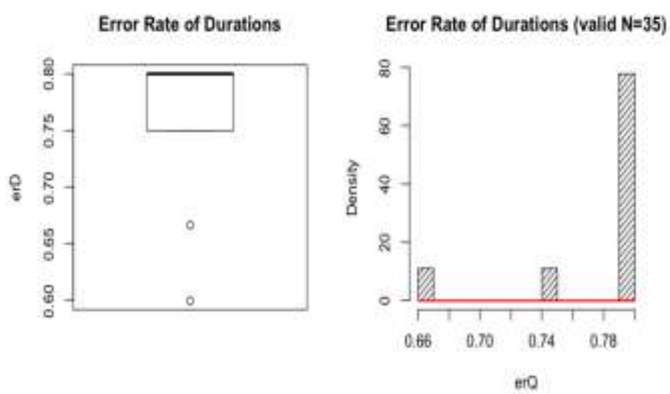



```
newAD=DurDays[DurDays<2&EstDur>3]
newED=EstDur[DurDays<2&EstDur>3]
        Paired t-test

data:  newED and newAD
t = 31, df = 7, p-value = 4.693e-09
alternative hypothesis: true difference in means is greater than 0
95 percent confidence interval:
 3.638178      Inf
sample estimates:
```

```
mean of the differences
                  3.875


t = 31, df = 7, p-value = 9.385e-09
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 3.579422 4.170578
sample estimates:
mean of the differences
                  3.875

        Wilcoxon signed rank test with continuity correction

data:  EstDur and DurDays
V = 55, p-value = 0.002118
alternative hypothesis: true location shift is greater than 0
```

Consider the error rate of erD:

```
> describeBy(erD)
   vars  n mean   sd median trimmed mad min max range skew kurtosis   se
X1    1 10 0.76 0.07    0.8    0.78   0 0.6 0.8   0.2 -1.3     0.04 0.02
```

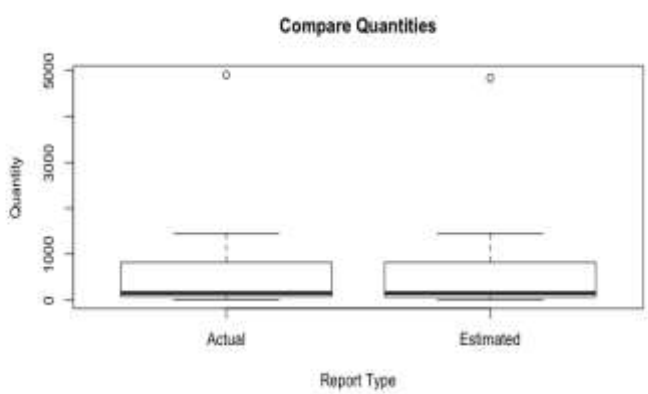


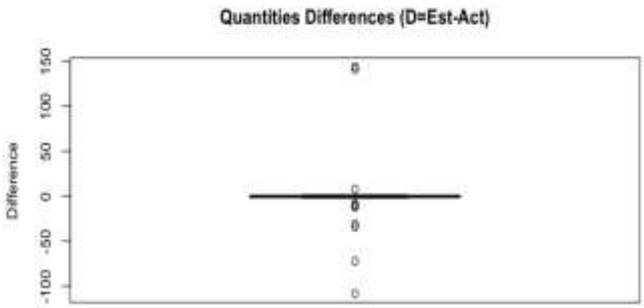

```
newED=erD[erD>0.6]

        One Sample t-test

data:  newED
t = 51.433, df = 8, p-value = 1.131e-11
alternative hypothesis: true mean is greater than 0


t = 51.433, df = 8, p-value = 2.262e-11
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 0.7446751 0.8145842
sample estimates:
```

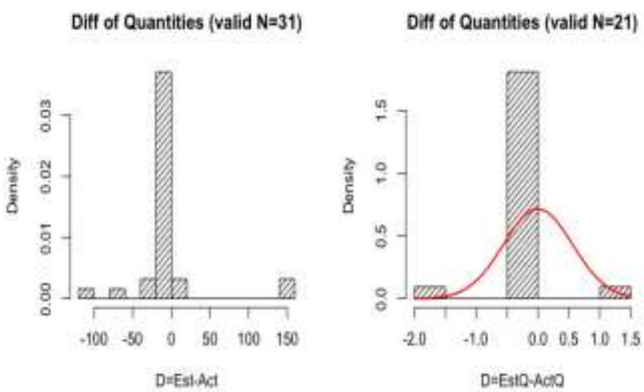
```
mean of x
0.7796296

        Wilcoxon signed rank test with continuity correction

data:  erD
V = 55, p-value = 0.002132
alternative hypothesis: true location is greater than 0


V = 55, p-value = 0.004263
alternative hypothesis: true location is not equal to 0
80 percent confidence interval:
 0.7332593 0.8000000
sample estimates:
(pseudo)median
     0.7999093
```

Item 0416_LF

1) Qty: (N=31)





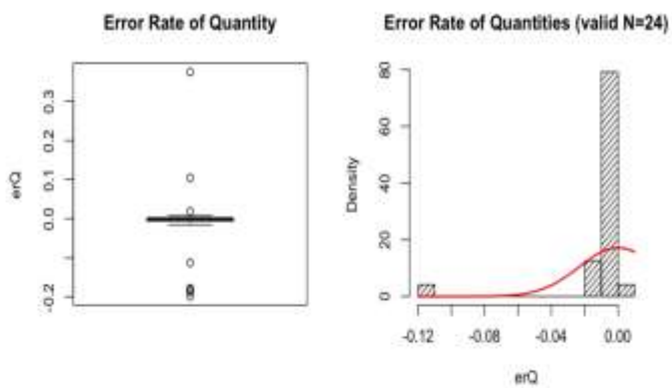



```
newAQ=ActQty[EstQty<4906&ActQty<4834]
newEQ=EstQty[EstQty<4906&ActQty<4834]

                Paired t-test

data:  newEQ and newAQ
t = 0.37624, df = 29, p-value = 0.3547
alternative hypothesis: true difference in means is greater than 0


t = 0.37624, df = 29, p-value = 0.7095
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -13.20871  19.16405
sample estimates:
mean of the differences
               2.977667

        Wilcoxon signed rank test with continuity correction

data:  EstQty and ActQty
V = 27.5, p-value = 0.194
alternative hypothesis: true location shift is less than 0
```

0

Consider the error rate of Q:

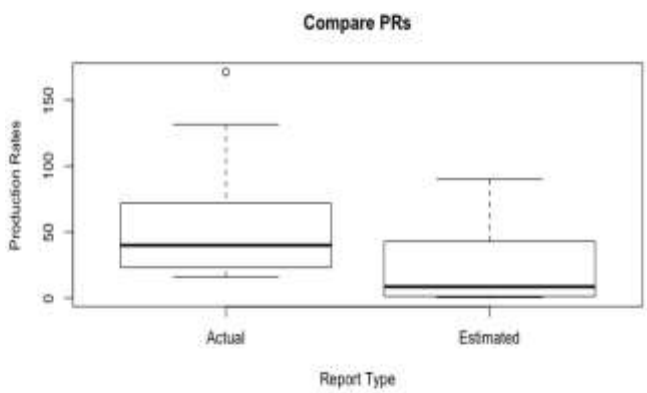
```
> describeBy(erQ)
   vars  n  mean  sd median trimmed mad  min  max range skew kurtosis   se
X1    1 31 -0.01 0.1      0    -0.01   0 -0.2 0.38  0.57 1.23     5.62 0.02
```

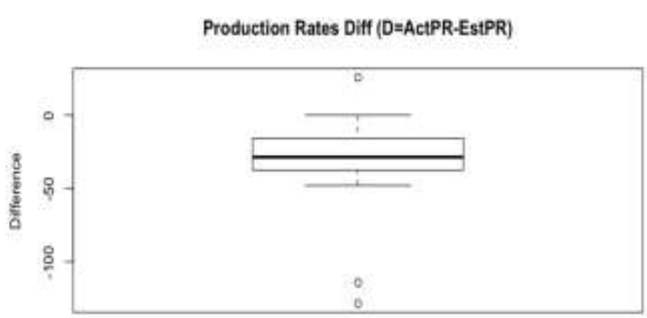


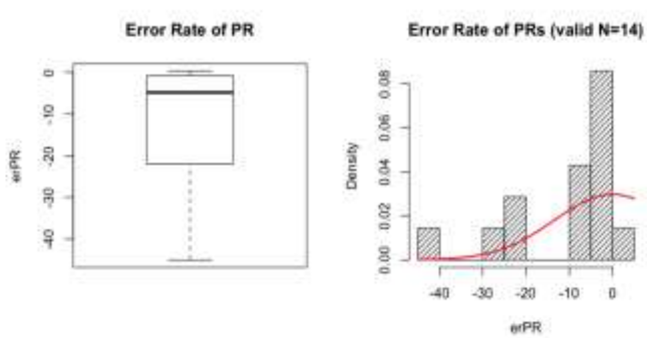

```
newER=erQ[erQ<0.0187500&erQ>-0.1126882]

                One Sample t-test

data:  newER
t = -1.281, df = 23, p-value = 0.1065
alternative hypothesis: true mean is less than 0


t = -1.281, df = 23, p-value = 0.213
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.015915177  0.003742498
sample estimates:
   mean of x
-0.006086339

        Wilcoxon signed rank test with continuity correction

data:  erQ
V = 24, p-value = 0.1277
alternative hypothesis: true location is less than 0

V = 24, p-value = 0.2553
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 -0.14491751  0.06153248
sample estimates:
```

```
(pseudo)median
   -0.04973733
```

2) PRs: (N=31, valid n=14)





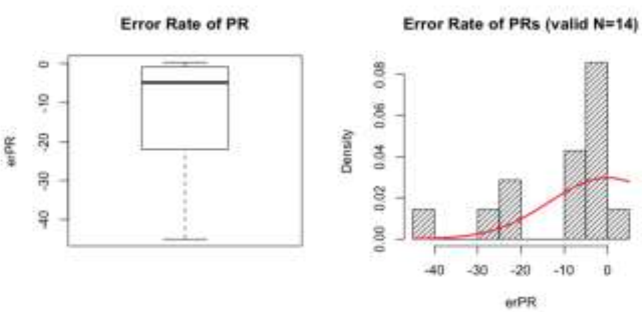



```
newEPR=EstPR[ActPR< 171.2]
```

```
newAPR=ActPR[ActPR< 171.2]

        Paired t-test

data:  newEPR and newAPR
t = -3.1962, df = 12, p-value = 0.003844
alternative hypothesis: true difference in means is less than 0


t = -3.1962, df = 12, p-value = 0.007687
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -47.654340  -9.019714
sample estimates:
mean of the differences
              -28.33703


        Wilcoxon signed rank test with continuity correction

data:  EstPR and ActPR
V = 6, p-value = 0.00321
alternative hypothesis: true location shift is less than 0
```

Consider the error rate of PR:

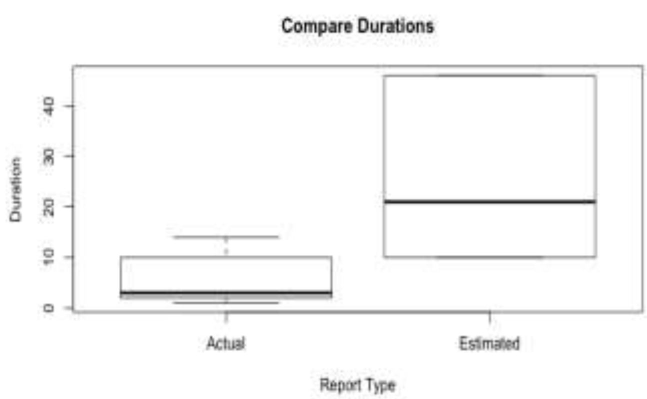
```
> describeBy(erPR)
   vars  n   mean    sd median trimmed  mad min  max range  skew kurtosis   se
X1    1 14 -10.31 13.42  -4.83    -8.3 6.42 -45 0.29 45.29 -1.29     0.53 3.59
```

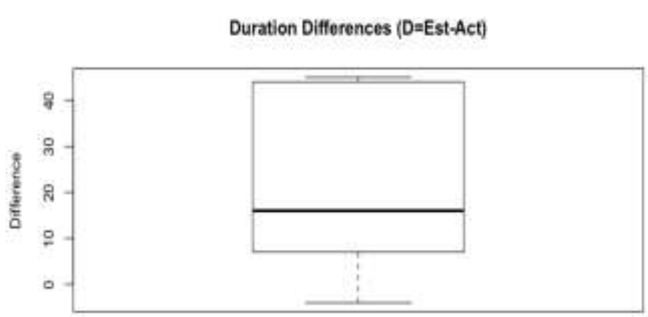


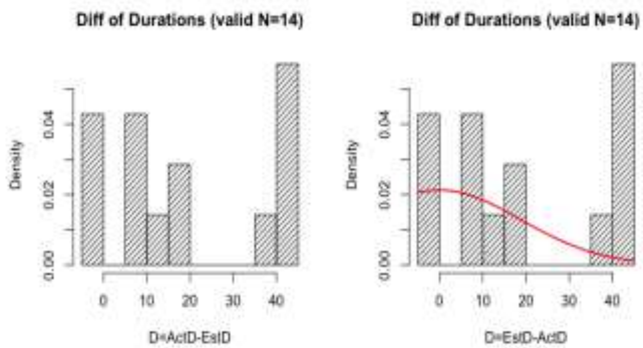

```
newER=erPR

                One Sample t-test

data:  newER
t = -2.8733, df = 13, p-value = 0.00653
alternative hypothesis: true mean is less than 0


t = -2.8733, df = 13, p-value = 0.01306
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -18.054507  -2.557251
sample estimates:
mean of x
```

```
-10.30588

        Wilcoxon signed rank test with continuity correction

data:  erPR
V = 2, p-value = 0.001324
alternative hypothesis: true location is less than 0


V = 2, p-value = 0.002647
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 -22.000021  -2.708962
sample estimates:
(pseudo)median
     -10.85713
```

3) Durations: (N=31, valid n=14)



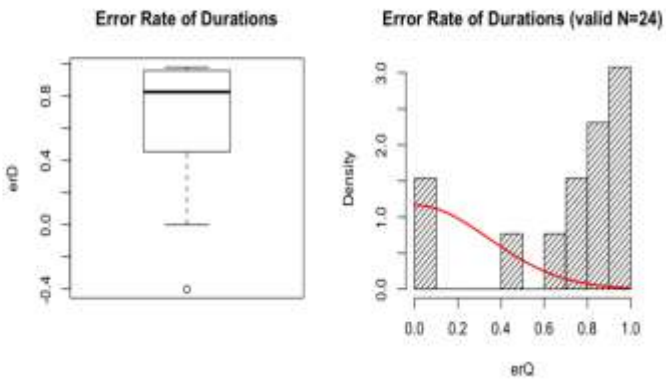





```
newAD=DurDays
newED=EstDur
        Paired t-test

data:  newED and newAD
t = 4.119, df = 13, p-value = 0.0006047
alternative hypothesis: true difference in means is greater than 0


t = 4.119, df = 13, p-value = 0.001209
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
  9.815861 31.469853
sample estimates:
mean of the differences
               20.64286


        Wilcoxon signed rank test with continuity correction

data:  EstDur and DurDays
V = 77, p-value = 0.001608
alternative hypothesis: true location shift is greater than 0
```

Consider the error rate of erD:

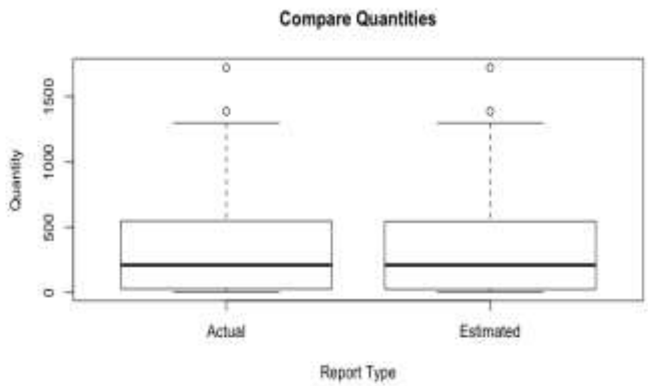
```
> describeBy(erD)
   vars  n mean   sd median trimmed  mad  min  max range  skew kurtosis   se
X1    1 14 0.62 0.44   0.82    0.68 0.19 -0.4 0.98  1.38 -1.13    -0.24 0.12
```

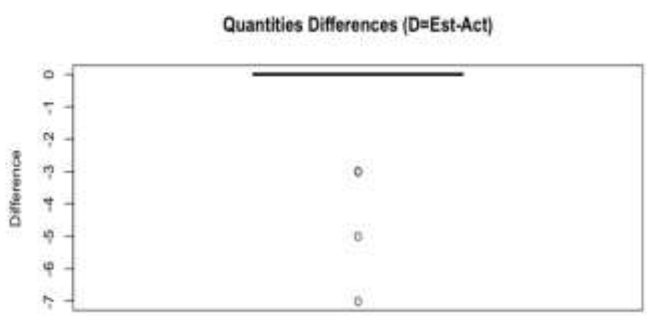


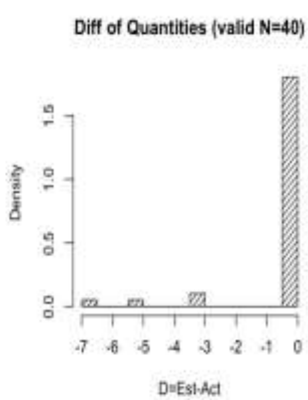

```
newED=erD[erD>-0.4]

        One Sample t-test

data:  newED
t = 7.4035, df = 12, p-value = 4.118e-06
alternative hypothesis: true mean is greater than 0


t = 7.4035, df = 12, p-value = 8.236e-06
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 0.4959243 0.9095485
sample estimates:
mean of x
0.7027364

        Wilcoxon signed rank test with continuity correction

data:  erD
V = 77, p-value = 0.001608
alternative hypothesis: true location is greater than 0


V = 77, p-value = 0.003216
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 0.5772974 0.9130445
sample estimates:
(pseudo)median
     0.8292476
```

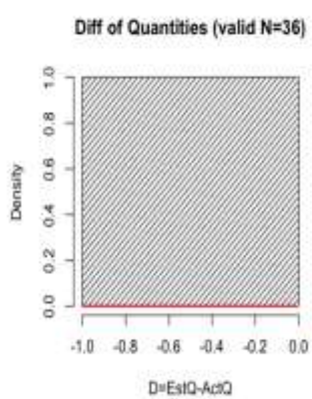
Item 0462_LF

1) Qty: (N=40)





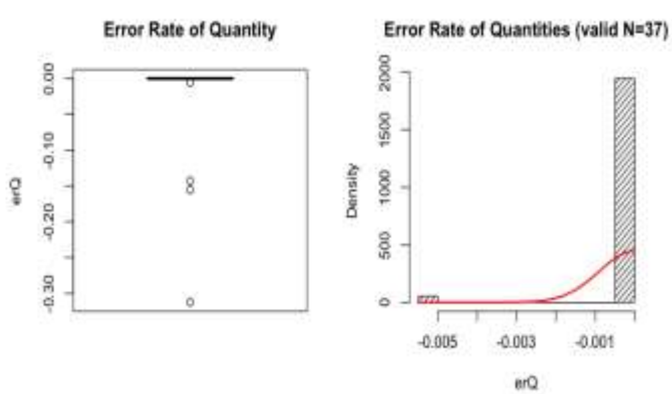




```
newAQ=ActQty[EstQty<1386&ActQty<1386]
newEQ=EstQty[EstQty<1386&ActQty<1386]

                Paired t-test

data:  newEQ and newAQ
t = -1.944, df = 37, p-value = 0.02976
alternative hypothesis: true difference in means is less than 0


t = -1.944, df = 37, p-value = 0.05952
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -0.96738387  0.02001545
sample estimates:
mean of the differences
             -0.4736842

        Wilcoxon signed rank test with continuity correction

data:  EstQty and ActQty
V = 0, p-value = 0.04876
alternative hypothesis: true location shift is less than 0
```

Consider the error rate of Q:

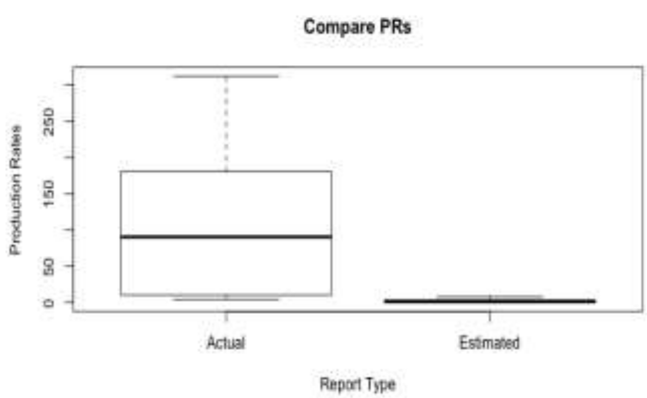
```
> describeBy(erQ)
   vars  n  mean   sd median trimmed mad   min max range  skew kurtosis   se
X1    1 40 -0.02 0.06      0       0   0 -0.31   0  0.31 -3.89     15.2 0.01
```

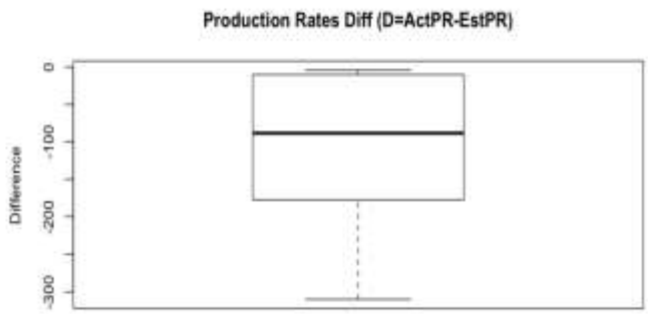


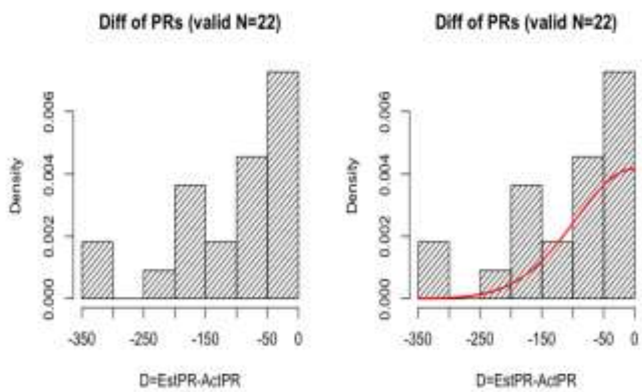

```
newER=erQ[erQ>-0.005434783]

                One Sample t-test

data:  newER
t = -1, df = 36, p-value = 0.162
```

```
alternative hypothesis: true mean is less than 0


t = -1, df = 36, p-value = 0.324
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.0004447847  0.0001510126
sample estimates:
   mean of x
-0.000146886


        Wilcoxon signed rank test with continuity correction

data:  erQ
V = 0, p-value = 0.05017
alternative hypothesis: true location is less than 0

V = 0, p-value = 0.1003
alternative hypothesis: true location is not equal to 0
80 percent confidence interval:
 -0.312407661 -0.005527122
sample estimates:
(pseudo)median
    -0.1494752
```

2) PRs: (N=31, valid n=22)



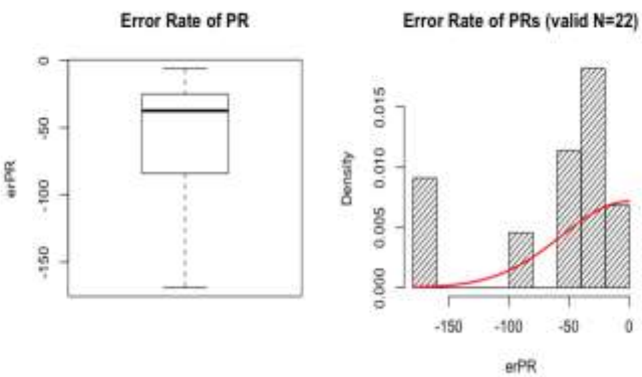





```
        Paired t-test

data:  EstPR and ActPR
t = -5.1406, df = 21, p-value = 2.152e-05
alternative hypothesis: true difference in means is less than 0


t = -5.1406, df = 21, p-value = 4.304e-05
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -147.34447  -62.46606
sample estimates:
mean of the differences
              -104.9053


        Wilcoxon signed rank test

data:  EstPR and ActPR
V = 0, p-value = 2.384e-07
alternative hypothesis: true location shift is less than 0
```

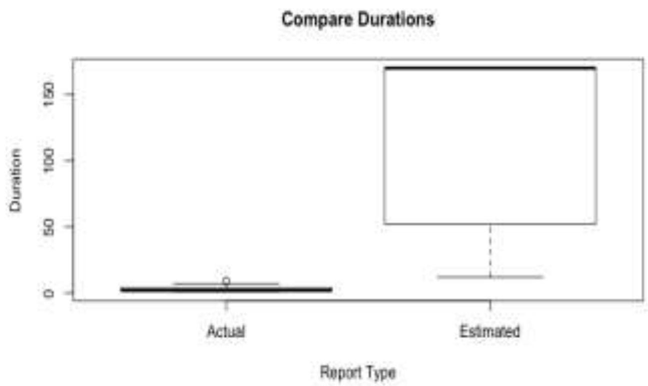
Consider the error rate of PR:

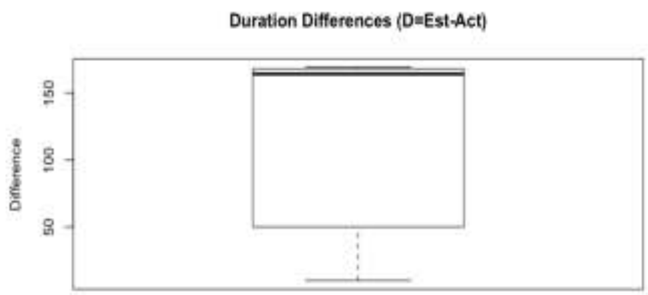
```
> describeBy(erPR)
   vars  n   mean    sd median trimmed  mad  min   max  range  skew kurtosis
X1    1 22 -61.38 55.73 -37.25  -55.25 27.3 -169 -5.93 163.07 -1.12    -0.32
      se
X1 11.88
```

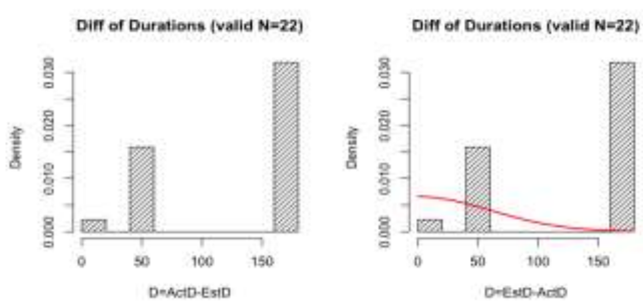



```
newER=erPR

                One Sample t-test

data:  newER
t = -5.1662, df = 21, p-value = 2.026e-05
alternative hypothesis: true mean is less than 0


t = -5.1662, df = 21, p-value = 4.052e-05
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -86.08819 -36.67203
sample estimates:
mean of x
-61.38011


        Wilcoxon signed rank test with continuity correction

data:  erPR
V = 0, p-value = 2.136e-05
alternative hypothesis: true location is less than 0


V = 0, p-value = 4.271e-05
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 -96.14292 -29.00003
sample estimates:
(pseudo)median
     -48.00002
```

3) Durations: (N=40, valid n=22)





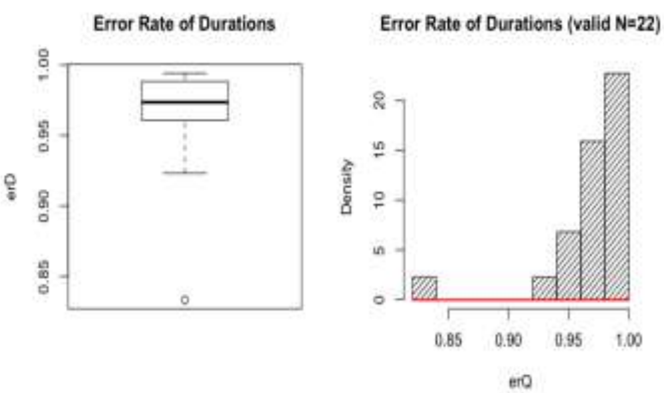



```
newAD=DurDays[DurDays<9]
newED=EstDur[DurDays<9]

        Paired t-test

data:  newED and newAD
t = 8.975, df = 20, p-value = 9.436e-09
alternative hypothesis: true difference in means is greater than 0


t = 8.975, df = 20, p-value = 1.887e-08
```

```
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
  92.36559 148.30108
sample estimates:
mean of the differences
               120.3333

        Wilcoxon signed rank test with continuity correction

data:  EstDur and DurDays
V = 253, p-value = 2.062e-05
alternative hypothesis: true location shift is greater than 0
```

Consider the error rate of erD:

```
> describeBy(erD)
   vars  n mean   sd median trimmed  mad  min  max range  skew kurtosis   se
X1    1 22 0.97 0.03   0.97    0.97 0.02 0.83 0.99  0.16 -2.51     6.96 0.01
```

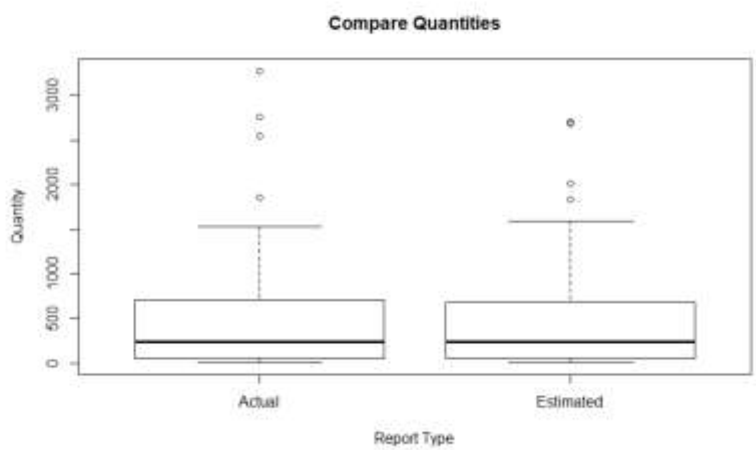


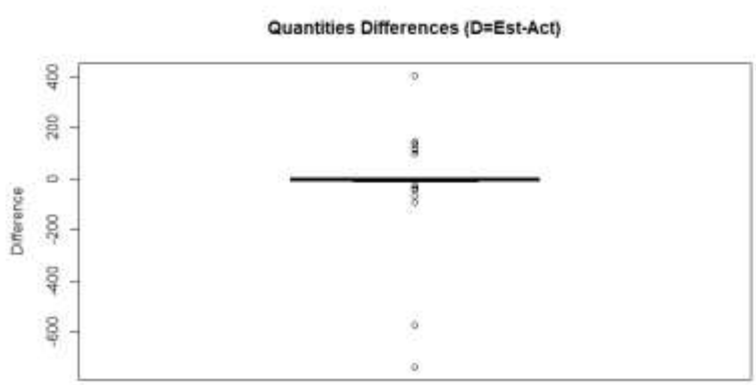

```
newED=erD[erD>0.8333333]

        One Sample t-test

data:  newED
t = 130.55, df = 21, p-value < 2.2e-16
alternative hypothesis: true mean is greater than 0


t = 130.55, df = 21, p-value < 2.2e-16
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 0.9507693 0.9815494
sample estimates:
mean of x
0.9661593
```

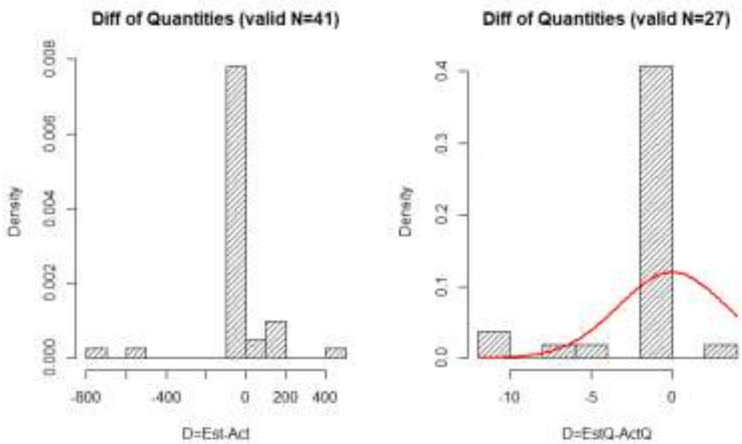
```
        Wilcoxon signed rank test with continuity correction

data:  erD
V = 253, p-value = 2.086e-05
alternative hypothesis: true location is greater than 0


V = 253, p-value = 4.173e-05
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 0.9607928 0.9794408
sample estimates:
(pseudo)median
     0.9719217
```

Item 0464_LF

1) Qty: (N=41, valid n=41)





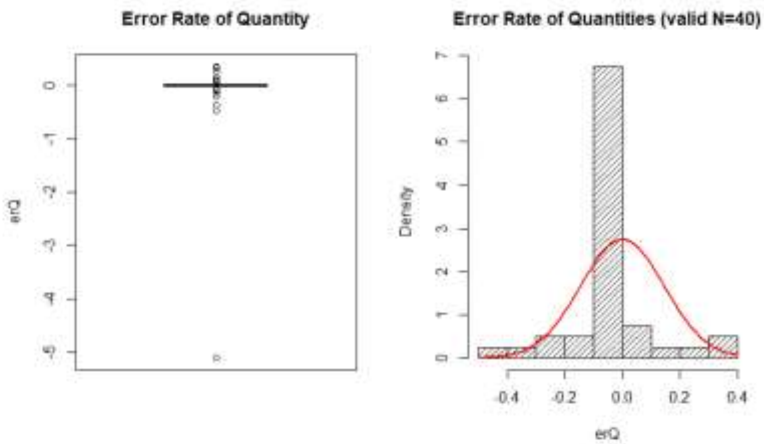



```
> newAQ=ActQty[ActQty<1857&EstQty<1830]
> newEQ=EstQty[ActQty<1857&EstQty<1830]

         Paired t-test

data:  newEQ and newAQ
t = 1.179, df = 36, p-value = 0.1231
alternative hypothesis: true difference in means is greater than 0


t = 1.179, df = 36, p-value = 0.2461
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -11.14281  42.08876
sample estimates:
mean of the differences
               15.47297



         Wilcoxon signed rank test with continuity correction

data:  EstQty and ActQty
V = 88, p-value = 0.6186
alternative hypothesis: true location shift is greater than 0
```

Consider the error rate of Q:

```
> describeBy(erQ)
   vars  n  mean   sd median trimmed mad   min  max range  skew kurtosis   se
X1    1 41 -0.14 0.81      0   -0.02   0 -5.11 0.35  5.46 -5.65    31.85 0.13
```

Setting erQ[erQ>-1], getting the following right graph



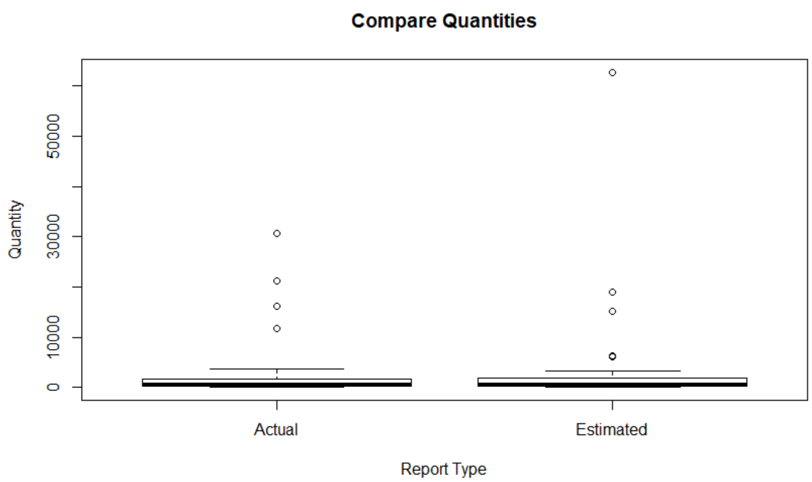

```
newER=erQ[erQ>-1]

         One Sample t-test

data:  newER
t = -0.52534, df = 39, p-value = 0.3012
alternative hypothesis: true mean is less than 0


t = -0.52534, df = 39, p-value = 0.6023
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.05864002  0.03445983
sample estimates:
  mean of x
-0.01209009



         Wilcoxon signed rank test with continuity correction

data:  erQ
V = 72, p-value = 0.1826
alternative hypothesis: true location is less than 0


alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 -0.1855608  0.0713097
sample estimates:
(pseudo)median
   -0.05020105
```

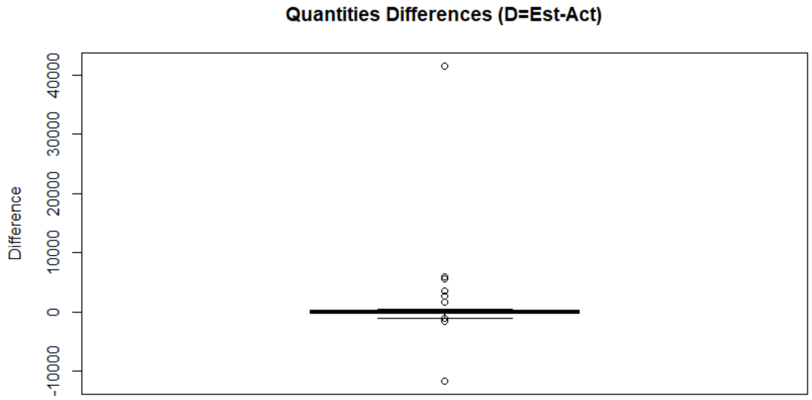
2) PRs: (N=41, valid n=2)

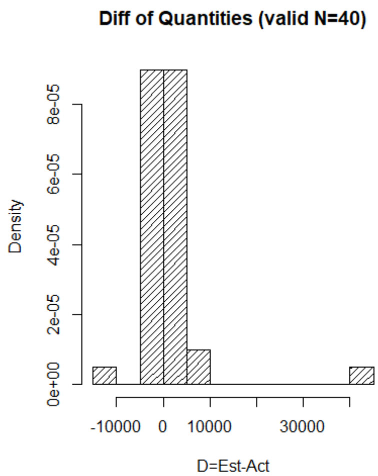
Quantity			Duration			Production Rate		
Estimated	Actual	erQ	Estimated	Actual	erD	Estimated	Actual	erPR
15	15	0.00	11	2	0.82	1.36	7.5	-4.50
18	18	0.00	11	2	0.82	1.64	9	-4.50

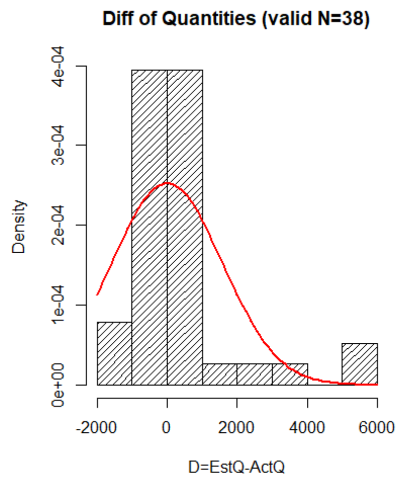
Item 0506_LF

1) Qty: (N=40, valid n=40)










```
> newAQ=ActQty[ActQty<10000&EstQty<6160]
> newEQ=EstQty[ActQty<10000&EstQty<6160]
```

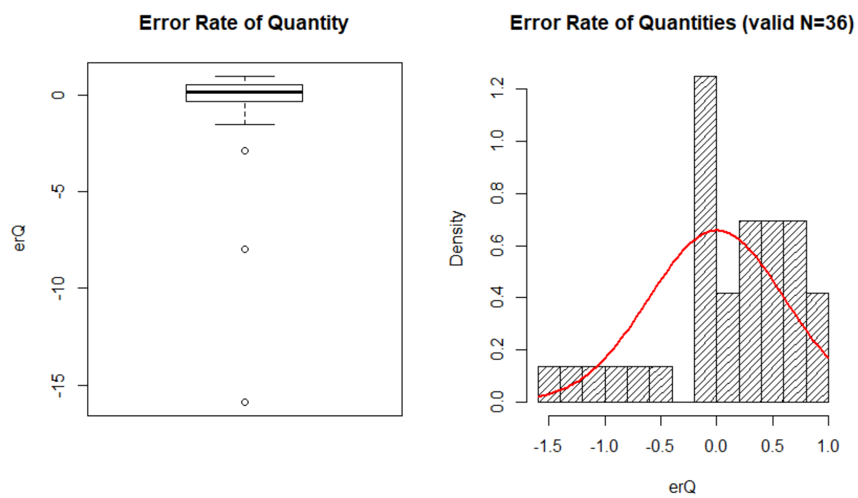
```
        Paired t-test

data:  newEQ and newAQ
t = -1.0261, df = 32, p-value = 0.1563
alternative hypothesis: true difference in means is less than 0


t = -1.0261, df = 32, p-value = 0.3125
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -295.61755   97.55694
sample estimates:
mean of the differences
              -99.0303
```

```
        Wilcoxon signed rank test with continuity correction

data:  EstQty and ActQty
V = 400, p-value = 0.6683
alternative hypothesis: true location shift is less than 0
```

Consider the error rate of Q:

```
> describeBy(erQ)
   vars  n  mean  sd median trimmed mad    min  max range skew kurtosis   se
X1    1 40 -0.64 2.9   0.12    0.01 0.6 -15.88 0.97 16.85   -4       17 0.46
```

Setting erQ[erQ>-2.88], getting the following right graph




```
> newER=erQ[erQ>-2.88]

        One Sample t-test

data:  newER
t = 1.0678, df = 35, p-value = 0.1465
alternative hypothesis: true mean is greater than 0


t = 1.0678, df = 35, p-value = 0.2929
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.09732918  0.31332373
sample estimates:
mean of x
0.1079973


        Wilcoxon signed rank test with continuity correction
```

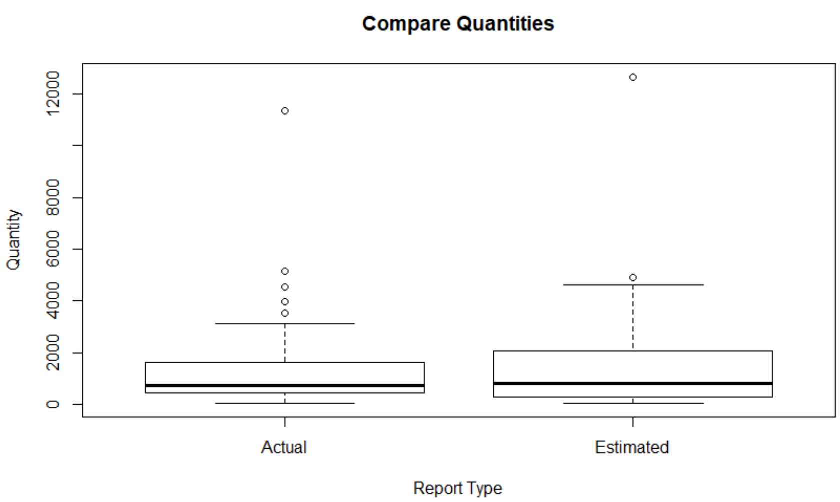
```
data:  erQ
V = 389, p-value = 0.397
alternative hypothesis: true location is greater than 0


V = 389, p-value = 0.794
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 -0.3809489  0.3001629
sample estimates:
(pseudo)median
    0.04194536
```

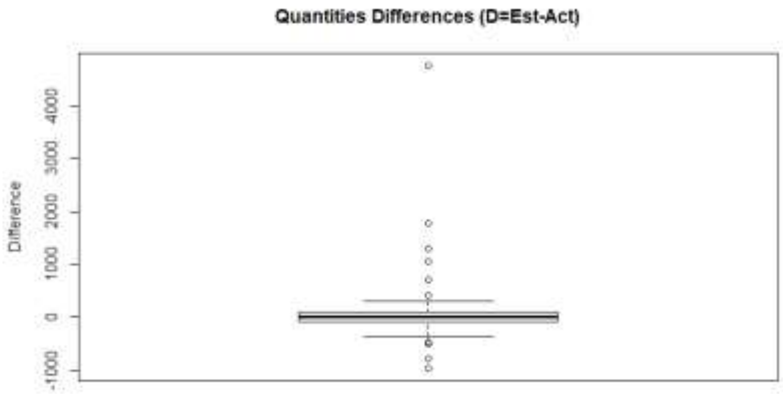
2) PRs: (N=41, valid n=3)

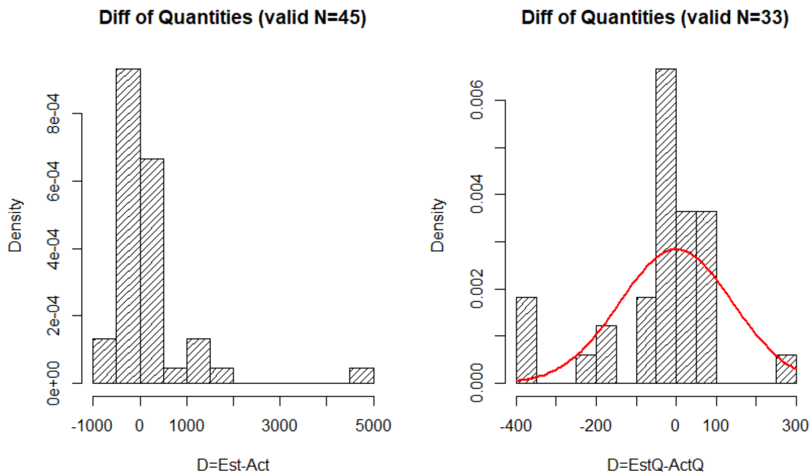
Quantity			Duration			Production Rate		
Estimated	Actual	erQ	Estimated	Actual	erD	Estimated	Actual	erPR
630	1455	-1.31	95	4	0.96	6.63	363.75	-53.85
630	1295	-1.06	95	7	0.93	6.63	185	-26.90
18945	30616	-0.62	95	12	0.87	199.42	2551.333	-11.79

Item 0512_LF

1) Qty: (N=45, valid n=45)





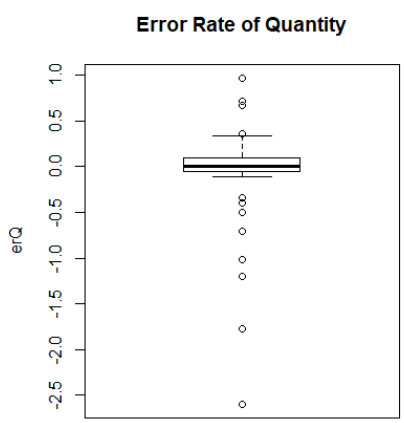


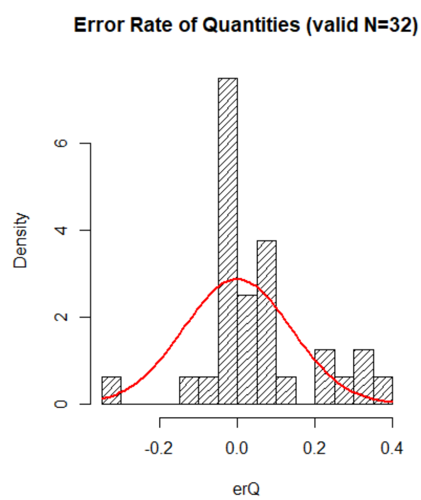

```
> newAQ=ActQty[ActQty<10000&EstQty<10000]
> newEQ=EstQty[ActQty<10000&EstQty<10000]

          Paired t-test

data:  newEQ and newAQ
t = 1.1914, df = 43, p-value = 0.12
alternative hypothesis: true difference in means is greater than 0


t = 1.1914, df = 43, p-value = 0.24
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -104.7932  407.3841
sample estimates:
mean of the differences
               151.2955
```

```
         Wilcoxon signed rank test with continuity correction

data:  EstQty and ActQty
V = 364.5, p-value = 0.7937
alternative hypothesis: true location shift is less than 0
```

Consider the error rate of Q:

```
> describeBy(erQ)
   vars  n mean   sd median trimmed  mad  min  max range  skew kurtosis   se
X1    1 45 -0.1 0.62      0   -0.02 0.15 -2.6 0.97  3.57 -1.89     5.03 0.09
```






```
> newER=erQ[erQ>-0.4&erQ<0.5]


         One Sample t-test

data:  newER
t = 2.4086, df = 31, p-value = 0.01107
alternative hypothesis: true mean is greater than 0


t = 2.4086, df = 31, p-value = 0.02215
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 0.009047004 0.109020149
sample estimates:
 mean of x
0.05903358



         Wilcoxon signed rank test with continuity correction

data:  erQ
V = 322, p-value = 0.4576
```

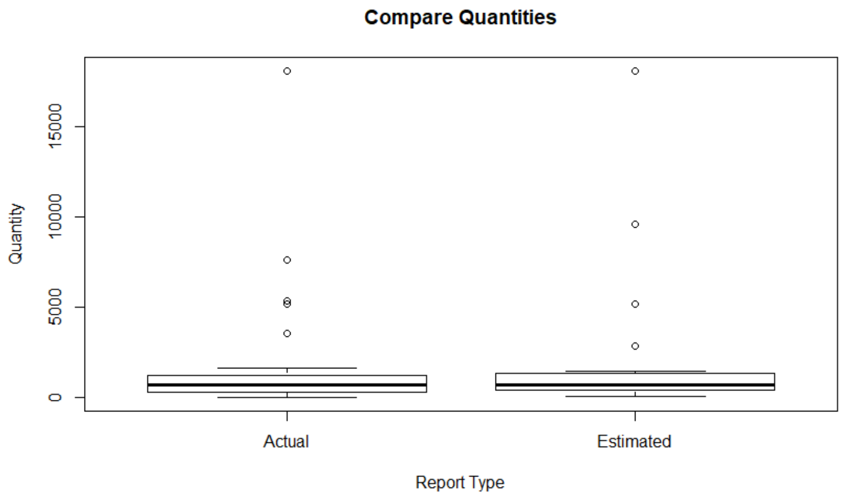
```
alternative hypothesis: true location is greater than 0


V = 322, p-value = 0.9152
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 -0.2412877  0.1331550
sample estimates:
(pseudo)median
   0.004219537
```

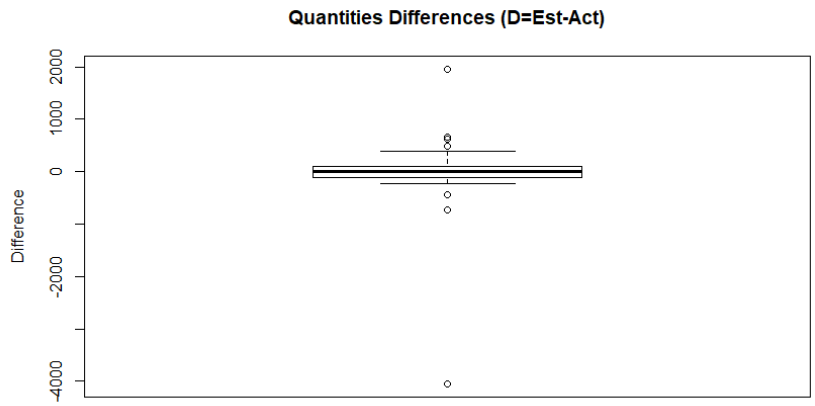
2) PRs: (N=, valid n=1)

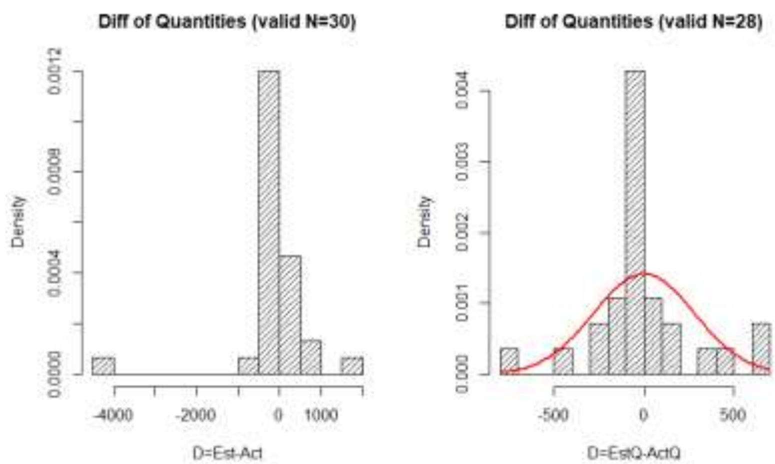
Quantity			Duration			Production Rate		
Estimated	Actual	erQ	Estimated	Actual	erD	Estimated	Actual	erPR
900	810	0.10	1	1	0.00	900.00	810	0.10

Item 0618_LF

1) Qty: (N=30, valid n=30)





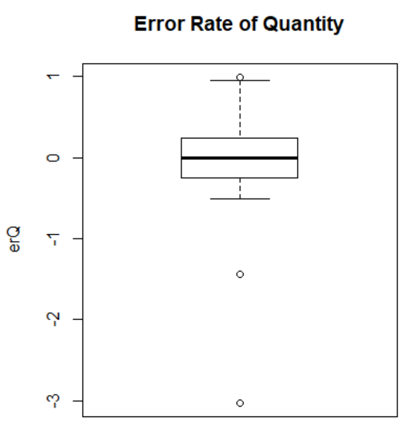


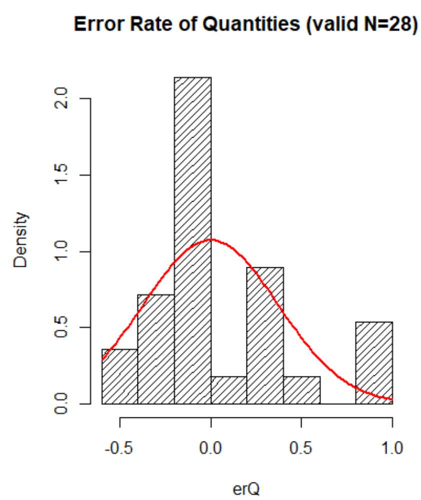

```
> newAQ=ActQty[ActQty<3564&EstQty<2841]
> newEQ=EstQty[ActQty<3564&EstQty<2841]

         Paired t-test

data:  newEQ and newAQ
t = 0.96177, df = 24, p-value = 0.1729


t = 0.96177, df = 24, p-value = 0.3458
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -56.29525 154.54645
sample estimates:
mean of the differences
                49.1256


         Wilcoxon signed rank test with continuity correction
```

```
data:  EstQty and ActQty
V = 117.5, p-value = 0.4792
alternative hypothesis: true location shift is greater than 0
```

Consider the error rate of Q:

```
> describeBy(erQ)
   vars  n  mean   sd median trimmed  mad   min  max range  skew kurtosis   se
X1    1 30 -0.07 0.72      0       0 0.36 -3.03 0.99  4.02 -2.25     7.36 0.13
```






```
> newER=erQ[erQ>-1]

         One Sample t-test

data:  newER
t = 1.1604, df = 27, p-value = 0.128
alternative hypothesis: true mean is greater than 0

t = 1.1604, df = 27, p-value = 0.2561
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.06261123  0.22560359
sample estimates:
 mean of x
0.08149618
         Wilcoxon signed rank test with continuity correction

data:  erQ
V = 110.5, p-value = 0.5758
alternative hypothesis: true location is greater than 0


V = 110.5, p-value = 0.8757
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 -0.2568549  0.2636698
sample estimates:
```

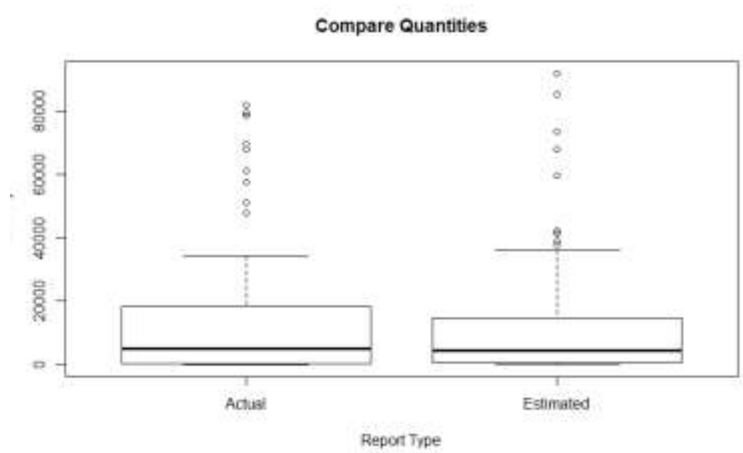
```
(pseudo)median
  -0.005580829
```

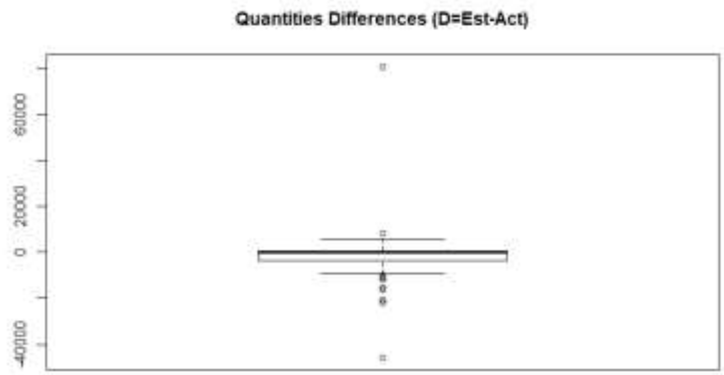
2) PRs: (N=30, valid n=0)

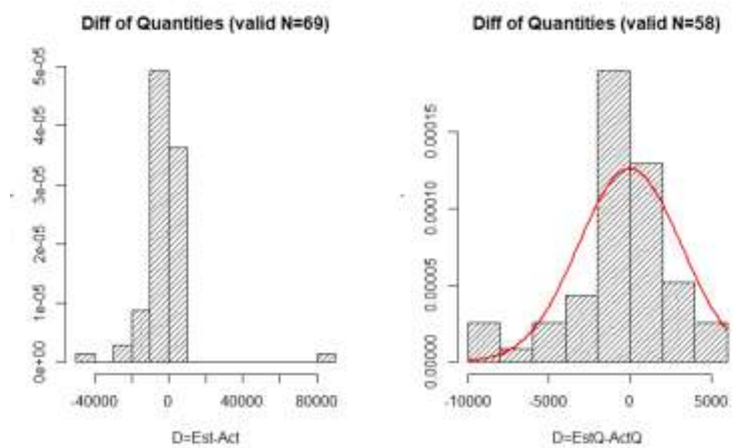
3) Durations: (N=30, valid n=0)

Item 0662_LF

4) Qty: (N=69, valid n=69)





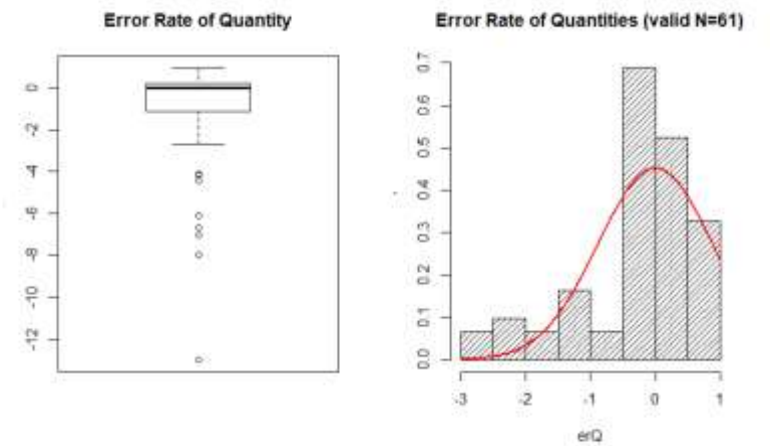



```
> newAQ=ActQty[ActQty<40000&EstQty<37731]
> newEQ=EstQty[ActQty<40000&EstQty<37731]

         Paired t-test

data:  newEQ and newAQ
t = -1.9848, df = 58, p-value = 0.02595
alternative hypothesis: true difference in means is less than 0


t = -1.9848, df = 58, p-value = 0.0519
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -2503.57851    10.59546
sample estimates:
mean of the differences
              -1246.492
```

```
          Wilcoxon signed rank test with continuity correction

data:  EstQty and ActQty
V = 665, p-value = 0.02215
alternative hypothesis: true location shift is less than 0
```

Consider the error rate of Q:

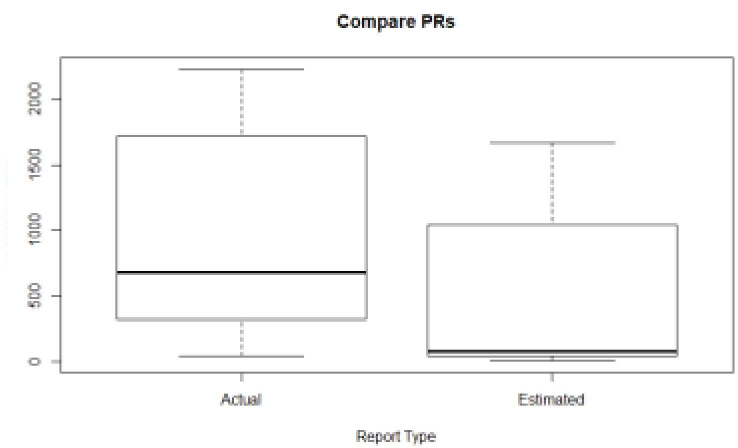
```
> describeBy(erQ)
   vars  n  mean   sd median trimmed  mad    min  max range  skew kurtosis   se
X1    1 69 -0.98 2.43  -0.01   -0.48 0.58 -13.01 0.96 13.96 -2.67     8.17 0.29
```

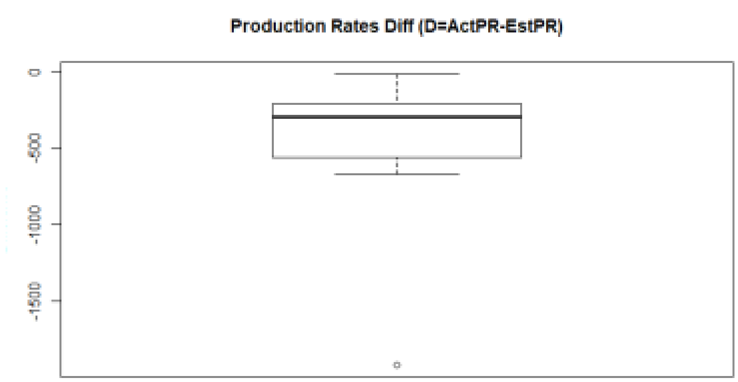


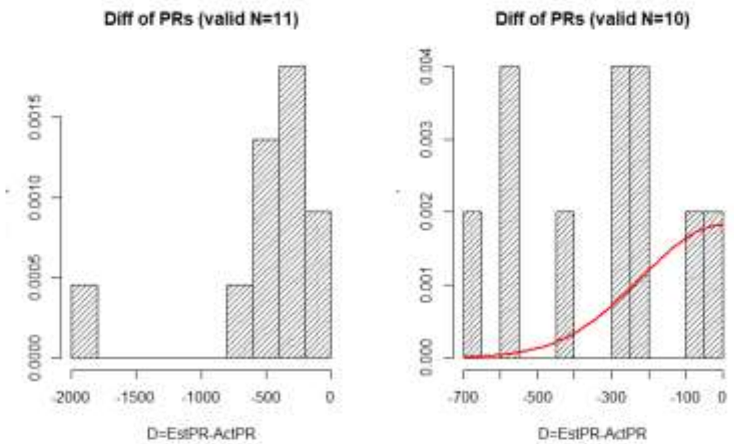

```
> newER=erQ[erQ>-4]

          One Sample t-test

data:  newER
t = -1.9993, df = 60, p-value = 0.02505
alternative hypothesis: true mean is less than 0


95 percent confidence interval:
 -0.451528065  0.000109694
sample estimates:
 mean of x
-0.2257092

          Wilcoxon signed rank test with continuity correction

data:  erQ
V = 599, p-value = 0.006473
alternative hypothesis: true location is less than 0


V = 599, p-value = 0.01295
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 -1.02400606 -0.06917655
sample estimates:
```

```
(pseudo)median
    -0.4373234
```

5) PRs: (N=69, valid n=11)



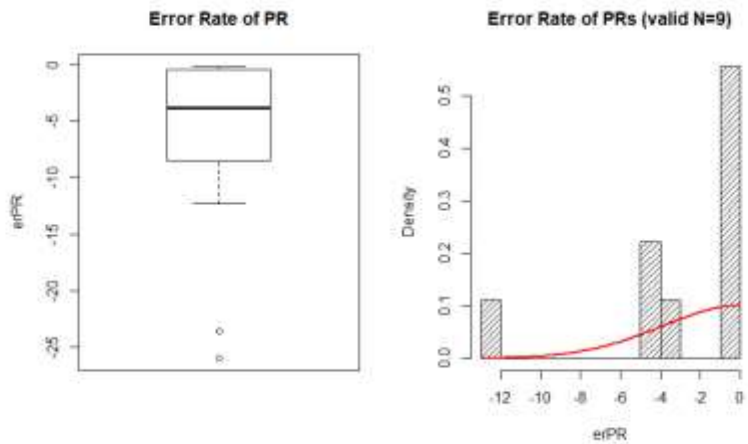





```
         Paired t-test

data:  EstPR and ActPR
t = -3.0254, df = 10, p-value = 0.006389
alternative hypothesis: true difference in means is less than 0


t = -3.0254, df = 10, p-value = 0.01278
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -825.4043 -125.2569
sample estimates:
mean of the differences
              -475.3306


         Wilcoxon signed rank test

data:  EstPR and ActPR
V = 0, p-value = 0.0004883
alternative hypothesis: true location shift is less than 0
```

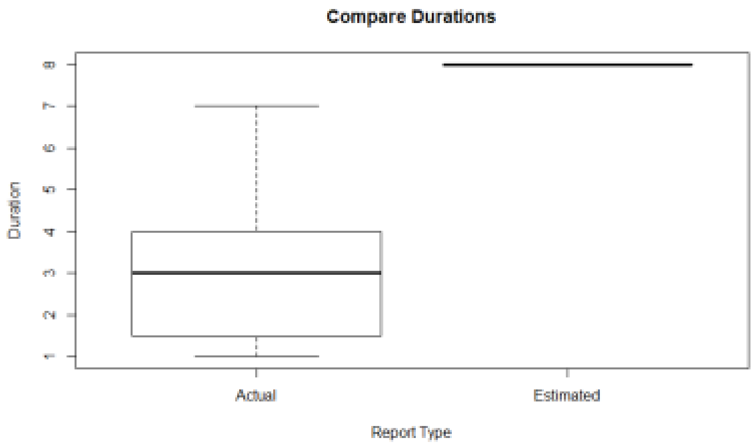
Consider the error rate of PR:

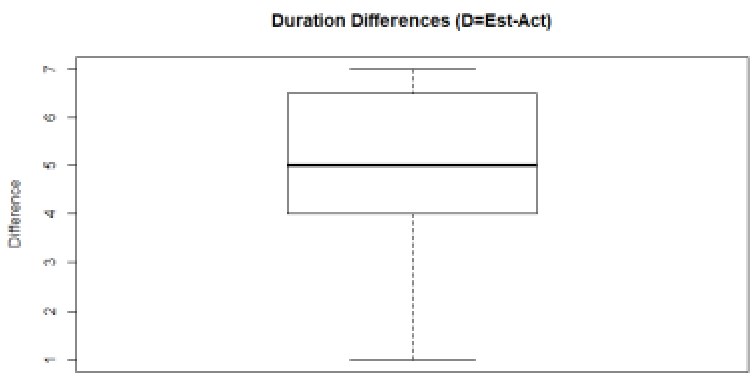
```
> describeBy(erPR)
   vars  n  mean   sd median trimmed  mad    min   max range  skew kurtosis   se
X1    1 11 -6.96 9.51  -3.85   -5.61 5.22 -25.98 -0.14 25.84 -1.07    -0.59 2.87
```

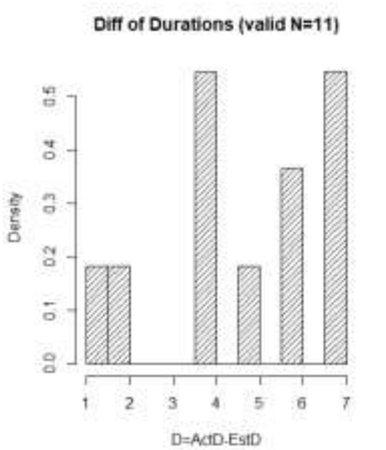


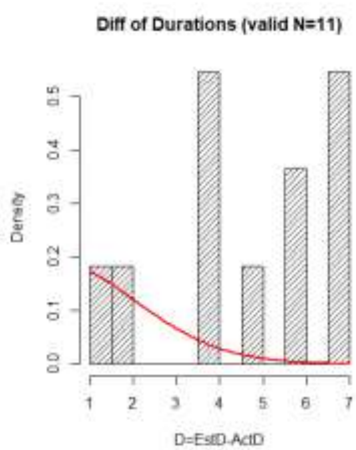

```
> newER=erPR[erPR>-15]

         One Sample t-test

data:  newER
t = -2.2664, df = 8, p-value = 0.02659
alternative hypothesis: true mean is less than 0


t = -2.2664, df = 8, p-value = 0.05319
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -6.0718936  0.0526028
sample estimates:
mean of x
-3.009645


         Wilcoxon signed rank test

data:  erPR
V = 0, p-value = 0.0004883
alternative hypothesis: true location is less than 0


V = 0, p-value = 0.0009766
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 -13.6928962  -0.4458874
sample estimates:
(pseudo)median
     -4.352413
```

6) Durations: (N=69, valid n=11)


Compare Durations
Duration
Actual
Estimated
Report Type


Duration Differences (D=Est-Act)
Difference

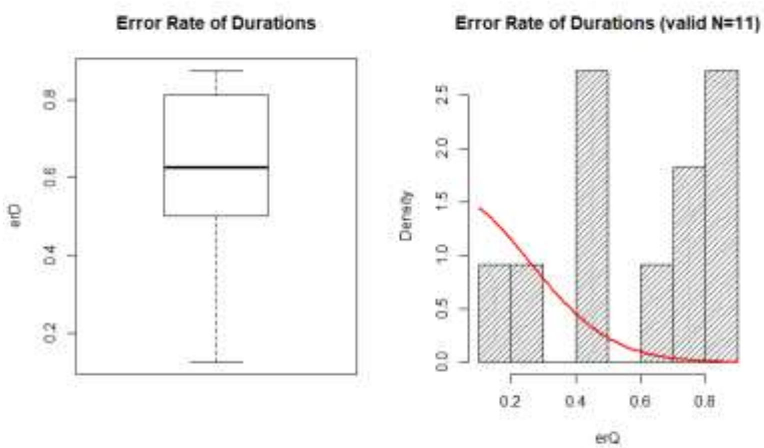

Diff of Durations (valid N=11)
Density
D=ActD-EstD


Diff of Durations (valid N=11)
Density
D=EstD-ActD

```
> newAD=DurDays
> newED=EstDur

         Paired t-test

data:  newED and newAD
t = 7.8315, df = 10, p-value = 7.091e-06
alternative hypothesis: true difference in means is greater than 0


t = 7.8315, df = 10, p-value = 1.418e-05
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 3.447356 6.189008
sample estimates:
mean of the differences
               4.818182


         Wilcoxon signed rank test with continuity correction

data:  EstDur and DurDays
V = 66, p-value = 0.001851
alternative hypothesis: true location shift is greater than 0
```

Consider the error rate of D:

```
> describeBy(erD)
   vars  n mean   sd median trimmed  mad  min  max range  skew kurtosis   se
X1    1 11  0.6 0.26   0.62    0.62 0.19 0.12 0.88  0.75 -0.48    -1.17 0.08
```

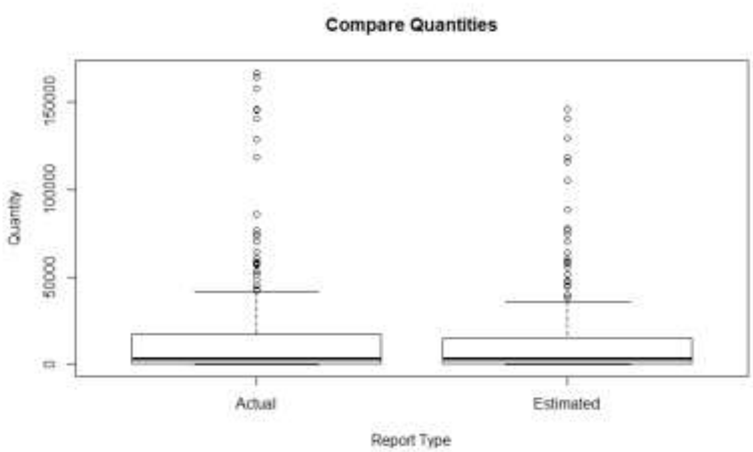



```
> newED=erD

         One Sample t-test

data:  newED
t = 7.8315, df = 10, p-value = 7.091e-06
alternative hypothesis: true mean is greater than 0
```

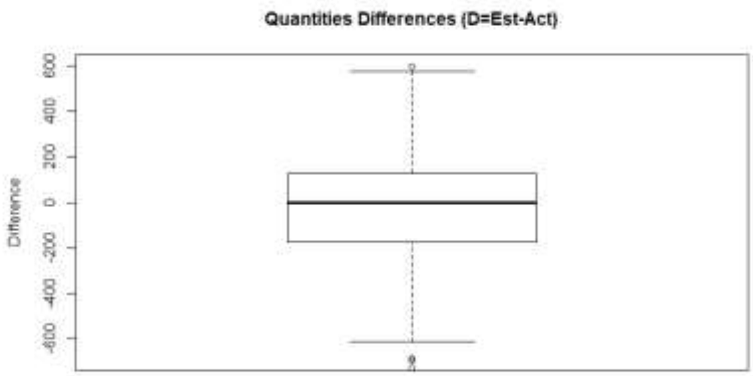
```
t = 7.8315, df = 10, p-value = 1.418e-05
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 0.4309195 0.7736260
sample estimates:
mean of x
0.6022727


         Wilcoxon signed rank test with continuity correction

data:  erD
V = 66, p-value = 0.001851
alternative hypothesis: true location is greater than 0



V = 66, p-value = 0.003702
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 0.4374775 0.8124203
sample estimates:
(pseudo)median
     0.6249634
```

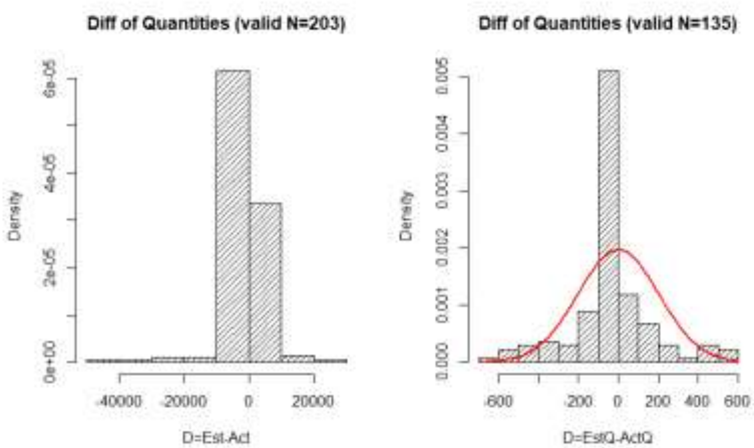
Item 0666_LF

1) Qty: (N=203, valid n=203)



Setting ylim=c (-686, 597) to drop the outliers and getting the following graph.



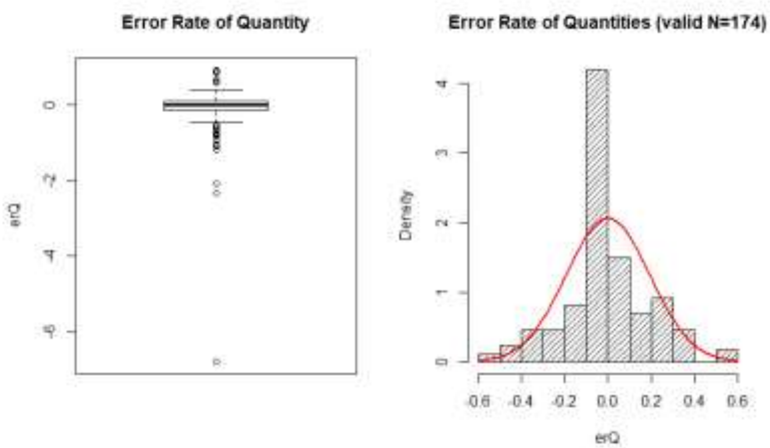



```
> newAQ=ActQty[ActQty<43005&EstQty<38212]
> newEQ=EstQty[ActQty<43005&EstQty<38212]

         Paired t-test

data:  newEQ and newAQ
t = -0.86551, df = 169, p-value = 0.194
alternative hypothesis: true difference in means is less than 0


t = -0.86551, df = 169, p-value = 0.388
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -339.0405  132.3623
sample estimates:
mean of the differences
              -103.3391
```

```
        Wilcoxon signed rank test with continuity correction

data:  EstQty and ActQty
V = 5155.5, p-value = 0.4492
alternative hypothesis: true location shift is less than 0
```

Consider the error rate of Q:

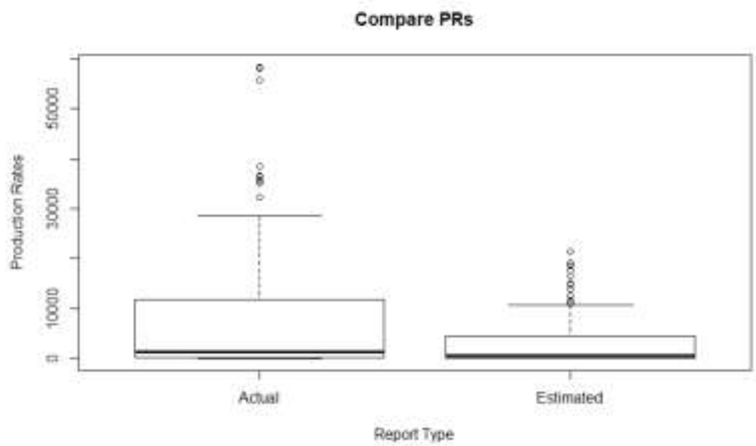
```
> describeBy(erQ)
   vars   n mean   sd median trimmed  mad   min  max range  skew kurtosis   se
X1    1 203 -0.1 0.63      0   -0.03 0.16 -6.79 0.93  7.72 -6.42    62.57 0.04
```

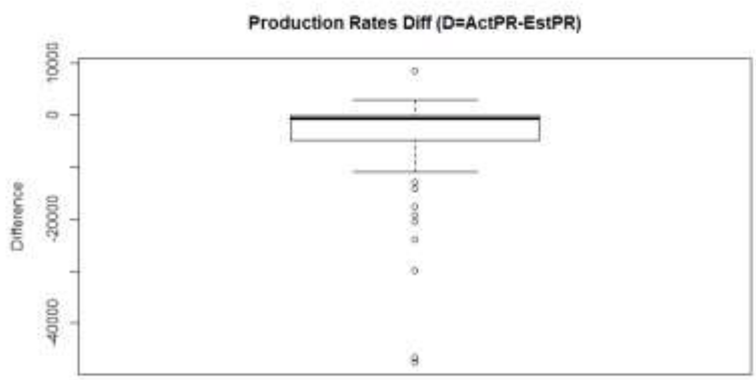


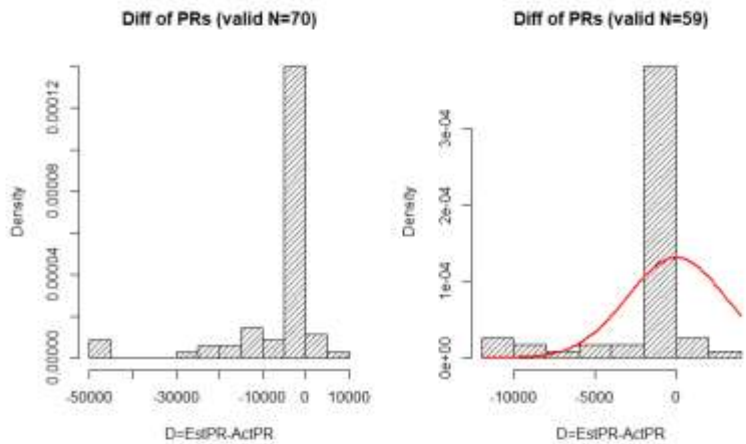

```
> newER=erQ[erQ>-0.52&erQ<0.596]

        One Sample t-test

data:  newER
t = 0.59063, df = 173, p-value = 0.2778
alternative hypothesis: true mean is greater than 0


t = 0.59063, df = 173, p-value = 0.5555
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.02030484  0.03764605
sample estimates:
  mean of x
0.008670604


        Wilcoxon signed rank test with continuity correction

data:  erQ
V = 4454, p-value = 0.9368
alternative hypothesis: true location is greater than 0


V = 4454, p-value = 0.1268
```

```
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 -0.12294393  0.01619744
sample estimates:
(pseudo)median
   -0.04914603
```

2) PRs: (N=203, valid n=70)



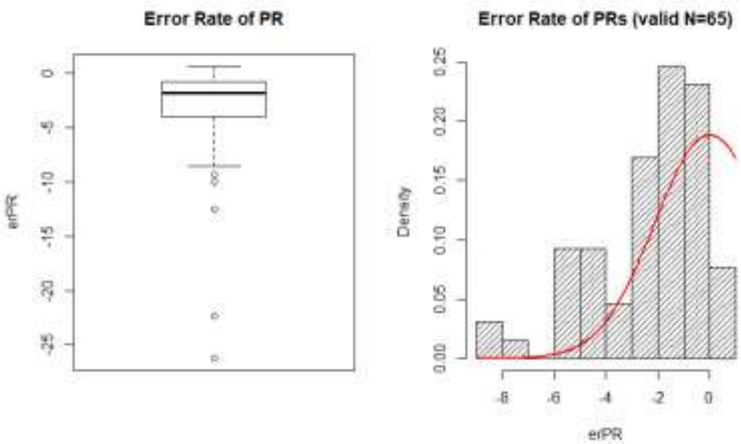





```
> newEPR=EstPR[EstPR<11118&ActPR<32272]
> newAPR=ActPR[EstPR<11118&ActPR<32272]

         Paired t-test

data:  newEPR and newAPR
t = -3.7012, df = 55, p-value = 0.000249
alternative hypothesis: true difference in means is less than 0


t = -3.7012, df = 55, p-value = 0.0004979
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -2470.8320  -735.0043
sample estimates:
mean of the differences
              -1602.918


         Wilcoxon signed rank test with continuity correction

data:  EstPR and ActPR
V = 170, p-value = 1.765e-10
alternative hypothesis: true location shift is less than 0
```

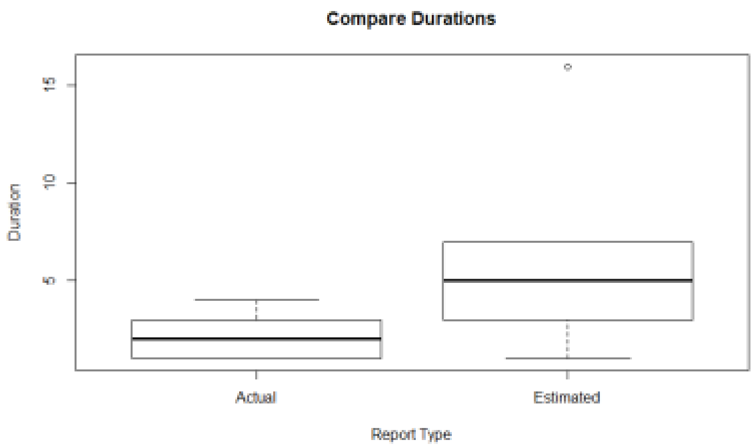
Consider the error rate of PR:

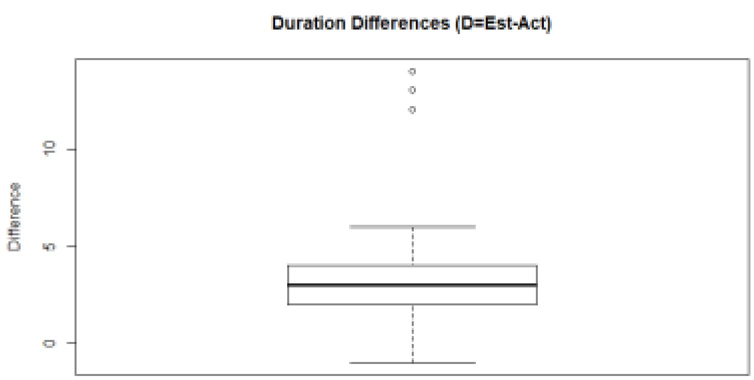
```
> describeBy(erPR)
   vars  n  mean   sd median trimmed  mad    min  max range  skew kurtosis   se
X1    1 70 -3.24 4.53  -1.86   -2.34 1.88 -26.27 0.62 26.89 -3.13     11.6 0.54
```

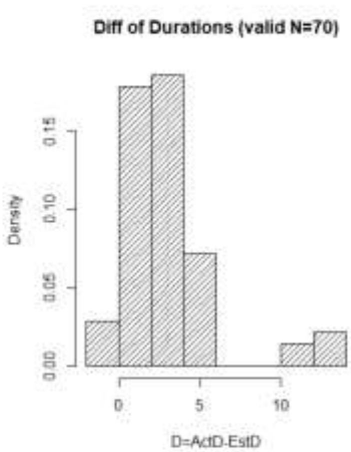


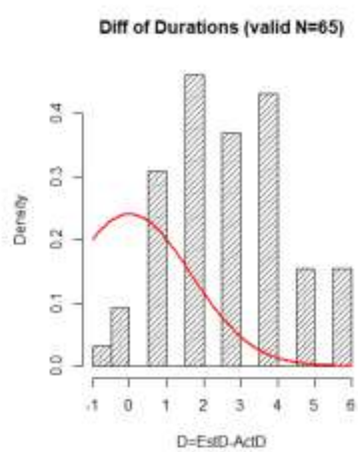

```
> newER=erPR[erPR>-9]

        One Sample t-test

data:  newER
t = -8.5731, df = 64, p-value = 1.581e-12
alternative hypothesis: true mean is less than 0


t = -8.5731, df = 64, p-value = 3.161e-12
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -2.773461 -1.725176
sample estimates:
mean of x
-2.249318


        Wilcoxon signed rank test with continuity correction

data:  erPR
V = 31.5, p-value = 6.991e-13
alternative hypothesis: true location is less than 0


V = 31.5, p-value = 1.398e-12
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 -3.056114 -1.668140
sample estimates:
(pseudo)median
     -2.326666
```

3) Durations: (N=203, valid n=70)


Compare Durations
Duration
15
10
5
Actual
Estimated
Report Type


Duration Differences (D=Est-Act)
Difference
10
5
0

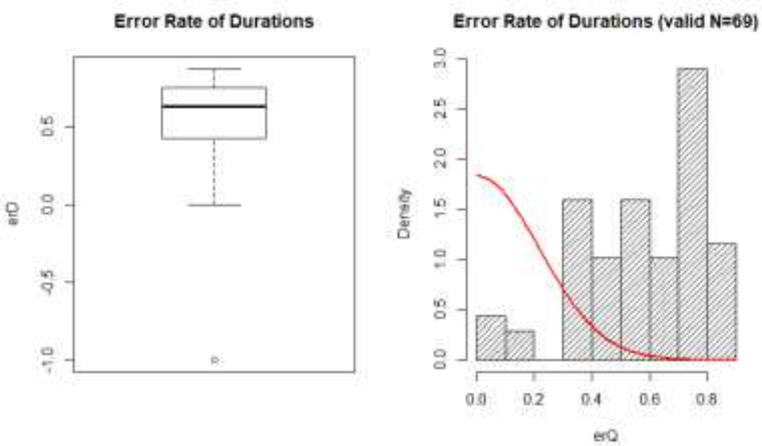

Diff of Durations (valid N=70)
Density
0.15
0.10
0.05
0.00
0
5
10
D=ActD-EstD


Diff of Durations (valid N=65)
Density
0.4
0.3
0.2
0.1
0.0
-1
0
1
2
3
4
5
6
D=EstD-ActD

```
> newAD=DurDays
> newED=EstDur


        Paired t-test

data:  newED and newAD
t = 9.7224, df = 69, p-value = 7.35e-15
alternative hypothesis: true difference in means is greater than 0


t = 9.7224, df = 69, p-value = 1.47e-14
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 2.849956 4.321473
sample estimates:
mean of the differences
               3.585714


        Wilcoxon signed rank test with continuity correction

data:  EstDur and DurDays
V = 2272, p-value = 6.173e-13
alternative hypothesis: true location shift is greater than 0
```

Consider the error rate of D:

```
> describeBy(erD)
   vars  n mean   sd median trimmed  mad min  max range  skew kurtosis   se
X1    1 70 0.57 0.29   0.63    0.61 0.25  -1 0.88  1.88 -2.57    10.62 0.03
```




```
> newED=erD[erD>-0.5]

        One Sample t-test

data:  newED
t = 22.701, df = 68, p-value < 2.2e-16
alternative hypothesis: true mean is greater than 0


t = 22.701, df = 68, p-value < 2.2e-16
```

```
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 0.5428602 0.6474952
sample estimates:
mean of x
0.5951777


         Wilcoxon signed rank test with continuity correction

data:  erD
V = 2211, p-value = 1.045e-11
alternative hypothesis: true location is greater than 0


V = 2211, p-value = 2.091e-11
alternative hypothesis: true location is not equal to 0
95 percent confidence interval:
 0.5749589 0.6750570
sample estimates:
(pseudo)median
     0.6249955
```

APPENDIX 3.5

RESULTS OF STATISTICAL ANALYSIS OF POOLED ITEMS BASED ON THE NATURE OF WORK

Earthworks

One sample t-Test

	ERDur
Mean	0.619059297
Variance	0.154471961
Observations	72
Hypothesized Mean	0
df	71
t Stat	13.36514483
P(T<=t) one-tail	2.29037E-21
t Critical one-tail	1.666599658
P(T<=t) two-tail	4.58073E-21
t Critical two-tail	1.993943368

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.401467123
R Square	0.161175851
Adjusted R Square	0.134906934
Standard Error	0.679762393
Observations	72

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	6.21500318	3.107502	6.725074362	0.002146292
Residual	70	32.34538379	0.462077		
Total	72	38.56038697			

Regression Analysis	***Coefficients***	***Standard Error***	***t Stat***	***P-value***
ERQty	0.011854939	0.067464767	0.17572	0.861020913
ERPr	-0.004027173	0.001346284	-2.99133	0.003832981

APPENDIX 3.7

RESULTS OF STATISTICAL ANALYSIS OF POOLED ITEMS BASED ON THE NATURE OF WORK

Finishing Works

t-Test: One sample

	ERDur
Mean	0.605501
Variance	0.162139
Observations	196
Hypothesized Mean	0
df	195
t Stat	21.05227
P(T<=t) one-tail	2.13E-52
t Critical one-tail	1.652705
P(T<=t) two-tail	4.26E-52
t Critical two-tail	1.972204

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.495913466
R Square	0.245930166
Adjusted R Square	0.236888569
Standard Error	0.634200388

Observations	196

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	25.44807709	12.72403855	31.63530088	1.30872E-12
Residual	194	78.02876563	0.402210132		
Total	196	103.4768427			

Regression Analysis	***Coefficients***	***Standard Error***	***t Stat***	***P-value***
ERQty	-0.127704366	0.067433849	-1.89377245	0.059743374
ERPr	-0.014210999	0.001935672	-7.34163442	5.66495E-12

APPENDIX 3.8

RESULTS OF STATISTICAL ANALYSIS OF POOLED ITEMS BASED ON THE NATURE OF WORK ASPHALT WORKS

t-Test: One Sample

	ERPr
Mean	2509.526844
Variance	79004233.53
Observations	55
Hypothesized Mean	0
df	54
t Stat	2.093861773
P(T<=t) one-tail	0.020490917
t Critical one-tail	1.673564906
P(T<=t) two-tail	0.040981835
t Critical two-tail	2.004879288

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.18938033
R Square	0.035864909
Adjusted R Square	-0.001194243
Standard Error	2.564186776
Observations	55

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	12.96304499	6.481522497	0.985775	0.380014224
Residual	53	348.4778525	6.575053822		
Total	55	361.4408975			

Regression Analysis	***Coefficients***	***Standard Error***	***t Stat***	***P-value***
ERQty	0.290855335	0.443727652	0.655481652	0.514993
EstPr	-0.068840513	0.051228257	-1.34379963	0.184738

APPENDIX 3.9

RESULTS OF STATISTICAL ANALYSIS OF POOLED ITEMS BASED ON THE NATURE OF WORK

Concrete Works

t-Test: One Sample

	ERDur
Mean	0.771278
Variance	0.107805
Observations	101
Hypothesized Mean	0
df	100
t Stat	23.6076
P(T<=t) one-tail	5.57E-43
t Critical one-tail	1.660234
P(T<=t) two-tail	1.11E-42
t Critical two-tail	1.983972

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.641142751
R Square	0.411064027
Adjusted R Square	0.395014169
Standard Error	0.64926832
Observations	101

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	29.12896208	14.56448	34.54988	4.4082E-12
Residual	99	41.73338574	0.421549		
Total	101	70.86234782			

Regression Analysis	Coefficients	Standard Error	t Stat	P-value
ERPr	-0.01042932	0.00125722	-8.29554	5.56E-13
ERQty	0.021141923	0.165807541	0.127509	0.898796

APPENDIX 3.10

RESULTS OF STATISTICAL ANALYSIS OF ERROR RATIOS OF POOLED DATA

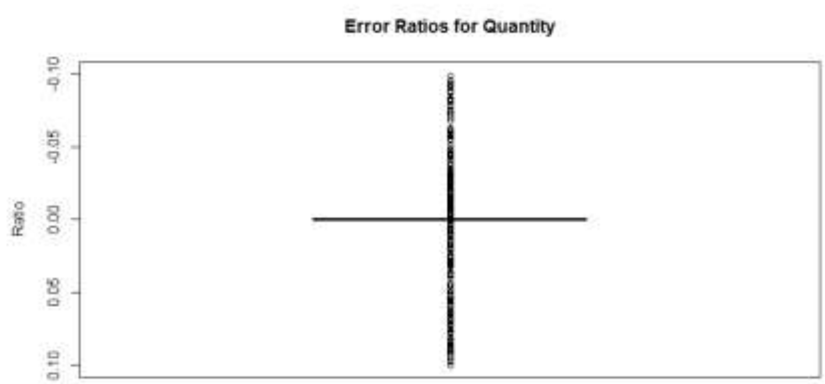
DISTRICT A

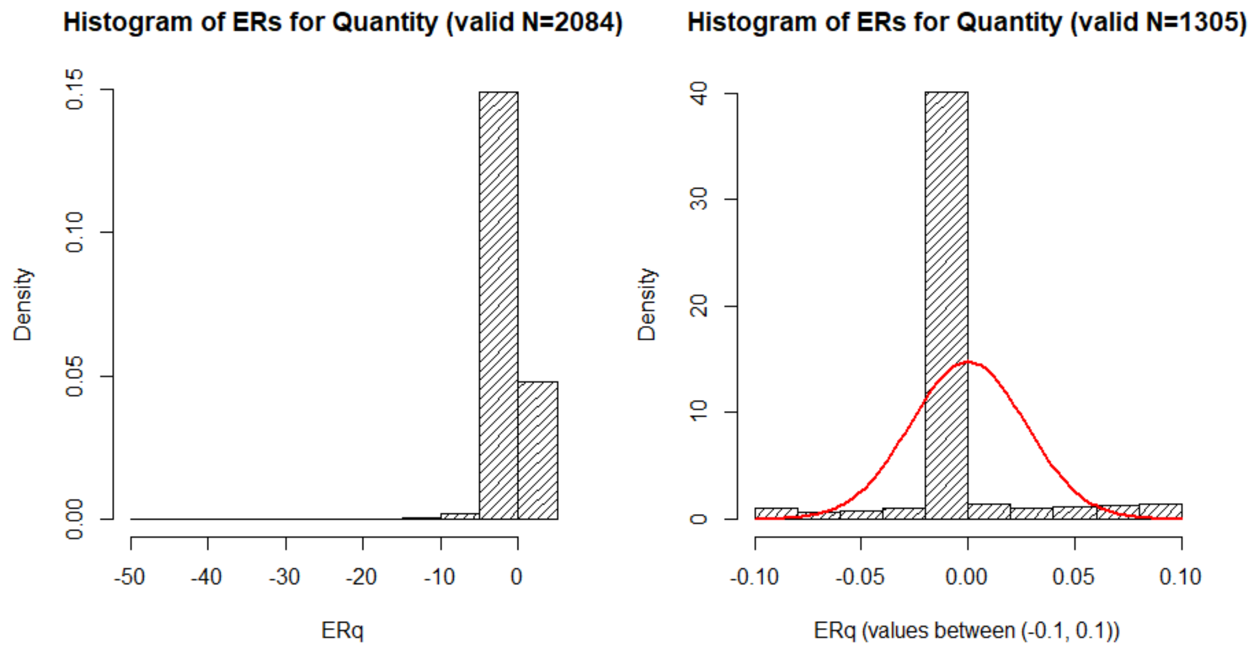
The pooled Austin data have 2089 entries. Due to missing data and estimated quantity being 0 (indicating a planning error), the valid N varies in the following analyses.

1. **Error Ratios for Quantity (valid N=2084)**

Frist, take a look at ERq.

Figure 1. Boxplot and histogram of ERq.





Some notes for explanation of the graphs:

- In the boxplot, we set the boundary of the plot to be (-0.1, 0.1) that gives a zoom-in looking of 1305 cases (62.6% of valid N 2084) with ERq values between (-0.1, 0.1). There are many outliers as we can see from the boxplot. The distribution is negatively skewed with majority of data smaller than or equal to 0.

- The histogram on the left-hand side shows all valid data.
- The histogram on the right-hand side shows the data bounded between -0.1 and 0.1. The high peak in the center is because there are a lot of 0 values (998 of them as shown in Table 1). This even impacts the y-scale. The error rate of quantity equal to 0 means that estimated quantity is same as the actual quantity.
- The red normal curve overlaid in the second histogram shows the normal distribution with mean 0 and standard deviation that is same as the data shown in that histogram (1305 values between -0.1 and 0.1).

Table 1. Distribution of error ratios for quantity. The last row percentages are normal distribution (with mean 0 and same standard deviation with data) percentages for reference.

Percent of ERq's Falling into the Intervals (valid N = 2084)								
ERq < $\bar{x} - 3s$	[$\bar{x} - 3s$, $\bar{x} - 2s$)	[$\bar{x} - 2s$, $\bar{x} - s$)	[$\bar{x} - s$, 0)	$\bar{x}$ = 0	(0, $\bar{x} + s$]	($\bar{x} + s$, $\bar{x} + 2s$]	($\bar{x} + 2s$, $\bar{x} + 3s$]	ERq > $\bar{x} + 3s$
28	8	44	506	998	500	0	0	0

1.3%	0.4%	2.1%	24.3%	47.9%	24.0%	0.0%	0.0%	0.0%
0.15%	2.35%	13.5%	68%			13.5%	2.35%	0.15%

Table 2. Summary statistics for ERq after excluding outliers. (valid N=2081)

Valid N	Mean	SD	Min	Median	Max	Range
2081	-0.21	1.2	-19.98	0	1	20.97

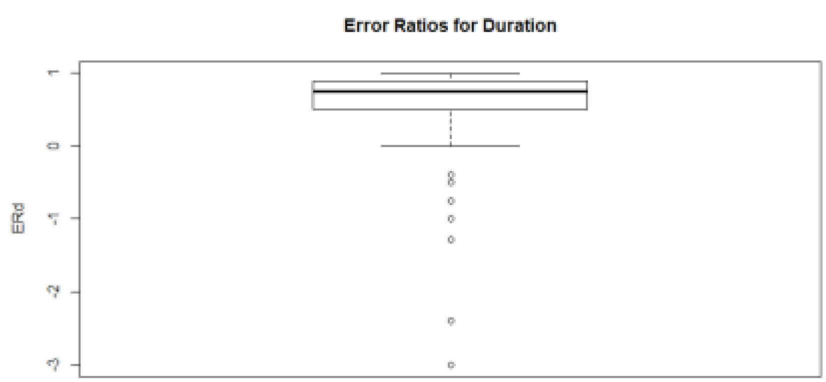
Next, we use non-parametric Wilcoxon signed rank test to test whether the average ERq is less than 0. It yielded significant result (p-value<.001) and the 95% CI for ERq is (-0.1, -0.04). The effect size (Hodges-Lehmann estimator) turned out to be -0.07 indicating a small effect.

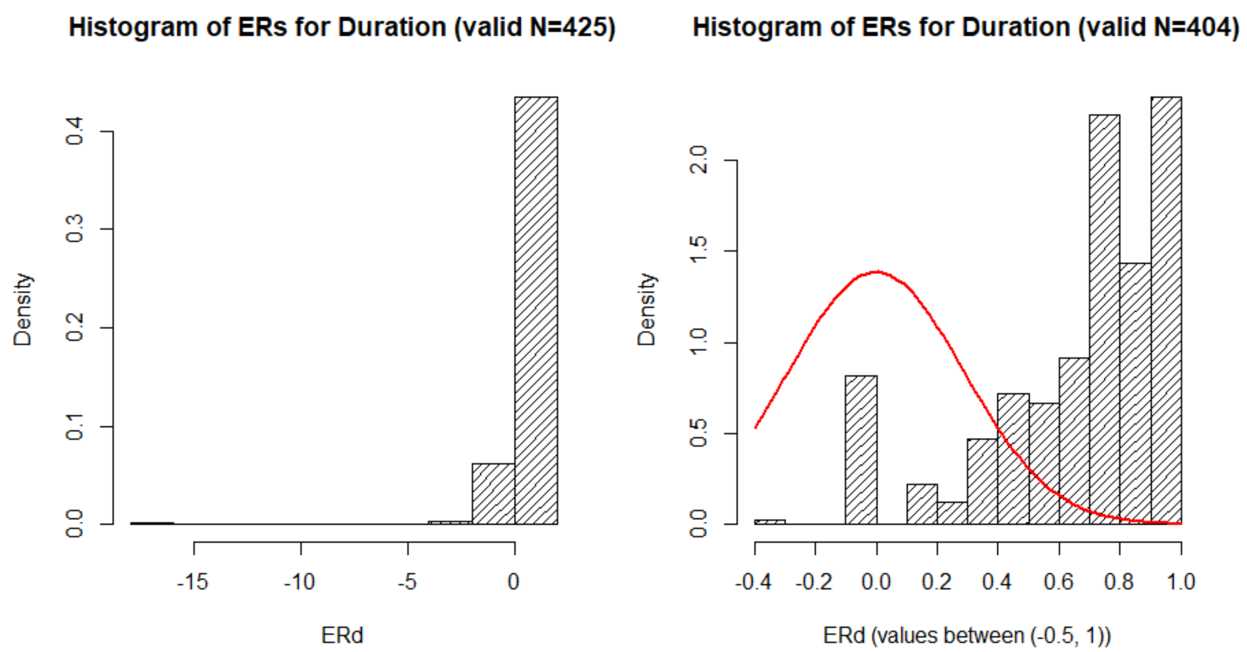
According to these results, we find that the average error rates for quantity is significantly less than 0. **Thus we conclude that the estimated quantities are significantly less than actual quantities for Brownwood district, regardless of construction items. However, it is worth to note that the significance should be taken with caution as the effect size is small.**

2. **Error Ratios for Duration: (valid N=425)**

Frist, take a look at ERd. There is one extreme outlier, -18, that is excluded from the plotting graphs.

Figure 2. Boxplot and histogram of ERd.





Some notes for explanation of the graphs:

- There are a few outliers as we can see from the boxplot. The distribution is negatively skewed with majority of the data bigger than 0.
- The histogram on the left-hand side shows all data and also indicates a negatively skewed distribution.
- The histogram on the right-hand side shows the data bounded between -0.5 and 1. The pattern is so clear that it is negatively skewed with majority of the data bigger than 0. The error rate of duration close to 1 means that estimated duration is much larger than actual duration.
- The red normal curve overlaid in the second histogram shows the normal distribution with mean 0 and standard deviation that is same as the data shown in that histogram (404 values between -0.5 and 1).

Table 3 and 4 display the comparison of data distribution to the normal distribution and the summary statistics.

Table 3. Compare distribution of error ratios for duration to a normal distribution with mean 0 and same standard deviation with data. The percentages in red are normal distribution percentages for reference.

Percent of ERd's Falling into the Intervals (Valid N = 425)								
ERd < $\bar{x}-3s$	[$\bar{x}-3s$, $\bar{x}-2s$)	[$\bar{x}-2s$, $\bar{x}-s$)	[$\bar{x}-s$, 0)	$\bar{x}$ = 0	(0, $\bar{x}+s$]	($\bar{x}+s$, $\bar{x}+2s$]	($\bar{x}+2s$, $\bar{x}+3s$]	ERd $\bar{x}+3s$

1	2	1	18	33	370	0	0	0
0.2%	0.5%	0.2%	4.2%	7.8%	87.1%	0%	0%	0%
0.15%	2.35%	13.5%	68%			13.5%	2.35%	0.1

Table 4. Summary statistics for ERd after excluding outliers. (valid N=424)

Valid N	Mean	SD	Min	Median	Max	Range
424	0.6	0.48	-3	0.75	0.99	3.99

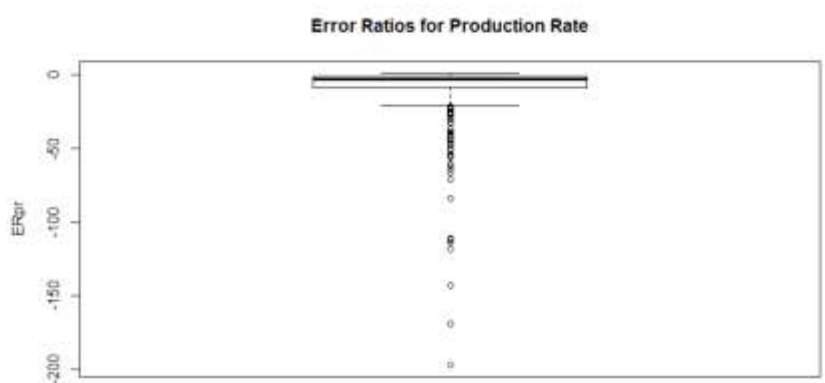
Next, we use non-parametric Wilcoxon signed rank test to test whether the average ERd is greater than 0. It yielded significant result (p-value<.001) and the 95% CI for ERq is (0.72, 0.77). The effect size (Hodges-Lehmann estimator) turned out to be 0.74 indicating a large effect.

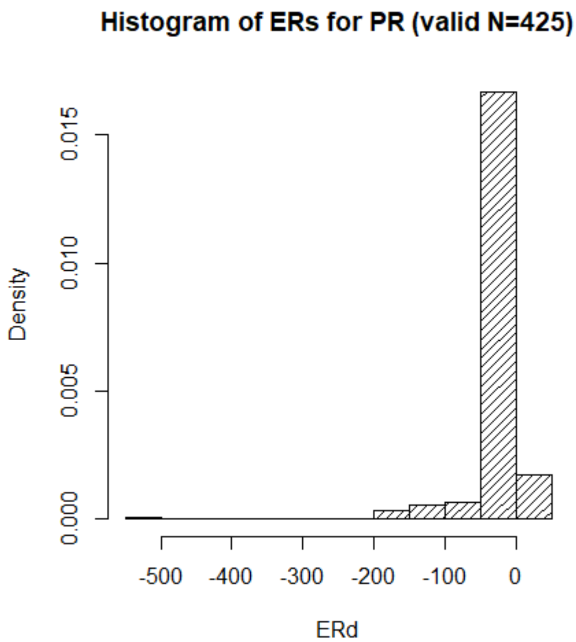
According to these results, we find that the average error rates for duration is significantly greater than 0. **Thus we conclude that the estimated durations are significantly greater than actual durations for Brownwood district, regardless of construction items.**

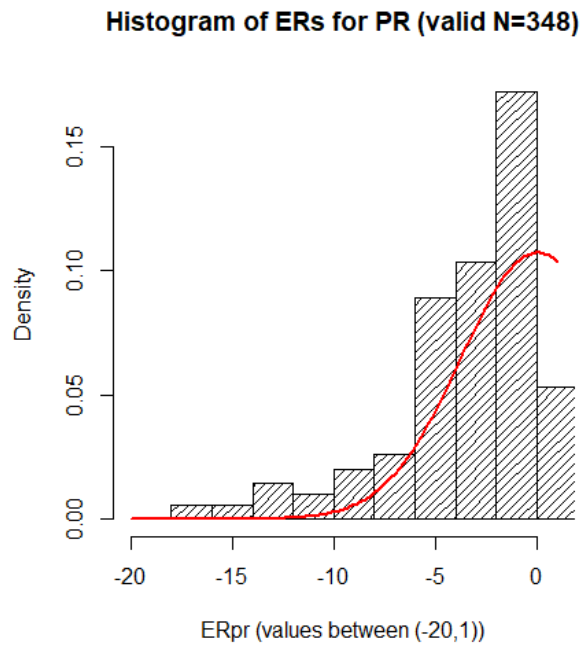
3. <u>Error Ratios for Production Rate (valid N= 425)</u>

Frist, take a look at the error ratios for production rates. There is one extreme outlier, -530.24, that is excluded from the plotting graphs.

Figure 3. Boxplot and histogram of ERpr.







Some notes for explanation of the graphs:

- There are a few outliers as we can see from the boxplot. The distribution is negatively skewed with most of the data less than 0.
- The histogram on the left-hand side shows all data and also indicates a negatively skewed distribution.
- The histogram on the right-hand side shows the data bounded between -20 and 1. The pattern is so clear that it is negatively skewed with majority of the data smaller than 0.
- The red normal curve overlaid in the second histogram shows the normal distribution with mean 0 and standard deviation that is same as the data shown in that histogram (348 values larger than -20).

Table 5 and 6 display the comparison of data distribution to the normal distribution and the summary statistics.

Table 5. Compare distribution of error ratios for production rate to a normal distribution with mean 0 and same standard deviation with data. The percentages in red are normal distribution percentages for reference.

Percent of ERpr's Falling into the Intervals (Valid N = 425)								
ERd < $\bar{x} - 3s$	[$\bar{x} - 3s$, $\bar{x} - 2s$)	[$\bar{x} - 2s$, $\bar{x} - s$)	[$\bar{x} - s$, 0)	$\bar{x}$ = 0	(0, $\bar{x} + s$]	($\bar{x} + s$, $\bar{x} + 2s$]	($\bar{x} + 2s$, $\bar{x} + 3s$]	ERd > $\bar{x} + 3s$
12	9	22	329	16	37	0	0	0
2.8%	2.1%	5.2%	77.4%	3.8%	8.7%	0%	0%	0%

0.15%	2.35%	13.5%	68%	13.5%	2.35%	0.15%

Table 6. Summary statistics for ERpr after excluding outliers. (valid N=413)

Valid N	Mean	SD	Min	Median	Max	Range
424	-14.18	31.83	-197	-3	-0.96	197.96

Next, we use non-parametric Wilcoxon signed rank test to test whether the average ERpr is less than 0. It yielded significant result (p-value<.001) and the 95% CI for ERq is (-6.2, -4.0). The effect size (Hodges-Lehmann estimator) turned out to be -4.9 indicating a large effect.

According to these results, we find that the average error rates for production rates is significantly less than 0. **Thus we conclude that the estimated production rates are significantly less than actual production rates for Brownwood district, regardless of construction items.**

APPENDIX 4.1

WEATHER DATA FROM NOAA WEBSITE FOR ALL 30 PROJECTS

Project Number 0074-02-072					
Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
5/16/2016	888.89	0351-6002	2.27	87	
5/17/2016	1222.22	0351-6002	0	88	
4/11/2016	5939	0354-6002	0.01	80	
4/12/2016	4636	0354-6002	0.02	80	
4/13/2016	5720	0354-6002	0.02	81	
4/26/2016	1536	0354-6002	0	84	
4/28/2016	2111	0354-6002	0	85	
5/3/2016	1462	0354-6002	0	83	
5/5/2016	2888	0354-6002	0	93	
5/16/2016	2267	0354-6002	2.27	87	
5/20/2016	50	0354-6002	0	85	
11/1/2016	12288	0354-6002	0	87	
4/22/2016	1786.26	0344-6120	0	84	
4/23/2016	1318.5	0344-6120	0	83	
4/25/2016	1738.28	0344-6120	0	82	
4/26/2016	1902.81	0344-6120	0	84	

4/27/2016	1641.48	0344-6120	0	86	
4/28/2016	1501.32	0344-6120	0	85	
4/29/2016	1519.02	0344-6120	0	84	
5/2/2016	1453.87	0344-6120	0	78	
5/3/2016	1783.27	0344-6120	0	83	
5/4/2016	819.39	0344-6120	0	90	
5/6/2016	1344.53	0344-6120	0	88	
5/7/2016	518.74	0344-6120	0	85	
5/9/2016	945.49	0344-6120	0.07	87	
5/10/2016	1816.79	0344-6120	0	89	
5/11/2016	1734.17	0344-6120	0	90	
5/12/2016	1655.01	0344-6120	0	88	
5/13/2016	567.87	0344-6120	0	91	
5/20/2016	1344.11	0344-6120	0	85	
5/21/2016	1395.05	0344-6120	0.04	87	
5/23/2016	755.28	0344-6120	0.01	86	
5/24/2016	1130.95	0344-6120	0	88	
5/25/2016	1200.06	0344-6120	0	89	
5/26/2016	1338.54	0344-6120	0	88	
5/27/2016	657.95	0344-6120	0	89	
5/31/2016	809.21	0344-6120	0.16	90	
6/8/2016	1697.64	0344-6120	0	88	

6/9/2016	1107.8	0344-6120	0	88	
6/10/2016	632.04	0344-6120	0	90	
7/1/2016	1958.19	0344-6120	0	91	
11/1/2016	161.96	0344-6120	0	87	
7/27/2016	100911	0666-6315	0	95	
6/30/2016	178040	0533-6001	0	91	
5/5/2016	422	0351-6012	0	93	
5/12/2016	422	0351-6012	0	88	
5/16/2016	422	0351-6012	2.27	87	
5/20/2016	10	0351-6012	0	85	
11/1/2016	546	0351-6012	0	87	
Project Number 0074-03-041					
Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
6/24/2015	70911	0354-2045	0.13	89	
4/29/2015	8666	0354-2045	0	75	
5/26/2015	75338	0354-2045	0	87	
4/28/2015	77845	0354-2045	0.03	78	
6/23/2015	21200	0316-2403	0.15	89	
7/27/2015	10500	0316-2403	0	90	
5/26/2015	26425	0316-2403	0	87	
4/28/2015	3850	0316-2403	0.03	78	
4/29/2015	5450	0316-2403	0	75	

5/26/2015	13725	0316-2403	0	87	
8/24/2015	31350	0316-2403	0	97	
8/25/2015	42850	0316-2403	0	97	
8/26/2015	65450	0316-2403	0	95	
10/19/2015	2000	0316-2403	0	83	
1/5/2016	2050	0316-2403	0	62	
6/24/2015	1991.58	3268-2042	0.13	89	
6/25/2015	1534.41	3268-2042	0	90	
6/26/2015	1662.88	3268-2042	0	90	
6/27/2015	1510.29	3268-2042	0	90	
6/29/2015	1188.37	3268-2042	0	89	
7/27/2015	4631.01	3268-2042	0	90	
8/24/2015	224.54	3268-2042	0	97	
1/5/2016	240	3268-2042	0	62	
1/6/2016	240	3268-2042	0.25	70	
6/27/2015	9036.35	3268-2042	0	90	
1/5/2016	541.44	3268-2042	0	62	
1/6/2016	47.66	3268-2042	0.25	70	
4/29/2015	1629.34	3268-2042	0	75	
5/26/2015	6979.66	3268-2042	0	87	
8/25/2015	8391.98	3268-2042	0	97	
8/26/2015	1715.39	3268-2042	0	95	

8/27/2015	1192.11	3268-2042	0	93	
9/25/2015	16636.59	3268-2042	0	89	
9/28/2015	1200.39	3268-2042	0	89	
9/29/2015	2014.65	3268-2042	0	89	
9/30/2015	1906.71	3268-2042	0	91	
10/19/2015	8003.03	3268-2042	0	83	
6/26/2015	84	0134-2004	0	90	
6/27/2015	84	0134-2004	0	90	
9/29/2015	128	0134-2004	0	89	
6/26/2015	186	0134-2004	0	90	
6/26/2015	184	0134-2004	0	90	
9/29/2015	243	0134-2004	0	89	
9/25/2015	40	0134-2004	0	89	
10/19/2015	718	0134-2004	0	83	
9/18/2015	59188	0533-2006	0.17	89	
9/18/2015	37110	0533-2006	0.17	89	
9/18/2015	6774	0533-2006	0.17	89	
10/27/2015	48454	0533-2006		83	
10/28/2015	60009	0533-2006	0	86	
10/31/2015	72425	0533-2006	0		
8/27/2015	240	0438-2002	0	95	
8/27/2015	560	0438-2002	0	95	

10/26/2015	2000	0438-2002	0	82	
10/28/2015	600	0438-2002	0	86	
7/27/2015	25837	8251-2017	0	90	
9/18/2015	653	8251-2017	0.17	89	
1/5/2016	6138	8251-2017	0	62	
5/26/2015	1167	8251-2017	0	87	
6/27/2015	18341	8251-2017	0	90	
1/5/2016	337	8251-2017	0	62	
5/26/2015	18437	8251-2017	0	87	
9/28/2015	23930	8251-2017	0	89	
9/25/2015	23826	8251-2017	0	89	
10/26/2015	58711	8251-2017	0	82	
11/10/2015	1178	8251-2017	0	84	
1/5/2016	185	8251-2017	0	62	
Project Number 0074-03-042					
Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
9/29/2015	640	0506-6042	0	94	
9/29/2015	210	0506-6042	0	94	
10/26/2015	1022	0351-6013	0	80	
10/27/2015	244	0351-6013	0	82	
10/28/2015	488	0351-6013	0	92	
10/1/2015	25333	0354-6021	0	95	

10/2/2015	19296	0354-6021	0	88	
10/26/2015	85234	0354-6021	0	80	
10/27/2015	3989	0354-6021	0	82	
10/28/2015	36966	0354-6021	0	92	
11/5/2015	47120	0354-6021	0		
10/7/2015	5250	0316-6007	0	89	
10/26/2015	47725	0316-6007	0	80	
10/28/2015	700	0316-6007	0	92	
10/29/2015	1290	0316-6007	0	85	
10/28/2015	4950	0316-6007	0	92	
10/29/2015	8390	0316-6007	0	85	
11/3/2015	5000	0316-6007	0	83	
11/4/2015	9300	0316-6007	0	84	
11/5/2015	6675	0316-6007	0		
10/7/2015	643.23	0344-6120	0	89	
10/26/2015	10968.79	0344-6120	0	80	
10/27/2015	1247.96	0344-6120	0	82	
10/28/2015	596.9	0344-6120	0	92	
10/29/2015	1065.15	0344-6120	0	85	
12/22/2015	104	0344-6120	0	78	
10/28/2015	799.37	0344-6120	0	92	
10/29/2015	512.91	0344-6120	0	85	

11/3/2015	2172.33	0344-6120	0	83	
11/4/2015	2309.78	0344-6120	0	84	
11/5/2015	1942.18	0344-6120	0		
11/6/2015	1056.67	0344-6120	0.05		
11/9/2015	1058.84	0344-6120	0	77	
11/30/2015	616	0438-6001	0.01	59	
11/17/2015	31228	0666-6314	0.06	80	
11/17/2015	19679	0666-6314	0.06	80	

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Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
7/9/2013	10272	0354-2045	0	97	
7/11/2013	12089	0354-2045	0	98	
7/12/2013	8444	0354-2045	0	98	
7/22/2013	12667	0354-2045	0	94	
7/23/2013	12667	0354-2045	0	95	
7/24/2013	12667	0354-2045	0	95	
7/25/2013	10978	0354-2045	0	96	
8/7/2013	15150	0354-2045	0	99	
8/8/2013	12667	0354-2045	0	98	
8/9/2013	8444	0354-2045	0	98	
8/12/2013	7406	0354-2045	0	97	
8/13/2013	13511	0354-2045	0	101	

8/14/2013	12667	0354-2045	0	102	
8/15/2013	12652	0354-2045	0	97	
9/11/2013	16889	0354-2045	0.09	88	
9/30/2013	16889	0354-2045	0	87	
10/2/2013	16889	0354-2045	0	89	
10/3/2013	16889	0354-2045	0.02	88	
10/4/2013	7786	0354-2045	0	89	
10/31/2013	8467	0354-2045	0.17	87	
7/10/2013	435	0351-2002	0	97	
8/20/2013	59	0351-2002	0.26	84	
8/29/2013	41.55	0351-2002	0	98	
7/11/2013	1930	0316-2403	0	98	
7/12/2013	1300	0316-2403	0	98	
7/15/2013	750	0316-2403	0	96	
7/22/2013	7775	0316-2403	0	94	
7/23/2013	5065	0316-2403	0	95	
7/24/2013	5055	0316-2403	0	95	
7/25/2013	5900	0316-2403	0	96	
7/26/2013	3790	0316-2403	0	96	
8/12/2013	3980	0316-2403	0	97	
8/13/2013	5930	0316-2403	0	101	
8/14/2013	10860	0316-2403	0	102	

8/15/2013	5031	0316-2403	0	97	
8/16/2013	2035	0316-2403	0.24	99	
8/29/2013	5100	0316-2403	0	98	
9/3/2013	1925	0316-2403	0	92	
9/25/2013	6725	0316-2403	0	92	
10/3/2013	3755	0316-2403	0.02	88	
10/8/2013	1980	0316-2403	0	82	
10/9/2013	8100	0316-2403	0	85	
10/10/2013	5260	0316-2403	0	87	
10/17/2013	2770	0316-2403	0	78	
7/29/2013	1123.69	3224-2048	0	94	
7/30/2013	577.29	3224-2048	0	96	
7/31/2013	1513.88	3224-2048	0	97	
8/1/2013	1220.85	3224-2048	0	99	
8/2/2013	434.94	3224-2048	0	98	
8/5/2013	1420.78	3224-2048	0	98	
8/6/2013	780.18	3224-2048	0	99	
8/13/2013	11.83	3224-2048	0	101	
8/19/2013	2466.4	3224-2048	0	96	
8/21/2013	1224.05	3224-2048	0	95	
8/22/2013	2035.03	3224-2048	0.01	96	
8/28/2013	410.55	3224-2048	0	94	

9/4/2013	1132.55	3224-2048	0	91	
9/5/2013	827.54	3224-2048	0	92	
9/23/2013	800.17	3224-2048		87	
9/24/2013	1072.39	3224-2048	0	93	
9/26/2013	374.23	3224-2048	0	90	
9/27/2013	186.6	3224-2048	0	90	
10/8/2013	1141.69	3224-2048	0	82	
10/9/2013	1508.83	3224-2048	0	85	
10/10/2013	1169.79	3224-2048	0	87	
10/11/2013	283.28	3224-2048	0	88	
10/15/2013	1513.2	3224-2048	0	86	
10/17/2013	1844.68	3224-2048	0	78	
10/21/2013	487.34	3224-2048	0.99	81	
10/28/2013	1159.58	3224-2048	0		
10/30/2013	900	0540-2001	0	85	
11/21/2013	1850	0540-2001	0	75	
10/21/2013	914	0666-2005	0.99	81	
10/22/2013	103	0666-2005	0		
Project Number 0074-06-222					
Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
9/20/2015	4874	0354-6003	0	88	
9/21/2015	4874	0354-6003	0	88	

9/22/2015	6007	0354-6003	0	90	
9/23/2015	6370	0354-6003	0	89	
9/24/2015	1794	0354-6003	0	90	
9/27/2015	4094	0354-6003	0	88	
9/28/2015	5422	0354-6003	0	92	
9/29/2015	6383	0354-6003	0	94	
9/30/2015	2722	0354-6003	0	95	
10/1/2015	2226	0354-6003	0	95	
10/4/2015	2528	0354-6003	0	86	
10/5/2015	3375	0354-6003	0	89	
10/6/2015	4400	0354-6003	0	89	
10/7/2015	4908	0354-6003	0	89	
10/12/2015	3719	0354-6003	0	93	
10/13/2015	6267	0354-6003	0	94	
10/14/2015	4227	0354-6003	0	94	
10/15/2015	7129	0354-6003	0	90	
10/16/2015	1161	0354-6003	0	87	
10/19/2015	4644	0354-6003	0	83	
10/20/2015	5543	0354-6003	0	87	
10/21/2015	4117	0354-6003	0.13	87	
10/26/2015	7447	0354-6003	0	80	
10/27/2015	7351	0354-6003	0	82	

10/28/2015	7447	0354-6003	0	92	
10/29/2015	7050	0354-6003	0	85	
11/2/2015	2841	0354-6003	0	81	
11/3/2015	3114	0354-6003	0	83	
11/4/2015	6535	0354-6003	0	84	
11/5/2015	5111	0354-6003	0		
11/8/2015	7143	0354-6003	0	74	
11/9/2015	2333	0354-6003	0	77	
11/10/2015	7181	0354-6003	0	84	
9/20/2015	1350	0316-6001	0	88	
9/21/2015	1350	0316-6001	0	88	
9/22/2015	1500	0316-6001	0	90	
9/23/2015	1680	0316-6001	0	89	
9/24/2015	450	0316-6001	0	90	
9/27/2015	1100	0316-6001	0	88	
9/28/2015	1450	0316-6001	0	92	
9/29/2015	1650	0316-6001	0	94	
9/30/2015	700	0316-6001	0	95	
10/1/2015	650	0316-6001	0	95	
10/4/2015	750	0316-6001	0	86	
10/5/2015	950	0316-6001	0	89	
10/6/2015	1250	0316-6001	0	89	

10/7/2015	1206	0316-6001	0	89	
10/12/2015	1100	0316-6001	0	93	
10/13/2015	1700	0316-6001	0	94	
10/14/2015	1150	0316-6001	0	94	
10/15/2015	1950	0316-6001	0	90	
10/16/2015	300	0316-6001	0	87	
10/19/2015	1300	0316-6001	0	83	
10/20/2015	1500	0316-6001	0	87	
10/21/2015	1050	0316-6001	0.13	87	
10/26/2015	1900	0316-6001	0	80	
10/27/2015	1900	0316-6001	0	82	
10/28/2015	1950	0316-6001	0	92	
10/29/2015	1900	0316-6001	0	85	
11/1/2015	550	0316-6001	0.03	82	
11/2/2015	750	0316-6001	0	81	
11/3/2015	850	0316-6001	0	83	
11/4/2015	1750	0316-6001	0	84	
11/5/2015	1350	0316-6001	0		
11/8/2015	1950	0316-6001	0	74	
11/9/2015	650	0316-6001	0	77	
11/10/2015	1844	0316-6001	0	84	
9/20/2015	681.99	0341-6089	0	88	

9/21/2015	681.99	0341-6089	0	88	
9/22/2015	845.8	0341-6089	0	90	
9/23/2015	859.19	0341-6089	0	89	
9/24/2015	257.1	0341-6089	0	90	
9/27/2015	588.05	0341-6089	0	88	
9/28/2015	752.56	0341-6089	0	92	
9/29/2015	870.41	0341-6089	0	94	
9/30/2015	396.23	0341-6089	0	95	
10/1/2015	303.06	0341-6089	0	95	
10/4/2015	379.31	0341-6089	0	86	
10/5/2015	540.97	0341-6089	0	89	
10/6/2015	586.77	0341-6089	0	89	
10/7/2015	645.07	0341-6089	0	89	
10/12/2015	562.18	0341-6089	0	93	
10/13/2015	794.47	0341-6089	0	94	
10/14/2015	634.27	0341-6089	0	94	
10/15/2015	961.4	0341-6089	0	90	
10/16/2015	164.19	0341-6089	0	87	
10/19/2015	610.09	0341-6089	0	83	
10/20/2015	801.96	0341-6089	0	87	
10/21/2015	569.38	0341-6089	0.13	87	
10/26/2015	1018.35	0341-6089	0	80	

10/27/2015	1015.64	0341-6089	0	82	
10/28/2015	1019.65	0341-6089	0	92	
10/29/2015	1002.75	0341-6089	0	85	
11/1/2015	299.94	0341-6089	0.03	82	
11/2/2015	402.97	0341-6089	0	81	
11/3/2015	451.67	0341-6089	0	83	
11/4/2015	928.4	0341-6089	0	84	
11/5/2015	668.22	0341-6089	0		
11/8/2015	974.77	0341-6089	0	74	
11/9/2015	332.56	0341-6089	0	77	
11/10/2015	903.88	0341-6089	0	84	
9/28/2015	534	0351-6019	0	92	
9/30/2015	200	0351-6019	0	95	
11/9/2015	306	0351-6019	0	77	
12/2/2015	632	0348-6009	0	60	
12/3/2015	663	0348-6009	0	64	
12/4/2015	652	0348-6009	0	64	
12/5/2015	768	0348-6009	0	68	
12/6/2015	383	0348-6009	0	75	
12/7/2015	761	0348-6009	0	73	
12/16/2015	527	0348-6009	0	72	
12/17/2015	710	0348-6009	0	69	

12/18/2015	237	0348-6009	0	61	
12/19/2015	683	0348-6009	0	73	
12/20/2015	616	0348-6009	0	78	
12/21/2015	730	0348-6009	0	77	
12/22/2015	285	0348-6009	0	78	
1/22/2016	0.13	0348-6009	0	65	
12/21/2015	774	0438-6001	0	77	
1/22/2016	766	0438-6001	0	65	
3/23/2016	221	0438-6001	0	79	
7/31/2016	880	0438-6001	0	95	
1/20/2016	12810	0666-6315	0	77	
3/31/2016	11498	0666-6315	0	90	
9/27/2015	10	0432-6001	0	88	
9/28/2015	10	0432-6001	0	92	
9/29/2015	20	0432-6001	0	94	
9/30/2015	10	0432-6001	0	95	
10/1/2015	10	0432-6001	0	95	
10/4/2015	10	0432-6001	0	86	
10/5/2015	14.5	0432-6001	0	89	
10/6/2015	18.5	0432-6001	0	89	
10/7/2015	16	0432-6001	0	89	
10/12/2015	9	0432-6001	0	93	

10/20/2015	10	0432-6001	0	87	
10/21/2015	14.5	0432-6001	0.13	87	
10/26/2015	10	0432-6001	0	80	
10/27/2015	17	0432-6001	0	82	
10/28/2015	17	0432-6001	0	92	
10/29/2015	10	0432-6001	0	85	
11/1/2015	15.5	0432-6001	0.03	82	
11/2/2015	8	0432-6001	0	81	
3/21/2016	741	0636-6009	0	66	
3/22/2016	453.75	0636-6009	0	77	
3/23/2016	737.5	0636-6009	0	79	
3/24/2016	913	0636-6009	0	75	
4/29/2016	97.75	0636-6009	0	84	
3/21/2016	5	0644-6001	0	66	
3/22/2016	1	0644-6001	0	77	
3/23/2016	4	0644-6001	0	79	
3/28/2016	2	0644-6001	0	72	
3/31/2016	8	0644-6001	0	90	
4/29/2016	1	0644-6001	0	84	

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Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
11/26/2014	448	0464-2003	0	74	

1/30/2015	784	0464-2003	0	66	
2/26/2015	204	0464-2003	0	67	
3/3/2015	16	0464-2003	0.01	68	
7/29/2015	144	0464-2003	0	97	
9/19/2015	8	0464-2003	0	89	
1/22/2015	9	0112-2002	0.97	71	
3/30/2015	10	0112-2002	0	80	
3/31/2015	30	0112-2002	0	80	
4/30/2015	13	0112-2002	0	81	
5/28/2015	50	0112-2002	0	88	
1/30/2015	2862.702	0247-2366	0	66	
2/26/2015	68	0247-2366	0	67	
3/30/2015	456	0247-2366	0	80	
4/30/2015	2198	0247-2366	0	81	
5/28/2015	2421.3	0247-2366	0	88	
6/12/2015	32086	0354-2048	0	92	
6/12/2015	6945	0316-2015	0	92	
6/16/2015	3450	0316-2015	0	90	
6/22/2015	190	0316-2015	0	89	
7/31/2015	530	0316-2015	0.62	101	
6/25/2015	2043	0351-2002	0.1	91	
7/31/2015	2042	0351-2002	0.62	101	

6/12/2015	9280	0316-2403	0	92	
6/25/2015	5540	0316-2403	0.1	91	
6/26/2015	275	0316-2403	0	91	
7/14/2015	1325	0316-2403	0	95	
6/29/2015	1278.44	3268-2042	0	91	
6/30/2015	579.39	3268-2042	0.05	89	
7/2/2015	345.88	3268-2042	0	89	
7/3/2015	647.84	3268-2042	0	91	
7/6/2015	905.12	3268-2042	0	92	
7/31/2015	5462.97	3268-2042	0.62	101	
8/26/2015	2.31	3268-2042	0	91	
7/31/2015	27564	8251-2017	0.62	101	

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Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
8/18/2009	12805	0354-2045	0	97	
8/24/2009	151.34	0318-2002	0	100	
8/25/2009	144.82	0318-2002	0	99	
8/26/2009	123.43	0318-2002	0	98	
8/27/2009	50.22	0318-2002	0	98	
9/14/2009	817.2	0341-2032	0	92	
9/15/2009	1439.16	0341-2032	0	95	
9/16/2009	1486.89	0341-2032	0	96	

9/17/2009	1139.06	0341-2032	0	95	
9/18/2009	966.35	0341-2032	0	93	
9/21/2009	907.38	0341-2032	0	94	
9/25/2009	566.75	0341-2032	0	85	
9/29/2009	519.47	0341-2032	0.18	87	
10/16/2009	1034.57	0341-2032	0	84	
10/17/2009	1087.96	0341-2032	0	80	
10/19/2009	1442.85	0341-2032	0	83	
10/20/2009	1625.89	0341-2032	0.06	85	
10/23/2009	938.79	0341-2032	0	79	
10/27/2009	944.72	0341-2032	0	73	
10/28/2009	293.14	0341-2032	0	83	
10/29/2009	1107.72	0341-2032	0.03	86	
10/30/2009	1153.81	0341-2032	0	73	
11/3/2009	892.86	0341-2032	0	76	
11/4/2009	697.82	0341-2032	0.01		
11/5/2009	812.46	0341-2032	0	78	
11/6/2009	784.79	0341-2032	0.01		
11/9/2009	145.42	0341-2032	0.01		
11/10/2009	986.44	0341-2032	0	81	
11/11/2009	1268.39	0341-2032	0	80	
11/12/2009	796.22	0341-2032	0	77	

11/13/2009	679.52	0341-2032	0.01	80	
11/16/2009	913.8	0341-2032	0	76	
11/17/2009	846.7	0341-2032	0	70	
11/18/2009	875.1	0341-2032	0	71	
11/19/2009	752.22	0341-2032	1.64	78	
8/19/2009	200	0540-2001	0	99	
8/20/2009	325	0540-2001	0	99	
8/31/2009	1175	0540-2001	0	95	
9/14/2009	875	0540-2001	0	92	
9/15/2009	175	0540-2001	0	95	
9/17/2009	350	0540-2001	0	95	
10/5/2009	100	0540-2001	0	93	
10/14/2009	625	0540-2001	0	93	
11/30/2009	275	0540-2001	0.24		

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Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
10/19/2015	8444	0354-6113	0	83	
10/20/2015	14731	0354-6113	0	87	
10/28/2015	23175	0354-6113	0	92	
11/6/2015	333	0354-6113	0.05		
11/9/2015	25707	0354-6113	0	77	
11/10/2015	20641	0354-6113	0	84	

11/19/2015	24020	0354-6113	0	79	
12/1/2015	21956	0354-6113	0.01	56	
12/2/2015	3088	0354-6113	0	60	
12/9/2015	16889	0354-6113	0	83	
12/10/2015	15366	0354-6113	0	87	
12/28/2015	24280.33	0354-6113	0	59	
1/4/2016	24440	0354-6113	0	63	
1/6/2016	8600	0354-6113	0.25	70	
10/21/2015	6667	0351-6012	0.13	87	
10/29/2015	13334	0351-6012	0	85	
11/11/2015	13333	0351-6012	0	85	
12/3/2015	6933	0351-6012	0	64	
12/11/2015	9141	0351-6012	0	83	
12/29/2015	6865.33	0351-6012	0	55	
1/5/2016	4857	0351-6012	0	62	
1/7/2016	9693	0351-6012	0	69	
1/12/2016	855	0351-6012	0	66	
3/31/2016	600	0316-6001	0	90	
4/27/2016	2470	0316-6001	0	86	
10/21/2015	2150	0316-6001	0.13	87	
10/26/2015	3800	0316-6001	0	80	
10/27/2015	2600	0316-6001	0	82	

11/2/2015	3900	0316-6001	0	81	
11/3/2015	3800	0316-6001	0	83	
11/12/2015	5150	0316-6001	0.31	75	
11/13/2015	3450	0316-6001	0	72	
11/14/2015	6800	0316-6001	0	77	
11/17/2015	2400	0316-6001	0.06	80	
11/18/2015	950	0316-6001	0	77	
11/23/2015	2500	0316-6001	0	65	
11/24/2015	4550	0316-6001	0	76	
11/25/2015	2650	0316-6001	0.08	73	
12/4/2015	5750	0316-6001	0	64	
12/7/2015	5350	0316-6001	0	73	
12/14/2015	5150	0316-6001	0	76	
12/15/2015	1550	0316-6001	0	80	
12/16/2015	6800	0316-6001	0	72	
1/8/2016	4650	0316-6001	0	67	
1/9/2016	4650	0316-6001	0	66	
1/13/2016	5050	0316-6001	0	67	
1/14/2016	4350	0316-6001	0	73	
1/15/2016	4650	0316-6001	0	80	
1/18/2016	4100	0316-6001	0	69	
4/27/2016	6880	0316-6001	0	86	

10/26/2015	471.04	0341-6042	0	80	
10/27/2015	1694.71	0341-6042	0	82	
11/2/2015	190.76	0341-6042	0	81	
11/4/2015	1526.92	0341-6042	0	84	
11/5/2015	1246.67	0341-6042	0		
11/6/2015	46.86	0341-6042	0.05		
11/12/2015	989.33	0341-6042	0.31	75	
11/13/2015	1508.02	0341-6042	0	72	
11/14/2015	1392.28	0341-6042	0	77	
11/16/2015	281.83	0341-6042	0	84	
11/17/2015	232.19	0341-6042	0.06	80	
11/20/2015	47.37	0341-6042	0.05	78	
11/24/2015	1434.53	0341-6042	0	76	
11/25/2015	613.63	0341-6042	0.08	73	
12/2/2015	232.41	0341-6042	0	60	
12/3/2015	46.41	0341-6042	0	64	
12/4/2015	1085.89	0341-6042	0	64	
12/8/2015	1310.99	0341-6042	0	74	
12/14/2015	711.57	0341-6042	0	76	
12/15/2015	1265.3	0341-6042	0	80	
12/16/2015	1293.41	0341-6042	0	72	
12/17/2015	1007.39	0341-6042	0	69	

12/18/2015	234.36	0341-6042	0	61	
1/5/2016	71.37	0341-6042	0	62	
1/8/2016	983.57	0341-6042	0	67	
1/9/2016	1073.62	0341-6042	0	66	
1/13/2016	1193.84	0341-6042	0	67	
1/14/2016	1109.33	0341-6042	0	73	
1/15/2016	1075	0341-6042	0	80	
1/18/2016	373.65	0341-6042	0	69	
1/19/2016	561.8	0341-6042	0	74	
3/28/2016	1030.57	0341-6042	0	72	
4/29/2016	45.97	0341-6042	0	84	
5/26/2016	1.68	0341-6042	0	87	
2/12/2016	308	0438-6001	0	76	
11/19/2015	16950	0666-6011	0	79	
12/15/2015	7810	0666-6011	0	80	
12/29/2015	9664	0666-6011	0	55	
1/21/2016	15598	0666-6011	0	79	
5/6/2016	6410	0666-6011	0	84	

Project Number 0101-05-035					
Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
3/29/2016	5200	0354-6051	0	77	
3/23/2016	17750	0354-6051	0	79	

1/29/2016	74039	0354-6051	0	78	
3/29/2016	12075	0316-6010	0	77	
3/31/2016	7515	0316-6010	0	90	
4/26/2016	25920	0316-6010	0	84	
4/28/2016	2000	0316-6010	0	85	
5/23/2016	10875	0316-6010	0	86	
6/1/2016	25	0316-6010		88	
3/23/2016	6125	0316-6010	0	79	
1/25/2016	475	0316-6010	0	77	
2/24/2016	26615	0316-6010	0	69	
1/20/2016	12225	0316-6010	0	77	
4/26/2016	9249.8	0341-6042	0	84	
4/29/2016	1162.42	0341-6042	0	84	
5/23/2016	4770.62	0341-6042	0	86	
3/23/2016	1690.39	0341-6042	0	79	
5/23/2016	24225	0666-6011	0	86	
3/23/2016	2957	0666-6011	0	79	
5/31/2016	647	0666-6011	0.26	89	
3/23/2016	18607	0666-6011	0	79	
5/31/2016	1075	0666-6011	0.26	89	
11/23/2015	9839	0666-6011	0	65	
12/28/2015	7661	0666-6011	0	59	

12/31/2015	8	0666-6011	0	58	

Project Number 0101-03-082					
Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
5/29/2012	117643	0354-2045	0	90	
5/30/2012	25550	0316-2403	0	89	
6/26/2012	93875	0316-2403	0	106	
6/26/2012	9482.85	3224-2027	0	106	
6/27/2012	3222.96	3224-2027	0	101	
6/28/2012	2385.1	3224-2027	0	97	
7/26/2012	24787.15	3224-2027	0	95	
7/26/2012	6630	0530-2017	0	95	

Project Number 0101-04-108					
Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
4/25/2011	59875	0354-2041	0	84	
4/28/2011	14968.75	0354-2041	0	79	
5/31/2011	44906.25	0354-2041	0	89	
5/11/2011	888.1	0341-2104	0	84	
5/12/2011	1101.49	0341-2104	0.15	83	
5/16/2011	1280.26	0341-2104	0	81	
5/17/2011	1161.38	0341-2104	0	83	
5/18/2011	842.49	0341-2104	0	82	
5/19/2011	661.96	0341-2104	0	85	

5/20/2011	1361.59	0341-2104	0	88	
5/23/2011	903.4	0341-2104	0	90	
5/24/2011	1797.9	0341-2104	0	93	
5/25/2011	1604.81	0341-2104	0	94	
5/26/2011	688.96	0341-2104	0	95	
4/13/2011	3050	0316-2403	0	80	
4/14/2011	6820	0316-2403	0	82	
4/17/2011	2010	0316-2403	0	79	
4/18/2011	4385	0316-2403	0	84	
4/19/2011	3340	0316-2403	0	84	
4/20/2011	1595	0316-2403	0	83	
4/25/2011	2440	0316-2403	0	84	
4/26/2011	3220	0316-2403	0	85	
4/27/2011	2340	0316-2403	0	96	
4/28/2011	2670	0316-2403	0	79	
5/2/2011	2720	0316-2403	0.05	77	
5/10/2011	6260	0316-2403	0	90	

Project Number 0254-01-130					
Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
5/31/2011	27463.5	0354-2045	0	94	
6/1/2011	244	0354-2045	0	91	
6/6/2011	8118.5	0354-2045	0	97	

6/7/2011	9251	0354-2045	0	96	
6/8/2011	2196	0354-2045	0	95	
5/31/2011	6053	0351-2002	0	94	
6/9/2011	2792	0351-2002	0	90	
5/31/2011	5740	0316-2403	0	94	
6/1/2011	2300	0316-2403	0	91	
6/2/2011	450	0316-2403	0	87	
6/3/2011	400	0316-2403	0	89	
6/9/2011	3350	0316-2403	0	90	
6/11/2011	2350	0316-2403	0	95	
5/31/2011	1012	0662-2115	0	94	
6/1/2011	524	0662-2115	0	91	
6/6/2011	351	0662-2115	0	97	
6/7/2011	68	0662-2115	0	96	
6/10/2011	694	0662-2115	0	95	
5/31/2011	988.65	0341-2064	0	94	
6/2/2011	1047.86	0341-2064	0	87	
6/3/2011	902.88	0341-2064	0	89	
6/10/2011	1068.14	0341-2064	0	95	
6/13/2011	1107.35	0341-2064	0	96	
6/14/2011	233.08	0341-2064	0	98	
6/15/2011	1964	0530-2005	0	96	

6/18/2011	523	0666-2035	0	97	
7/20/2011	21	0644-2022	0	97	

Project Number 0254-01-137

Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
9/18/2015	1780	1122-2049	0.17	89	
4/28/2015	31079	0351-2002	0.03	78	
7/21/2015	234	0351-2002	0	90	
7/30/2015	1382.66	0351-2002	0	99	
7/31/2015	2513.34	0351-2002	0.62	101	
8/6/2015	3556.34	0351-2002	0	91	
8/25/2015	1066.66	0351-2002	0	97	
11/11/2015	0.01	0351-2002	0	85	
11/12/2015	4666.67	0351-2002	0.31	75	
12/8/2015	73.33	0351-2002	0	74	
6/27/2015	2123	0530-2073	0	90	
8/3/2015	19262	0316-2403	2.09	90	
8/4/2015	4575	0316-2403	0	92	
8/5/2015	16200	0316-2403	0	94	
8/6/2015	12600	0316-2403	0	95	
8/7/2015	3300	0316-2403	0	95	
11/11/2015	750	0316-2403	0	85	
11/13/2015	1700	0316-2403	0	68	

3/2/2016	134	0316-2403	0	77	
6/1/2015	400	0540-2001	0	85	
6/2/2015	175	0540-2001	0	86	
6/6/2015	175	0540-2001	0	87	
6/26/2015	425	0540-2001	0	90	
10/2/2015	3903	0666-2035	0	85	
10/6/2015	505	0666-2035	0	86	
12/17/2015	1170	0666-2035	0	69	
3/1/2016	30	0666-2035	0	86	
Project Number 0348-06-023					
Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
9/17/2015	4302.2	0275-6038	0	90	
9/18/2015	4124.4	0275-6038	0.17	89	
9/21/2015	3946.6	0275-6038	0	87	
9/22/2015	3946.6	0275-6038	0	89	
10/13/2015	12799.94	0275-6038	0	90	
10/19/2015	4088.9	0275-6038	0	83	
10/21/2015	4444.44	0275-6038	0.04	88	
10/27/2015	4444.44	0275-6038		83	
2/3/2016	3314	0275-6038	0	67	
2/4/2016	3314	0275-6038	0	62	
2/8/2016	3314	0275-6038	0	72	

2/9/2016	3314	0275-6038	0	72	
2/10/2016	3314	0275-6038	0	69	
2/11/2016	3314	0275-6038	0	75	
2/15/2016	3314	0275-6038	0	82	
2/16/2016	3314	0275-6038	0	76	
2/17/2016	3314	0275-6038	0	73	
2/18/2016	3314	0275-6038	0	77	
2/24/2016	2631	0275-6038	0	69	
2/26/2016	2631	0275-6038	0	67	
3/31/2016	3313.78	0275-6038	0	90	
4/1/2016	3314	0275-6038	0	76	
4/4/2016	3314	0275-6038	0	79	
4/5/2016	3314	0275-6038	0	77	
4/6/2016	3314	0275-6038	0	81	
4/7/2016	3314	0275-6038	0	81	
4/11/2016	4985	0275-6038	0.01	80	
4/12/2016	4985	0275-6038	0.02	80	
4/13/2016	4971	0275-6038	0.02	81	
4/14/2016	4971	0275-6038	0	80	
5/26/2016	34161.78	0275-6038	0	88	
6/6/2016	10666.67	0275-6038	0.44	87	
7/12/2016	4977.7	0275-6038	0	92	

7/13/2016	4977.7	0275-6038	0	93	
7/14/2016	4977.7	0275-6038	0	93	
7/15/2016	4977.77	0275-6038	0	94	
7/19/2016	4977.77	0275-6038	0	94	
7/20/2016	4977.77	0275-6038	0	94	
7/21/2016	3338.6	0275-6038	0	94	
7/22/2016	3338.6	0275-6038	0	94	
9/14/2016	4977.77	0275-6038	0	92	
9/15/2016	4977.77	0275-6038	0.04	92	
9/19/2016	5066.66	0275-6038	0	94	
9/20/2016	5066.66	0275-6038	0	94	
9/22/2016	3313.77	0275-6038	1.98	91	
9/23/2016	3313.77	0275-6038	0.02	92	
9/28/2016	3352.88	0275-6038	0	88	
9/29/2016	3352.88	0275-6038	0	90	
10/12/2016	5066.66	0275-6038	0	89	
10/13/2016	5066.66	0275-6038	0	89	
12/13/2016	2400	0275-6038	0	76	
12/14/2016	2400	0275-6038	0	66	
9/28/2015	17774	5001-6002	0	89	
10/13/2015	19054.2	5001-6002	0	90	
11/13/2015	8629.3	5001-6002	0	72	

2/9/2016	4978	5001-6002	0	72	
2/10/2016	1422	5001-6002	0	69	
2/11/2016	5689	5001-6002	0	75	
2/15/2016	4622	5001-6002	0	82	
2/17/2016	1778	5001-6002	0	73	
2/18/2016	5333	5001-6002	0	77	
2/29/2016	6400	5001-6002	0	78	
3/1/2016	5689	5001-6002	0	80	
3/2/2016	2489	5001-6002	0	77	
4/6/2016	6044	5001-6002	0	81	
4/7/2016	6756	5001-6002	0	81	
4/11/2016	4622	5001-6002	0.01	80	
4/13/2016	7822	5001-6002	0.02	81	
4/14/2016	3911	5001-6002	0	80	
4/19/2016	6400	5001-6002	0	80	
4/20/2016	3733	5001-6002	0	82	
5/26/2016	34666.67	5001-6002	0	88	
6/16/2016	9244.44	5001-6002	0	91	
7/28/2016	31644.4	5001-6002	0	95	
8/1/2016	3911.11	5001-6002	0		
8/26/2016	4764.43	5001-6002	0	92	
9/19/2016	2844.44	5001-6002	0	94	

9/20/2016	35555.55	5001-6002	0	94	
9/21/2016	3022.22	5001-6002	0	93	
9/22/2016	387.02	5001-6002	1.98	91	
12/15/2016	266.66	5001-6002	0	63	
12/16/2016	1777.77	5001-6002	0.08	76	
12/19/2016	3200	5001-6002	0	48	
12/20/2016	711.11	5001-6002	0	54	
9/28/2015	2869.27	0247-6041	0	89	
10/13/2015	2602.07	0247-6041	0	90	
10/20/2015	5059.5	0247-6041	0	85	
11/13/2015	1447.3	0247-6041	0	72	
12/23/2015	568.62	0247-6041	0	82	
2/9/2016	667	0247-6041	0	72	
2/10/2016	190.5	0247-6041	0	69	
2/11/2016	762.5	0247-6041	0	75	
2/15/2016	320.5	0247-6041	0	82	
2/17/2016	238.25	0247-6041	0	73	
2/18/2016	714.75	0247-6041	0	77	
2/19/2016	571.8	0247-6041	0	78	
2/24/2016	667	0247-6041	0	69	
2/29/2016	857.5	0247-6041	0	78	
3/1/2016	762.5	0247-6041	0	80	

3/2/2016	834	0247-6041	0	77	
3/3/2016	667	0247-6041	0	83	
3/7/2016	810.05	0247-6041	0	79	
3/8/2016	619	0247-6041	0.01	77	
3/15/2016	858	0247-6041	0	82	
3/16/2016	239	0247-6041	0	79	
4/6/2016	810	0247-6041	0	81	
4/7/2016	905.5	0247-6041	0	81	
4/11/2016	619.5	0247-6041	0.01	80	
4/13/2016	1048.5	0247-6041	0.02	81	
4/14/2016	810.05	0247-6041	0	80	
4/19/2016	1238.9	0247-6041	0	80	
4/20/2016	881.53	0247-6041	0	82	
4/22/2016	542	0247-6041	0	84	
4/28/2016	4217.025	0247-6041	0	85	
5/26/2016	4645.88	0247-6041	0	88	
6/27/2016	7123.7	0247-6041	0	91	
7/28/2016	5636.02	0247-6041	0	95	
8/26/2016	4306.6	0247-6041	0	92	
9/19/2016	381.2	0247-6041	0	94	
9/20/2016	476.5	0247-6041	0	94	
9/21/2016	405.02	0247-6041	0	93	

9/22/2016	476.5	0247-6041	1.98	91	
9/23/2016	667.1	0247-6041	0.02	92	
9/27/2016	238.25	0247-6041	0	83	
9/28/2016	333.55	0247-6041	0	88	
9/29/2016	905.35	0247-6041	0	90	
9/30/2016	524.15	0247-6041	0	83	
10/3/2016	405.02	0247-6041	0	88	
10/4/2016	571.8	0247-6041	0	89	
10/5/2016	619.45	0247-6041	0	90	
10/6/2016	643.28	0247-6041	0	90	
10/7/2016	285.9	0247-6041	0.42	88	
10/10/2016	643.27	0247-6041	0	84	
10/11/2016	500.32	0247-6041	0	86	
10/12/2016	405.02	0247-6041	0	89	
10/13/2016	476.5	0247-6041	0	89	
10/19/2016	547.97	0247-6041	0	90	
10/20/2016	285.9	0247-6041	0.06	92	
10/21/2016	405.02	0247-6041	0	77	
10/25/2016	595.62	0247-6041	0	86	
12/15/2016	133.5	0247-6041	0	63	
12/16/2016	371.75	0247-6041	0.08	76	
12/19/2016	428.85	0247-6041	0	48	

12/20/2016	333.55	0247-6041	0	54	
1/4/2017	333.55	0247-6041	0	62	
1/5/2017	214.42	0247-6041	0	65	
1/6/2017	157.25	0247-6041	0	56	
3/28/2017	1990.125	0247-6041	0		
11/9/2015	12230	0316-6015	0	77	
3/29/2016	10165	0316-6015	0	77	
5/12/2016	6520	0316-6015	0	86	
5/13/2016	6400	0316-6015	0	86	
7/7/2016	5240	0316-6015	0	93	
7/8/2016	7820	0316-6015	0	92	
7/11/2016	1360	0316-6015	0	93	
9/12/2016	12720	0316-6015	0		
10/19/2016	8680	0316-6015	0	90	
10/21/2016	8240	0316-6015	0	77	
10/24/2016	9580	0316-6015	0	87	
10/25/2016	3300	0316-6015	0	86	
10/28/2016	7860	0316-6015	0	86	
10/29/2016	5640	0316-6015	0	85	
10/31/2016	4520	0316-6015	0.83	84	
11/1/2016	6760	0316-6015	0	87	
11/2/2016	3040	0316-6015	0.44	87	

10/20/2015	46.49	0134-6004	0	85	
11/13/2015	53.5	0134-6004	0	72	
1/27/2016	27.5	0134-6004	0	61	
4/4/2016	109	0134-6004	0	79	
6/30/2016	106	0134-6004	0	91	
11/28/2016	233.622	0134-6004	0	90	
3/28/2017	144.028	0134-6004	0		
11/11/2016	46150	0666-6303	0	77	
11/12/2016	59320	0666-6303	0	73	
2/7/2017	28286	0666-6303	0	81	
3/9/2017	11764	0666-6303	0.13	76	
3/10/2017	1175	0672-6009	0.79	73	
3/17/2017	254	0672-6009	0		
2/28/2017	39140.444	0164-6023	0	80	
3/28/2017	114994.667	0164-6023	0		

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Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
25/8/2009	19688.7	0354-2045	0	99	
25/8/2009	280	0351-2006	0	99	
25/8/2009	362.82	0318-2002	0	99	
29/12/2009	4.48	0318-2002	0.6	52	
28/9/2009	8884.21	0341-2064	0.35	100	

29/9/2009	939.71	0341-2064	0.02	95	
27/10/2009	9560.38	0341-2064	0	77	
29/9/2009	110	0134-2001	0.02	95	
27/10/2009	90	0134-2001	0	77	
4/11/2009	20.01	0134-2001	0.01		
25/8/2009	104.3	0432-2040	0	99	
27/10/2009	45228	6110-2002	0	77	
29/10/2009	1446	6110-2002	0.03	86	
Project Number 0371-03-114					
Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
4/22/2013	7813	0354-2045	0	87	
4/23/2013	12474	0354-2045	0	85	
4/25/2013	7666	0354-2045	0.02	70	
4/29/2013	6833	0354-2045	0.58	79	
4/30/2013	12563.2	0354-2045	0.4	80	
5/8/2013	13034	0354-2045	0	81	
5/9/2013	15157	0354-2045	0	80	
5/10/2013	5867	0354-2045	0.06	78	
5/13/2013	13377	0354-2045	0	79	
5/14/2013	15148	0354-2045	0	82	
5/20/2013	14778	0354-2045	0	85	
5/21/2013	15168	0354-2045	0	85	

5/22/2013	15587	0354-2045	0	85	
5/30/2013	15976	0354-2045	0	88	
5/31/2013	13063	0354-2045	0	90	
6/3/2013	15178	0354-2045	0	88	
6/4/2013	15166	0354-2045	0	87	
6/5/2013	17202	0354-2045	0	89	
6/6/2013	15075	0354-2045	0	91	
4/23/2013	1850	0316-2403	0	85	
4/25/2013	1250	0316-2403	0.02	70	
4/29/2013	1825	0316-2403	0.58	79	
5/1/2013	2050	0316-2403	0	86	
5/6/2013	4435	0316-2403	0	77	
5/7/2013	5145	0316-2403	0	79	
5/9/2013	5205	0316-2403	0	80	
5/13/2013	5620	0316-2403	0	79	
5/14/2013	4680	0316-2403	0	82	
5/16/2013	2435	0316-2403	0	84	
5/17/2013	3533	0316-2403	0	85	
5/21/2013	5375	0316-2403	0	92	
5/22/2013	5045	0316-2403	0	90	
5/23/2013	3870	0316-2403	0	92	
5/24/2013	3415	0316-2403	0	93	

5/31/2013	5290	0316-2403	0	90	
6/5/2013	15610	0316-2403	0	94	
6/10/2013	5900	0316-2403	0	90	
6/13/2013	2600	0316-2403	0	91	
6/14/2013	5505	0316-2403	0.02	89	
6/25/2013	550	0134-2004	0	97	
5/6/2013	1814.3	3224-2048	0	77	
5/7/2013	1392.85	3224-2048	0	79	
5/8/2013	844.43	3224-2048	0	81	
5/16/2013	2016.3	3224-2048	0	84	
5/17/2013	1269.44	3224-2048	0	85	
5/20/2013	944.61	3224-2048	0	85	
5/23/2013	1237.36	3224-2048	0	92	
5/24/2013	868.58	3224-2048	0	93	
5/28/2013	1795.48	3224-2048	0	87	
5/29/2013	1316.28	3224-2048	0.06	85	
5/30/2013	671.51	3224-2048	0	88	
5/31/2013	673.85	3224-2048	0	90	
6/7/2013	1195.39	3224-2048	0.13	92	
6/10/2013	1765.44	3224-2048	0	90	
6/11/2013	2088.68	3224-2048	0	91	
6/17/2013	2002.07	3224-2048	0	92	

Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
6/18/2013	2341.75	3224-2048	0	92	
6/19/2013	1835.64	3224-2048	0	91	
6/20/2013	586.56	3224-2048	0	91	
6/25/2013	54630	8251-2018	0	97	

Project Number 0371-07-006

Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
7/31/2009	15622.25	0354-2045	0	97	
8/25/2009	10549	0354-2045	0	97	
8/25/2009	141.51	0316-2042	0	97	
8/25/2009	10194.44	0341-2032	0	97	
8/25/2009	160.5	0134-2001	0	97	
10/16/2009	0.01	0134-2001	0	82	
8/25/2009	30154	6110-2002	0	97	
9/3/2009	795	6110-2002	0.21	93	

Project Number 0371-04-056

Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
7/15/2010	422	0354-2045	0	96	
7/16/2010	422	0354-2045	0	96	
7/15/2010	3800	0351-2013	0	96	
7/16/2010	5231	0351-2013	0	96	
7/16/2010	51.98	0316-2042	0	96	
7/17/2010	40.97	0316-2042	0	90	

7/19/2010	51.667	0316-2042	0.36	90	
7/20/2010	104.71	0316-2042	0	91	
8/2/2010	78.23	0316-2042	0	95	
8/3/2010	72.649	0316-2042	0	95	
7/17/2010	2386.32	0341-2064	0	90	
7/19/2010	2288.22	0341-2064	0.36	90	
7/20/2010	2293.23	0341-2064	0	91	
7/26/2010	283.67	0341-2064	0.2	89	
7/29/2010	1519.99	0341-2064	0	95	
7/31/2010	2321.76	0341-2064	0	97	
8/2/2010	2443.45	0341-2064	0	95	
8/3/2010	2447.31	0341-2064	0	95	
8/6/2010	2608	0341-2064	0	95	
8/7/2010	2216.79	0341-2064	0	95	
8/9/2010	2095.51	0341-2064	0	95	
8/10/2010	904.48	0341-2064	0.67	93	
8/11/2010	1498.22	0341-2064	0	96	
8/16/2010	1317.59	0341-2064	0	92	
7/31/2010	5379	0530-2017	0	97	
8/16/2010	304.54	0530-2017	0	92	
8/19/2010	5074.46	0530-2017	0	92	
1/20/2010	435.81	0134-2001	0	74	

7/31/2010	72.635	0134-2001	0	97	
8/19/2010	72.635	0134-2001	0	92	
1/21/2010	125	0540-2001	0.02	75	
1/26/2010	125	0540-2001	0	72	
8/11/2010	28841	8251-2005	0	96	
8/20/2010	29022	8251-2005	0	96	
9/9/2010	245	8251-2005	0	87	
Project Number 0371-04-061					
Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
6/27/2016	1033	0354-6020	0	93	
8/31/2016	145	0354-6020	0	93	
6/27/2016	10241	0351-6013	0	93	
6/27/2016	25281	0351-6013	0	93	
7/25/2016	8495.62	0344-6119	0	97	
7/27/2016	818.92	0344-6119	0	90	
7/28/2016	1011.31	0344-6119	0	95	
7/29/2016	1148.81	0344-6119	0	96	
8/16/2016	11310.77	0344-6119	0.01	86	
8/16/2016	53704	0666-6302	0.01	86	
8/31/2016	106867	0533-6001	0	93	
Project Number 0372-01-093					
Date	Reported Qty	Item Code	PRCP	TMAX	WSFG

11/2/2009	4222	0354-2045	0	78	
11/3/2009	4222	0354-2045	0	78	
11/2/2009	422	0351-2004	0	78	
11/3/2009	422	0351-2004	0	78	
1/21/2010	49.9	0316-2042	0	79	
2/18/2010	7.55	0316-2042	0.12	60	
2/22/2010	27.12	0316-2042	0	65	
2/25/2010	14.25	0316-2042	0	63	
2/26/2010	24.14	0316-2042	0	71	
3/1/2010	58.19	0316-2042	0.15	77	
3/2/2010	70.84	0316-2042	0	64	
3/3/2010	30.31	0316-2042	0	69	
3/4/2010	29.36	0316-2042	0	70	
3/5/2010	13.71	0316-2042	0	65	
2/8/2010	1691.32	0341-2064	0	72	
2/18/2010	2154.85	0341-2064	0.12	60	
2/22/2010	1646.84	0341-2064	0	65	
2/25/2010	898.65	0341-2064	0	63	
2/26/2010	1195.81	0341-2064	0	71	
3/1/2010	909.65	0341-2064	0.15	77	
3/2/2010	1658.73	0341-2064	0	64	
3/3/2010	1840.04	0341-2064	0	69	

3/4/2010	1611.47	0341-2064	0	70	
3/5/2010	1430.07	0341-2064	0	65	
3/6/2010	1986.88	0341-2064	0	71	
3/18/2010	1890.97	0341-2064	0		
3/19/2010	1291.2	0341-2064	0		
3/25/2010	102.66	0341-2064	0	75	
2/18/2010	1475.7	0530-2017	0.12	60	
3/22/2010	3934.55	0530-2017	0		
3/23/2010	7889.65	0530-2017	0		
3/24/2010	2293.32	0530-2017	0.05		
3/25/2010	2743.33	0530-2017	0	75	
10/7/2009	220.6	0134-2001	0	94	
3/31/2010	220.6	0134-2001	0	81	
10/5/2009	350	0542-2001	0	93	
10/6/2009	150	0542-2001	0	95	
10/7/2009	200	0542-2001	0	94	
10/8/2009	200	0542-2001	0	93	
10/15/2009	150	0542-2001	0	96	
10/16/2009	200	0542-2001	0	84	
10/19/2009	150	0542-2001	0	80	
3/30/2010	40770	8251-2017	0	82	

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Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
8/29/2011	5294.5	0354-2045	0	96	
8/30/2011	5294.5	0354-2045	0	93	
8/29/2011	6395	0354-2045	0	96	
8/30/2011	6395	0354-2045	0	93	
8/30/2011	1566	0316-2403	0	93	
8/31/2011	1370	0316-2403	0	95	
8/30/2011	1724	0316-2403	0	93	
8/31/2011	2400	0316-2403	0	95	
9/7/2011	1099.43	3224-2030	0	90	
10/2/2011	23.49	3224-2030	0	85	
9/7/2011	1369.55	3224-2030	0	90	
9/8/2011	2388	8251-2005	0	92	
9/8/2011	3228	8251-2005	0	92	
Project Number 0617-01-074					
Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
5/5/2011	673	0450-2013	0	83	
6/10/2011	639	0450-2013	0	95	
8/15/2011	9629	0354-2045	0	98	
8/16/2011	7400	0354-2045	0	98	
8/17/2011	7296	0354-2045	0	93	
8/18/2011	6344	0354-2045	0	93	

8/21/2011	6016	0354-2045	0	99	
8/23/2011	8456	0354-2045	0	93	
8/24/2011	3073	0354-2045	0	94	
8/28/2011	6708	0354-2045	0	100	
8/29/2011	5700	0354-2045	0	96	
8/30/2011	6700	0354-2045	0	93	
8/31/2011	5407	0354-2045	0	95	
9/7/2011	12258	0354-2045	0	92	
9/8/2011	7467	0354-2045	0	97	
9/11/2011	5600	0354-2045	0	98	
9/12/2011	4788	0354-2045	0	100	
9/13/2011	14379	0354-2045	0	102	
9/14/2011	12099	0354-2045	0	95	
9/15/2011	8708	0354-2045	0	93	
9/25/2011	13640	0354-2045	0	103	
9/26/2011	6222	0354-2045	0	100	
9/27/2011	9529	0354-2045	0	99	
9/28/2011	8296	0354-2045	0	98	
10/2/2011	11582	0354-2045	0	87	
10/3/2011	8667	0354-2045	0	86	
10/4/2011	12814	0354-2045	0	88	
10/5/2011	3726	0354-2045	0	90	

10/6/2011	13062	0354-2045	0	94	
10/10/2011	6644	0354-2045	0	86	
10/12/2011	13512	0354-2045	0	95	
10/16/2011	11676	0354-2045	0	88	
10/17/2011	6434	0354-2045	0	92	
10/18/2011	10634	0354-2045	0	82	
10/19/2011	8391	0354-2045	0	78	
10/20/2011	15363	0354-2045	0	85	
10/24/2011	14417	0354-2045	0	90	
10/25/2011	5767	0354-2045	0	90	
11/13/2011	14079	0354-2045	0	88	
11/15/2011	13689	0354-2045	0.06	83	
11/16/2011	9738	0354-2045	0	93	
12/1/2011	8612	0354-2045	0	83	
8/28/2011	1400	0316-2001	0	100	
8/29/2011	1770	0316-2001	0	96	
8/30/2011	1525	0316-2001	0	93	
8/31/2011	10350	0316-2001	0	95	
9/1/2011	1600	0316-2001	0	98	
9/6/2011	1340	0316-2001	0	95	
9/7/2011	1790	0316-2001	0	92	
9/8/2011	1700	0316-2001	0	97	

9/11/2011	1500	0316-2001	0	98	
9/12/2011	1200	0316-2001	0	100	
9/13/2011	3593	0316-2001	0	102	
9/14/2011	3025	0316-2001	0	95	
9/15/2011	2175	0316-2001	0	93	
9/19/2011	790	0316-2001	0	89	
9/25/2011	3410	0316-2001	0	103	
9/26/2011	1555	0316-2001	0	100	
9/27/2011	2380	0316-2001	0	99	
9/28/2011	2070	0316-2001	0	98	
10/2/2011	2895	0316-2001	0	87	
10/3/2011	2166	0316-2001	0	86	
10/4/2011	3200	0316-2001	0	88	
10/5/2011	930	0316-2001	0	90	
10/6/2011	3275	0316-2001	0	94	
10/10/2011	1660	0316-2001	0	86	
10/12/2011	3380	0316-2001	0	95	
10/16/2011	2920	0316-2001	0	88	
10/17/2011	1610	0316-2001	0	92	
10/20/2011	3670	0316-2001	0	85	
10/24/2011	2840	0316-2001	0	90	
10/25/2011	3350	0316-2001	0	90	

10/26/2011	2860	0316-2001	0	90	
11/20/2011	3730	0316-2001	0	87	
11/21/2011	2500	0316-2001	0	85	
11/22/2011	2490	0316-2001	0	88	
11/30/2011	980	0316-2001	0	70	
12/1/2011	85	0316-2001	0	83	
8/23/2011	914.51	0341-2064	0	93	
8/24/2011	982.01	0341-2064	0	94	
8/28/2011	1275.9	0341-2064	0	100	
8/29/2011	916.75	0341-2064	0	96	
8/30/2011	2873.53	0341-2064	0	93	
8/31/2011	945.16	0341-2064	0	95	
9/1/2011	1658.75	0341-2064	0	98	
9/12/2011	2135.94	0341-2064	0	100	
9/13/2011	336.91	0341-2064	0	102	
9/15/2011	33.65	0341-2064	0	93	
9/21/2011	1599.89	0341-2064	0	91	
10/3/2011	1662.38	0341-2064	0	88	
10/5/2011	2313.73	0341-2064	0	90	
10/10/2011	1301.23	0341-2064	0	86	
10/12/2011	1714.04	0341-2064	0	95	
10/18/2011	1952.11	0341-2064	0	82	

10/23/2011	1788.43	0341-2064	0	91	
10/25/2011	1888.66	0341-2064	0	90	
10/26/2011	750.98	0341-2064	0	90	
10/31/2011	2481.9	0341-2064	0	80	
11/2/2011	1523.3	0341-2064	0	87	
11/6/2011	1185.89	0341-2064	0	81	
11/17/2011	259.99	0341-2064	0	72	
11/21/2011	2146.88	0341-2064	0	85	
11/22/2011	1059.69	0341-2064	0	88	
11/30/2011	879.88	0341-2064	0	70	
9/8/2011	8259	8251-2005	0	97	
10/12/2011	3531	8251-2005	0	95	
10/13/2011	20248	8251-2005	0.96	92	
11/15/2011	13216	8251-2005	0.06	83	
11/30/2011	18233	8251-2005	0	70	
Project Number 0617-04-180					
Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
11/4/2013	3882	0354-2021	0	79	
11/5/2013	4237	0354-2021	0	83	
11/10/2013	4237	0354-2021	0		
11/11/2013	4449	0354-2021	0	80	
11/19/2013	5567	0354-2021	0	74	

11/20/2013	3192	0354-2021	0.01	86	
11/21/2013	3148	0354-2021	0	87	
4/29/2014	79580	0354-2021	0	95	
5/29/2014	36606	0354-2021	0	91	
11/4/2013	825	0316-2402	0	79	
11/5/2013	950	0316-2402	0	83	
11/10/2013	975	0316-2402	0		
11/11/2013	1075	0316-2402	0	80	
11/19/2013	1325	0316-2402	0	74	
11/20/2013	750	0316-2402	0.01	86	
11/21/2013	800	0316-2402	0	87	
4/29/2014	21500	0316-2402	0	95	
4/30/2014	750	0316-2402	0.08	78	
5/29/2014	7975	0316-2402	0	91	
11/4/2013	400.18	3268-2048	0	79	
11/5/2013	448.49	3268-2048	0	83	
11/10/2013	430.15	3268-2048	0		
11/11/2013	412.94	3268-2048	0	80	
11/19/2013	681.03	3268-2048	0	74	
11/20/2013	413.98	3268-2048	0.01	86	
11/21/2013	382.4	3268-2048	0	87	
4/29/2014	5997.04	3268-2048	0	95	

4/30/2014	376.14	3268-2048	0.08	78	
5/29/2014	7012.97	3268-2048	0	91	
6/9/2014	23.06	3268-2048	0	91	
6/9/2014	4187.5	0315-2011	0	91	
1/31/2014	2176	8251-2005	0	75	
6/9/2014	30879	8251-2005	0	91	
6/9/2014	460.77	0429-2007	0	91	

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Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
2/24/2014	2195	0351-2012	0	72	
2/28/2014	6232	0351-2012	0	88	
3/1/2014	3949	0351-2012	0	77	
3/2/2014	1616.5	0351-2012	0	79	
3/31/2014	21539.5	0351-2012	0	80	
2/24/2014	733	0354-2090	0	72	
2/28/2014	43083	0354-2090	0	88	
6/20/2014	3250	0677-2003	0	91	
4/21/2014	254	0529-2009	0.02	86	
4/9/2014	1400	3142-2007	0	79	
4/10/2014	2200	3142-2007	0	80	
4/15/2014	1300	3142-2007	0	65	
4/16/2014	2800	3142-2007	0	75	

4/17/2014	1500	3142-2007	0.12	75	
4/21/2014	1750	3142-2007	0.02	86	
4/22/2014	5900	3142-2007	0	92	
4/23/2014	3900	3142-2007	0	83	
4/24/2014	3500	3142-2007	0	84	
4/25/2014	2500	3142-2007	0	82	
4/28/2014	2200	3142-2007	0	103	
4/29/2014	1700	3142-2007	0	99	
4/30/2014	3450	3142-2007	0.05	81	
5/1/2014	3000	3142-2007	0.02	76	
5/31/2014	5700	3142-2007	0.21	95	
6/20/2014	100	3142-2007	0	91	
4/9/2014	369.51	3142-2009	0	79	
4/10/2014	494.74	3142-2009	0	80	
4/15/2014	355.4	3142-2009	0	65	
4/16/2014	807.82	3142-2009	0	75	
4/17/2014	369.08	3142-2009	0.12	75	
4/21/2014	376.38	3142-2009	0.02	86	
4/22/2014	1355.1	3142-2009	0	92	
4/23/2014	952.36	3142-2009	0	83	
4/24/2014	504.23	3142-2009	0	84	
4/25/2014	774.73	3142-2009	0	82	

4/28/2014	655.78	3142-2009	0	103	
4/29/2014	530.19	3142-2009	0	99	
4/30/2014	990.57	3142-2009	0.05	81	
5/1/2014	1329.22	3142-2009	0.02	76	
5/31/2014	1681.35	3142-2009	0.21	95	
3/31/2014	14842	0662-2004	0.21	95	
4/25/2014	24229	0662-2004	0	82	
5/31/2014	16352	0662-2004	0.21	95	

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Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
9/23/2011	116	0112-2002	0	98	
11/28/2011	98	0112-2002	0	69	
11/30/2011	46	0112-2002	0	66	
1/30/2012	26	0112-2002	0.04	71	
10/26/2011	40384	0275-2071	0	90	
11/28/2011	37022	0275-2071	0	69	
12/28/2011	20400	0275-2071	0	73	
1/30/2012	9765	0275-2071	0.04	71	
10/26/2011	5020	0316-2015	0	90	
10/31/2011	2960	0316-2015	0	80	
11/28/2011	4970	0316-2015	0	69	
12/29/2011	3880	0316-2015	0	77	

1/30/2012	4040	0316-2015	0.04	71	
10/26/2011	5720	0316-2402	0	90	
11/28/2011	7840	0316-2402	0	69	
3/14/2012	5100	0316-2402	0	80	
4/26/2012	11800	0316-2402	0	85	
10/26/2011	56	0464-2005	0	90	
11/28/2011	63	0464-2005	0	69	
5/30/2012	58547	8251-2006	0	91	
7/5/2012	166	8251-2006	0.02	95	
1/30/2012	21	0644-2058	0.04	71	
2/28/2012	12	0644-2058	0	80	
2/29/2012	12	0644-2058	0	85	

Project Number 1088-04-023					
Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
10/31/2011	128	0100-2002	0	80	
1/27/2012	4	0462-2010	0	78	
7/31/2012	27	0400-2005	0	100	
10/31/2011	108	0464-2007	0	80	
11/4/2011	32	0464-2007	0	66	
10/24/2011	64	0112-2002	0	90	
11/4/2011	64	0112-2002	0	66	
10/31/2011	24177.78	0275-2038	0	80	

11/11/2011	24045.22	0275-2038	0	71	
11/30/2011	6240.8	0247-2056	0	66	
12/30/2011	780.1	0247-2056	0	84	
1/27/2012	780.1	0247-2056	0	78	
12/30/2011	6225	0316-2402	0	84	
3/14/2012	6350	0316-2402	0	80	
3/15/2012	1868.53	3224-2030	0	80	
3/16/2012	2257.06	3224-2030	0	81	
3/19/2012	682.53	3224-2030	0	80	
4/18/2012	75	0668-2105	0	79	
5/24/2012	3	0668-2105	0	89	
5/24/2012	67260	0164-2035	0	89	
Project Number 1093-01-027					
Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
5/31/2012	0.83	0752-2020	0	89	
6/19/2012	0.83	0752-2020	0.01	93	
5/31/2012	73.73	0112-2002	0	89	
6/26/2012	74.66	0112-2002	0	106	
7/16/2012	11.61	0112-2002	0	92	
5/31/2012	1876.43	0247-2056	0	89	
6/29/2012	3776.53	0247-2056	0.02	96	
7/26/2012	3163.04	0247-2056	0	95	

6/14/2012	1500	0316-2015	0	93	
6/15/2012	4300	0316-2015	0	93	
7/6/2012	2025	0316-2015	0.17	95	
7/16/2012	2405	0316-2015	0	92	
7/27/2012	1850	0316-2015	0	96	
5/31/2012	808	0110-2001	0	89	
7/26/2012	2299	0110-2001	0	95	
8/22/2012	950	0132-2008	0	99	
7/13/2012	4300	0316-2402	0.78	92	
7/17/2012	7525	0316-2402	0	90	
8/16/2012	5935	0316-2402	0	98	
8/23/2012	669.67	3224-2021	0	98	
8/24/2012	130.38	3224-2021	0	97	
8/14/2012	775	0540-2001	0	99	
8/31/2012	24270	8251-2006	0	100	
10/3/2012	8090	8251-2006	0	87	
8/8/2012	25	0644-2060	0	99	
8/29/2012	40125	0164-2023	0	107	

Project Number 1193-03-016

Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
6/26/2015	40	0100-2002	0	91	
7/28/2015	9	0100-2002	0	96	

9/28/2015	126.5	0100-2002	0	92	
10/23/2015	157.95	0100-2002	0.34	81	
11/16/2015	17.55	0100-2002	0	84	
4/28/2015	8	0464-2007	0.03	78	
5/8/2015	16	0464-2007	0	84	
5/28/2015	20	0464-2007	0	88	
5/28/2015	5	0462-2011	0	88	
6/26/2015	28	0462-2011	0	91	
7/28/2015	20	0462-2011	0	96	
8/21/2015	62	0462-2011	0.02	89	
9/23/2015	297	0530-2006	0	89	
10/15/2015	298	0530-2006	0	90	
6/26/2015	48.8	0112-2001	0	91	
7/28/2015	126.82	0112-2001	0	96	
8/5/2015	98.755	0112-2001	0	91	
9/28/2015	76.615	0112-2001	0	92	
6/26/2015	1493	0247-2366	0	91	
7/28/2015	9255	0247-2366	0	96	
8/5/2015	38.862	0247-2366	0	91	
8/19/2015	1407.6	0247-2366	0	100	
8/20/2015	1697.94	0247-2366	0.35	88	
8/28/2015	5123.97	0247-2366	0	89	

9/28/2015	2037.63	0247-2366	0	92	
7/17/2015	3660	0316-2015	0	96	
8/15/2015	3140	0316-2015	0	92	
9/23/2015	3400	0316-2015	0	89	
10/1/2015	1130	0316-2015	0	95	
10/2/2015	880	0316-2015	0	88	
7/28/2015	27223	0275-2046	0	96	
8/5/2015	5437	0275-2046	0	91	
8/6/2015	4525	0275-2046	0	91	
9/1/2015	1334.16	0275-2046	0.02	90	
9/2/2015	2090.286	0275-2046	0	91	
9/3/2015	692.478	0275-2046	0	93	
9/8/2015	1372.104	0275-2046	0	93	
9/9/2015	663.714	0275-2046	0	94	
9/12/2015	404.838	0275-2046	0	88	
9/28/2015	25160.42	0275-2046	0	92	
10/5/2015	5530	0316-2403	0	89	
10/6/2015	8780	0316-2403	0	89	
10/7/2015	20900	0316-2403	0	89	
10/8/2015	16580	0316-2403	0.01	90	
10/9/2015	1480	0316-2403	0.06	79	
10/10/2015	10760	0316-2403	0	89	

8/17/2015	498	0530-2012	0	91	
9/23/2015	595	0530-2012	0	89	
10/23/2015	1105	0530-2012	0.34	81	
11/16/2015	39	0530-2012	0	84	
10/19/2015	60	0438-2002	0	83	
9/28/2015	240	0450-2641	0	92	
8/18/2015	350	0540-2001	0	90	
10/15/2015	69347	8251-2006	0	90	
12/31/2015	48	0644-2022	0	58	
Project Number 1557-01-035					
Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
29/4/2011	825	5049-2001	0	82	
29/4/2011	3.55271E-15	0479-2005	0	82	
6/12/2011	64	0479-2005	0	91	
29/4/2011	38081.3	0354-2045	0	82	
25/5/2011	27208.96	0354-2045	0	88	
29/4/2011	541.667	0351-2004	0	82	
25/5/2011	483.33	0351-2004	0	88	
29/4/2011	13280	0316-2403	0	82	
25/5/2011	7550	0316-2403	0	88	
29/4/2011	3681.66	0341-2104	0	82	
25/5/2011	3058.84	0341-2104	0	88	

6/12/2011	0.01	0341-2104	0	91	
Project Number 2343-01-030					
Date	Reported Qty	Item Code	PRCP	TMAX	WSFG
11/17/2011	94.1	0100-2002	0	72	
12/30/2011	106	0100-2002	0.01	85	
1/31/2012	33	0100-2002	0.06	79	
2/29/2012	54	0100-2002	0	85	
3/27/2012	15.9	0100-2002	0	84	
11/30/2011	37.6	0112-2002	0	66	
12/30/2011	56	0112-2002	0.01	85	
1/31/2012	118	0112-2002	0.06	79	
2/29/2012	60.5	0112-2002	0	85	
3/27/2012	30.9	0112-2002	0	84	
11/30/2011	84	0464-2005	0	66	
12/30/2011	146	0464-2005	0.01	85	
2/29/2012	14	0464-2005	0	85	
4/30/2012	64	0464-2005	0	89	
7/11/2012	32	0464-2005	0	88	
12/30/2011	34468	0275-2038	0.01	85	
1/31/2012	49136	0275-2038	0.06	79	
2/29/2012	24168	0275-2038	0	85	
3/27/2012	13216	0275-2038	0	84	

12/30/2011	5424	0247-2056	0.01	85	
1/31/2012	3617	0247-2056	0.06	79	
2/29/2012	6728.4	0247-2056	0	85	
3/27/2012	3276	0247-2056	0	84	
3/5/2012	543	0316-2590	0	77	
3/31/2012	159	0316-2590	0	93	
4/30/2012	161	0316-2590	0	89	
3/5/2012	20150	0316-2402	0	77	
3/31/2012	5477	0316-2402	0	93	
4/30/2012	5266	0316-2402	0	89	
7/12/2012	1493.5	3224-2048	0	92	
7/13/2012	1573.25	3224-2048	0.78	92	
7/14/2012	1259.18	3224-2048	0.06	93	
7/16/2012	1207.75	3224-2048	0	92	
7/17/2012	1723.56	3224-2048	0	90	
7/18/2012	1233.68	3224-2048	0	95	
11/30/2011	12140	0110-2001	0	66	
12/30/2011	3235	0110-2001	0.01	85	
1/31/2012	2863	0110-2001	0.06	79	
2/29/2012	3414	0110-2001	0	85	
3/27/2012	4298	0110-2001	0	84	
11/30/2011	945	0132-2006	0	66	

1/31/2012	1182	0132-2006	0.06	79	
3/27/2012	629	0132-2006	0	84	
7/24/2012	59364	8251-2005	0	98	
9/6/2012	286	8251-2005	0	92	
4/30/2012	34	0644-2001	0	89	

APPENDIX 4.2

MODELS RESULTS BY ITEMS FOR ALL 30 PROJECTS.

Project Number: 0074-03-041	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0354-2045 June	1	1	3	1	1	2
0354-2045 April	2	2	3	2	2	3
0354-2045 May	1	1	2	1	1	2
0316-2403 June	1	1	3	1	1	3
0316-2403 July	1	1	3	1	1	5
0316-2403 May	1	1	2	1	1	2
0316-2403 April	2	2	3	2	2	3
0316-2403 August	3	3	21	3	1	7
0316-2403 October	1	1	2	1	1	2
0316-2403 January	1	1	2	1	1	2
3268-2042 June	6	6	17	6	4	12
3268-2042 July	1	1	5	1	1	5
3268-2042 May	1	1	2	1	1	2
3268-2042 April	1	1	2	1	1	2
3268-2042 January	3	3	4	3	1	2
3268-2042 August	4	3	21	4	1	2
3268-2042 September	4	4	10	4	4	10
3268-2042 October	1	1	2	1	1	2
0134-2004 June	4	4	12	4	4	12
0134-2004 September	3	3	8	3	3	8
0134-2004 October	1	1	2	1	1	2
0533-2006 September	3	3	8	3	1	3
0533-2006 October	3	3	4	3	3	4
0438-2002 August	2	2	14	2	1	7

0438-2002 October	2	2	3	2	2	3
8251-2017 July	1	1	5	1	1	5
8251-2017 September	3	3	8	3	2	3
8251-2017 January	2	2	3	2	2	3
8251-2017 May	2	2	3	2	2	3
8251-2017 June	1	1	3	1	1	3
8251-2017 October	1	1	2	1	1	2
8251-2017 November	1	1	2	1	1	2
Project Number: 0074-03-042	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0506-6042 September	2	2	5	2	1	3
0351-6013 October	3	3	4	3	2	3
0354-6021 October	5	5	7	5	3	2
0354-6021 November	1	1	2	1	1	2
0316-6007 October	6	6	8	6	4	6
0316-6007 November	3	3	4	3	3	3
0344-6120 October	7	7	10	7	5	7
0344-6120 November	5	5	7	5	4	6
0344-6120 December	1	1	1	1	1	2
0438-6001 November	1	1	2	1	1	2
0666-6314 November	2	2	3	2	1	2
Project Number: 0074-05-094	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0354-2045 July	7	5	24	7	1	5
0354-2045 August	7	5	34	7	1	7
0354-2045 September	2	2	5	2	1	3
0354-2045 October	4	4	6	4	3	4
0351-2002 July	1	1	5	1	1	5
0351-2002 August	2	2	14	2	1	7
0316-2403 July	8	6	29	8	1	5
0316-2403 August	6	5	34	6	1	7
0316-2403 September	2	2	5	2	1	3
0316-2403 October	5	5	7	5	4	6
3224-2048 July	3	3	4	3	1	2
3224-2048 August	9	7	8	9	1	2
3224-2048 September	6	6	7	6	4	5

3224-2048 October	8	8	11	8	7	10
0540-2001 October	1	1	2	1	1	2
0540-2001 November	1	1	2	1	1	2
0666-2005 October	2	2	3	2	1	2
Project Number: 0074-06-222	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0354-6003 September	9	8	20	9	6	15
0354-6003 October	17	14	19	17	11	15
0354-6003 November	7	7	10	7	7	10
0316-6001 September	9	8	20	9	6	15
0316-6001 October	17	14	19	17	11	15
0316-6001 November	8	8	11	8	7	10
0341-6089 September	9	8	20	9	6	15
0341-6089 October	17	14	19	17	11	15
0341-6089 November	8	8	11	8	7	10
0351-6019 September	2	2	5	2	1	2
0351-6019 November	1	1	2	1	1	2
0348-6009 December	13	13	13	13	13	13
0348-6009 January	1	1	2	1	1	2
0438-6001 December	1	1	1	1	1	1
0438-6001 January	1	1	2	1	1	2
0438-6001 March	1	1	2	1	1	2
0438-6001 July	1	1	5	1	1	5
0666-6315 January	1	1	2	1	1	2
0666-6315 March	1	1	2	1	1	2
0432-6001 September	4	4	10	4	1	3
0432-6001 October	12	12	16	12	9	12
0432-6001 November	2	2	3	2	2	3
0636-6009 March	4	4	5	4	4	5
0636-6009 April	1	1	2	1	1	2
0644-6001 March	5	5	7	5	5	7
0644-6001 April	1	1	2	1	1	2
Project Number: 0100-07-045	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0354-2045 August	1	2	14	1	1	7
0318-2002 August	4	4	28	4	1	7

0341-2032 September	8	6	15	8	1	3
0341-2032 October	9	9	12	9	7	9
0341-2032 November	13	13	18	13	8	10
0540-2001 August	3	3	89	3	1	34
0540-2001 September	3	3	8	3	1	3
0540-2001 October	2	2	3	2	1	2
0540-2001 November	1	1	2	1	1	2
Project Number: 0101-01-066	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0354-6113 October	3	3	4	3	2	3
0354-6113 November	4	4	6	4	3	4
0354-6113 December	5	5	5	5	4	5
0354-6113 January	1	1	2	1	1	2
0351-6012 October	2	2	3	2	1	2
0351-6012 November	1	1	2	1	1	2
0351-6012 December	3	3	3	3	3	4
0351-6012 January	3	3	4	3	3	4
0316-6001 October	3	3	4	3	2	3
0316-6001 November	10	9	12	10	7	10
0316-6001 December	5	5	5	5	5	6
0316-6001 January	6	6	8	6	6	8
0316-6001 March	1	1	2	1	1	2
0316-6001 April	2	2	3	2	2	3
0341-6042 October	2	2	3	2	2	3
0341-6042 November	12	10	14	12	7	10
0341-6042 December	9	9	9	9	9	11
0341-6042 January	8	8	10	8	8	10
0341-6042 March	1	1	2	1	1	2
0341-6042 April	1	1	2	1	1	2
0341-6042 May	1	1	2	1	1	2
0438-6001 February	1	1	2	1	1	2
0666-6011 November	1	1	2	1	1	2
0666-6011 December	2	2	2	2	2	4
0666-6011 January	1	1	2	1	1	2
0666-6011 May	1	1	2	1	1	2
Project Number: 0101-05-035	**Model 1**			**Model 2**		

Item Codes and Months	SAB	SPT	SPH	SAB	SPT	SPH
0354-6051 January	2	2	3	2	2	3
0354-6051 March	1	1	2	1	1	2
0316-6010 January	2	2	3	2	2	3
0316-6010 February	1	1	2	1	1	2
0316-6010 March	3	3	4	3	3	4
0316-6010 April	2	2	3	2	2	3
0316-6010 May	1	1	2	1	1	2
0316-6010 June	1	1	3	1	1	3
0341-6042 March	1	1	2	1	1	2
0341-6042 April	2	2	3	2	2	3
0341-6042 May	1	1	2	1	1	2
0666-6011 November	1	1	2	1	1	2
0666-6011 December	2	2	2	2	2	3
0666-6011 March	2	2	3	2	2	3
0666-6011 May	3	3	5	3	2	3
Project Number: 0101-03-082	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0354-2045 May	1	1	2	1	1	2
0316-2403 May	1	1	2	1	1	2
0316-2403 June	1	1	3	1	1	3
3224-2027 June	3	3	8	3	1	3
3224-2027 July	1	1	5	1	1	5
0530-2017 July	1	1	5	1	1	5
Project Number: 0101-04-108	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0354-2041 April	2	2	3	2	2	3
0354-2041 May	1	1	2	1	1	2
0341-2104 May	11	10	14	11	7	10
0316-2403 April	10	10	13	10	9	11
0316-2403 May	2	2	3	2	1	2
Project Number: 0254-01-130	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0354-2045 May	1	1	2	1	1	2
0354-2045 June	4	4	12	4	1	3
0351-2002 May	1	1	2	1	1	2

0351-2002 June	1	1	3	1	1	3
0316-2403 May	1	1	2	1	1	2
0316-2403 June	5	5	14	5	4	11
0662-2115 May	1	1	2	1	1	2
0662-2115 June	4	4	12	4	1	3
0341-2064 May	1	1	2	1	1	2
0351-6019 June	5	5	14	5	2	6
0530-2005 June	1	1	3	1	1	3
0666-2035 June	1	1	3	1	1	3
0644-2022 July	1	1	5	1	1	5
Project Number: 0254-01-137	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
1112-2049 September	1	1	3	1	1	3
0351-2002 April	1	1	2	1	1	2
0351-2002 July	3	3	15	3	1	5
0351-2002 August	2	2	14	2	1	7
0351-2002 November	2	2	3	2	1	2
0351-2002 December	1	1	1	1	1	1
0530-2073 June	1	1	3	1	1	3
0316-2043 August	5	4	27	5	1	7
0316-2043 November	2	2	3	2	2	3
0316-2043 March	1	1	2	1	1	2
0540-2001 June	4	4	12	4	4	12
0666-2035 October	2	2	3	2	2	3
0666-2035 December	1	1	1	1	1	1
0666-2035 March	1	1	2	1	1	2
Project Number: 0074-03-041	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0275-6038 September 2015	4	4	10	4	4	10
0275-6038 October2015	4	4	6	4	4	6
0275-6038 February 2016	12	12	15	12	12	15
0275-6038 March 2016	1	1	2	1	1	2
0275-6038 April 2016	9	9	11	9	9	11
0275-6038 May 2016	1	1	2	1	1	2
0275-6038 June 2016	1	1	3	1	1	3
0275-6038 July 2016	7	5	24	8	1	5

0275-6038 September 2016	8	6	15	8	2	5
0275-6038 October	2	2	3	2	2	3
0275-6038 December	2	2	2	2	2	3
5001-6002 September 2015	1	1	1	1	1	3
5001-6002 October 2015	1	1	1	1	1	1
5001-6002 November 2015	1	1	1	1	1	1
5001-6002 February 2016	7	7	7	7	7	9
5001-6002 March 2016	2	2	2	2	2	3
5001-6002 April 2016	7	7	7	7	5	7
5001-6002 May 2016	1	1	1	1	1	1
5001-6002 June 2016	1	1	1	1	1	3
5001-6002 July 2016	1	1	1	1	1	2
5001-6002 August 2016	2	2	2	2	1	7
5001-6002 September 2016	4	4	4	4	1	2
5001-6002 December 2016	4	4	4	4	3	4
0247-6041 September 2015	1	1	3	1	1	3
0247-6041 October 2015	2	2	3	2	2	3
0247-6041 November 2015	1	1	2	1	1	2
0247-6041 December 2015	1	1	2	1	1	2
0247-6041 February 2016	9	9	11	9	9	11
0247-6041 March 2016	7	7	9	7	7	9
0247-6041 April 2016	9	1	2	9	9	11
0247-6041 May 2016	1	1	2	1	1	2
0247-6041 June 2016	1	1	3	1	1	3
0247-6041 July 2016	1	1	5	1	1	5
0247-6041 August 2016	1	1	7	1	1	7
0247-6041 September 2016	7	7	18	7	2	5
0247-6041 October 2016	14	14	19	14	12	16
0247-6041 December 2016	4	4	4	4	4	5
0247-6041 January 2017	3	3	4	3	3	4
0247-6041 March 2017	1	1	2	1	1	2
0316-6015 November 2015	1	1	2	1	1	2
0316-6015 March 2016	1	1	2	1	1	2
0316-6015 May 2016	1	1	2	1	1	2
0316-6015 July 2016	3	3	15	3	1	3
0316-6015 September 2016	1	1	3	1	1	3
0316-6015 October 2016	6	6	8	6	5	7

0316-6015 November 2016	2	2	3	2	1	2
0134-6004 October 2015	1	1	2	1	1	2
0134-6004 November 2015	1	1	2	1	1	2
0134-6004 January 2016	1	1	2	1	1	2
0134-6004 April 2016	1	1	2	1	1	2
0134-6004 June 2016	1	1	3	1	1	3
0134-6004 November 2016	1	1	2	1	1	2
0134-6004 March 2017	1	1	2	1	1	2
0666-6303 November 2016	2	2	3	2	2	3
0666-6303 February 2017	1	1	2	1	1	2
0666-6303 March 2017	1	1	2	1	1	2
0672-6009 March 2017	2	2	3	2	1	2
0164-6023 february 2017	1	1	2	1	1	2
0164-6023 March 2017	1	1	2	1	1	2
Project Number: 0371-02-066	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0354-2045 August	1	1	7	1	1	7
0351-2006 August	1	1	7	1	1	7
0318-2002 August	1	1	7	1	1	7
0318-2002 December	1	1	1	1	1	1
0341-2064 September	2	2	5	2	1	3
0341-2064 October	1	1	2	1	1	2
0134-2001 September	1	1	3	1	1	3
0134-2001 October	1	1	2	1	1	2
0134-2001 November	1	1	2	1	1	2
0432-2040 August	1	1	7	1	1	7
6110-2002 October	2	2	2	2	1	2
Project Number: 0371-03-114	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0354-2045 April	5	5	7	5	2	3
0354-2045 May	10	10	14	10	9	13
0354-2045 June	4	4	12	4	4	12
0316-2403 April	3	3	4	3	1	2
0316-2403 May	13	12	17	13	10	14
0316-2403 June	4	4	12	4	2	6
0134-2004 June	1	1	3	1	1	3

3224-2048 May	12	11	15	12	9	13
3224-2048 June	7	6	17	7	4	12
8251-2018 June	1	1	3	1	1	3
Project Number: 0371-07-006	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0354-2045 July	1	1	5	1	1	5
0354-2045 August	1	1	7	1	1	7
0316-2042 August	1	1	7	1	1	7
0341-2032 August	1	1	7	1	1	7
0134-2001 August	1	1	7	1	1	7
0134-2001 October	1	1	2	1	1	2
6110-2002 August	1	1	7	1	1	7
6110-2002 September	1	1	3	1	1	3
Project Number: 0371-04-056	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0354-2045 July	2	2	10	2	1	5
0351-2013 July	2	2	10	2	1	5
0316-2042 July	4	4	20	4	2	10
0316-2042 August	2	2	14	2	1	2
0341-2064 July	6	5	24	6	2	10
0341-2064 August	8	6	41	8	1	5
0530-2017 July	1	1	5	1	1	5
0530-2017 August	2	2	14	2	1	5
0134-2001 January	1	1	2	1	1	2
0134-2001 July	1	1	5	1	1	5
0134-2001 August	1	1	7	1	1	7
0540-2001 January	2	2	3	2	2	3
8251-2005 August	2	2	14	2	1	5
8251-2005 September	1	1	3	1	1	3
Project Number: 0371-04-061	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0354-6020 June	1	1	3	1	1	3
0354-6020 August	1	1	7	1	1	7
0351-6013 June	2	2	5	2	1	3
0344-6119 July	4	4	20	4	1	5
0344-6119 August	1	1	7	1	1	7

0666-6302 August	1	1	7	1	1	7
0533-6001 August	1	1	7	1	1	7
Project Number: 0372-01-093	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0354-2045 November	2	2	3	2	2	3
0351-2004 November	2	2	3	2	2	3
0316-2042 January	1	1	2	1	1	2
0316-2042 February	4	4	5	4	3	4
0316-2042 March	5	5	7	5	4	5
0341-2064 February	5	5	6	5	4	5
0341-2064 March	9	9	11	9	8	10
0530-2017 Februry	1	1	2	1	1	2
0530-2017 March	4	4	5	4	3	4
0134-2001 October	1	1	2	1	1	2
0134-2001 March	1	1	2	1	1	2
0542-2001 October	7	6	8	7	2	3
8251-2017 March	1	1	2	1	1	2
Project Number: 0373-01-098	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0354-2045 August	4	4	28	4	1	7
0316-2403 August	4	4	28	4	1	7
3224-2030 September	2	2	5	2	2	5
3224-2030 October	1	1	2	1	1	2
8251-2005 September	2	2	5	2	1	3
Project Number: 0617-01-074	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0450-2013 May	1	1	2	1	1	2
0450-2013 June	1	1	3	1	1	3
0354-2045 August	11	7	48	11	1	7
0354-2045 September	11	7	18	11	1	3
0354-2045 October	14	13	18	14	11	15
0354-2045 November	3	3	4	3	1	2
0354-2045 December	1	1	2	1	1	2
0316-2001 August	4	3	21	4	1	7
0316-2001 September	14	8	20	14	1	7

0316-2001 October	13	12	16	13	10	14
0316-2001 November	4	4	6	4	4	6
0316-2001 December	1	1	2	1	1	2
0341-2064 August	6	5	34	6	1	7
0341-2064 September	5	4	10	5	1	3
0341-2064 October	9	9	12	9	8	11
0341-2064 November	6	6	8	6	6	8
8251-2005 September	1	1	3	1	1	3
8251-2005 October	2	2	3	2	1	2
8251-2005 November	2	2	3	2	1	2
Project Number: 0617-01-180	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0354-2021 November	7	7	10	7	7	10
0354-2021 April	1	1	2	1	1	2
0354-2021 May	1	1	2	1	1	2
0316-2402 November	7	7	10	7	7	10
0316-2402 April	2	2	3	2	1	2
0316-2402 May	1	1	2	1	1	2
0315-2011 June	2	2	6	2	2	6
3268-2048 November	7	7	10	7	7	10
3268-2048 April	2	2	3	2	1	2
3268-2048 May	1	1	2	1	1	2
3268-2048 June	1	1	3	1	1	3
8251-2005 January	1	1	2	1	1	2
8251-2005 June	1	1	3	1	1	3
0429-2007 June	1	1	3	1	1	3
Project Number: 0617-02-063	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0351-2012 February	2	2	2	2	2	3
0351-2012 March	3	3	4	3	3	4
0354-2090 February	2	2	3	2	2	3
0677-2003 June	1	1	3	1	1	2
0529-2009 April	1	1	2	1	1	3
3142-2007 April	13	11	14	13	8	39
3142-2007 May	2	2	3	2	1	7

3142-2007 June	1	1	3	1	1	3
3142-2009 April	13	11	14	13	8	11
3142-2009 May	2	2	3	2	1	2
0662-2004 March	1	1	2	1	1	2
0662-2004 April	1	1	2	1	1	2
0662-2004 May	1	1	2	1	1	2
Project Number: 0738-03-028	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0112-2002 September	1	1	3	1	1	3
0112-2002 November	2	2	3	2	2	3
0112-2002 January	1	1	2	1	1	2
0275-2071 October	1	1	2	1	1	2
0275-2071 November	1	1	2	1	1	2
0275-2071 December	1	1	1	1	1	1
0275-2071 January	1	1	2	1	1	2
0316-2015 October	2	2	3	2	2	3
0316-2015 November	1	1	2	1	1	2
0316-2015 December	1	1	1	1	1	1
0316-2015 January	1	1	2	1	1	2
0316-2402 October	1	1	2	1	1	2
0316-2402 November	1	1	2	1	1	2
0316-2402 March	1	1	2	1	1	2
0316-2402 April	1	1	2	1	1	2
0464-2005 October	1	1	2	1	1	2
0464-2005 November	1	1	2	1	1	2
8251-2006 May	1	1	2	1	1	2
8251-2006 July	1	1	2	1	1	2
0644-2058 January	1	1	2	1	1	2
0644-2058 February	2	2	2	2	2	3
Project Number: 1088-04-023	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0100-2002 October	1	1	2	1	1	2
0462-2010 January	1	1	2	1	1	2
0400-2005 July	1	1	5	1	1	5
0464-2007 October	1	1	2	1	1	2
0464-2007 November	1	1	2	1	1	2

0112-2002 October	1	1	2	1	1	2
0112-2002 November	1	1	2	1	1	2
0275-2038 October	1	1	2	1	1	2
0275-2038 November	1	1	2	1	1	2
0247-2056 November	1	1	2	1	1	2
0247-2056 December	1	1	2	1	1	2
0247-2056 January	1	1	2	1	1	2
0316-2402 December	1	1	2	1	1	2
0316-2402 March	1	1	2	1	1	2
3224-2030 March	3	3	3	3	3	4
0668-2105 April	1	1	2	1	1	2
0668-2105 May	1	1	2	1	1	2
0164-2035 May	1	1	2	1	1	2
Project Number: 1093-01-027	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0752-2020 May	1	1	2	1	1	2
0752-2020 June	1	1	3	1	1	3
0112-2002 May	1	1	2	1	1	2
0112-2002 June	1	1	3	1	1	3
0112-2002 July	1	1	5	1	1	5
0247-2056 May	1	1	2	1	1	2
0247-2056 June	1	1	3	1	1	3
0247-2056 July	1	1	5	1	1	5
0316-2015 June	2	2	6	2	1	2
0316-2015 July	3	3	9	3	1	3
0110-2001 May	1	1	2	1	1	2
0110-2001 July	1	1	5	1	1	5
0132-2008 August	1	1	7	1	1	7
0316-2402 July	2	2	10	2	1	5
0316-2402 August	1	1	7	1	1	7
3224-2021 August	2	2	14	2	1	7
0540-2001 August	1	1	7	1	1	7
8251-2006 August	1	1	7	1	1	7
8251-2006 October	1	1	2	1	1	2
0644-2060 August	1	1	7	1	1	7
0164-2023 August	1	1	7	1	1	7

Project Number: 1196-03-016	Model 1			Model 2		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0100-2002 June	1	1	3	1	1	3
0100-2002 July	1	1	5	1	1	5
0100-2002 September	1	1	3	1	1	3
0100-2002 October	1	1	2	1	1	2
0100-2002 November	1	1	2	1	1	2
0464-2007 April	1	1	2	1	1	2
0464-2007 May	2	2	3	2	2	3
0462-2011 May	1	1	2	1	1	2
0462-2011 June	1	1	3	1	1	3
0462-2011 July	1	1	5	1	1	5
0462-2011 August	1	1	7	1	1	7
0530-2006 September	1	1	2	1	1	3
0530-2006 October	1	1	2	1	1	2
0112-2001 June	1	1	3	1	1	3
0112-2001 July	1	1	5	1	1	5
0112-2001 August	1	1	7	1	1	7
0112-2001 September	1	1	3	1	1	3
0247-2366 June	1	1	3	1	1	3
0247-2366 July	1	1	5	1	1	5
0247-2366 August	4	4	28	4	2	14
0247-2366 September	1	1	3	1	1	3
0316-2015 July	1	1	5	1	1	5
0316-2015 August	1	1	7	1	1	7
0316-2015 September	1	1	3	1	1	3
0316-2015 October	2	2	3	2	1	2
0275-2046 July	1	1	5	1	1	5
0275-2046 August	2	2	14	2	2	14
0275-2046 September	7	6	15	7	3	8
0316-2403 October	6	6	15	6	5	7
0530-2012 August	1	1	2	1	1	7
0530-2012 September	1	1	3	1	1	3
0530-2012 October	1	1	2	1	1	2
0530-2012 November	1	1	2	1	1	2
0438-2002 October	1	1	2	1	1	2

0450-2641 September	1	1	3	1	1	3
0540-2001 August	1	1	7	1	1	7
8251-2006 October	1	1	2	1	1	2
0644-2022 December	1	1	2	1	1	2
Project Number: 1557-01-035	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
5049-2001 April	1	1	2	1	1	2
0479-2005 April	1	1	2	1	1	2
0479-2005 December	1	1	2	1	1	2
0354-2045 April	1	1	2	1	1	2
0354-2045 May	1	1	2	1	1	2
0351-2004 April	1	1	2	1	1	2
0351-2004 May	1	1	2	1	1	2
0316-2403 April	1	1	2	1	1	2
0316-2403 May	1	1	2	1	1	2
0341-2104 April	1	1	2	1	1	2
0341-2104 May	1	1	2	1	1	2
0341-2104 December	1	1	2	1	1	2
Project Number: 2343-01-030	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0100-2002 November	1	1	2	1	1	2
0100-2002 December	1	1	2	1	1	2
0100-2002 January	1	1	2	1	1	2
0100-2002 Febuary	1	1	2	1	1	2
0100-2002 March	1	1	2	1	1	2
0112-2002 November	1	1	2	1	1	2
0112-2002 December	1	1	2	1	1	2
0112-2002 January	1	1	2	1	1	2
0112-2002 February	1	1	2	1	1	2
0112-2002 March	1	1	2	1	1	2
0464-2005 November	1	1	2	1	1	2
0464-2005 December	1	1	2	1	1	2
0464-2005 Ferbuary	1	1	2	1	1	2
0464-2005 April	1	1	2	1	1	2
0464-2005 June	1	1	3	1	1	3
0275-2038 December	1	1	2	1	1	2

0275-2038 January	1	1	2	1	1	2
0275-2038 February	1	1	2	1	1	2
0275-2038 March	1	1	2	1	1	2
0247-2056 December	1	1	2	1	1	2
0247-2056 January	1	1	2	1	1	2
0247-2056 Feburary	1	1	2	1	1	2
0247-2056 March	1	1	2	1	1	2
0316-2590 March	2	2	2	2	2	3
0316-2590 April	1	1	2	1	1	2
0316-2402 March	2	2	2	2	2	2
0316-2402 April	1	1	2	1	1	2
3224-2048 July	6	5	24	6	1	5
0110-2001 November	1	1	2	1	1	2
0110-2001 December	1	1	2	1	1	2
0110-2001 January	1	1	2	1	1	2
0110-2001 Feburary	1	1	2	1	1	2
0110-2001 March	1	1	2	1	1	2
0132-2006 November	1	1	2	1	1	2
0132-2006 January	1	1	2	1	1	2
0132-2006 March	1	1	2	1	1	2
8251-2005 July	1	1	5	1	1	5
8251-2005 September	1	1	3	1	1	3
0644-2001 April	1	1	2	1	1	2
Project Number: 0074-02-072	**Model 1**			**Model 2**		
Item Codes and Months	**SAB**	**SPT**	**SPH**	**SAB**	**SPT**	**SPH**
0351-6002 May	2	2	2	2	1	2
0351-6012 May	4	4	4	4	2	3
0351-6012 Nov	1	1	1	1	1	2
0354-6002 April	5	4	5	5	2	3
0354-6002 May	4	4	4	4	2	3
0354-6002 Nov	1	1	1	1	1	2
0344-6120 April	7	6	6	7	7	9
0344-6120 May	18	3	4	18	14	19
0344-6120 June	3	3	7	3	3	9
0344-6120 July	1	1	5	1	1	5
0344-6120 Nov	1	1	1	1	1	2

0666-6315 July	1	1	5	1	1	5
0533-6001 June	1	1	3	1	1	3

APPENDIX 4.3

STATISTICAL ANALYSIS RESULTS BY ITEM

Model 1 Results

NO.	PROJECT	MODEL 1				
		S_{AB} VS S_{PT} (t Stat)	P(T<=t) two-tail	t Critical two-tail	SIGNIFICANT DIFFERENCE	$\frac{S_{PH}}{S_{AB}} > 1$
1	0371-03-114	1.963961012	0.081126189	2.262157163	NO	YES
2	0371-07-006	NO DIFFERENCE BETWEEN S_{AB} and S_{PT}			NO	YES
3	0371-04-056	1.384930607	0.189381206	2.160368656	NO	YES
4	0371-04-061	NO DIFFERENCE BETWEEN S_{AB} and S_{PT}			NO	YES
5	0372-01-093	1	0.337049058	2.17881283	NO	YES
6	0373-01-098	NO DIFFERENCE BETWEEN S_{AB} and S_{PT}			NO	YES
7	0617-01-074	2.516611478	0.021550153	2.10092204	YES	YES
8	0617-01-0180	NO DIFFERENCE BETWEEN S_{AB} and S_{PT}			NO	YES
9	0617-02-063	1.477097892	0.165406706	2.17881283	NO	YES
10	0738-03-028	NO DIFFERENCE BETWEEN S_{AB} and S_{PT}			NO	YES
11	1088-04-023	NO DIFFERENCE BETWEEN S_{AB} and S_{PT}			NO	YES
12	1093-01-027	NO DIFFERENCE BETWEEN S_{AB} and S_{PT}			NO	YES
13	1193-03-016	1	0.323805872	2.026192463	NO	YES
14	1557-01-035	NO DIFFERENCE BETWEEN S_{AB} and S_{PT}			NO	YES
15	2343-01-030	1	0.323636084	2.024394164	NO	YES
16	0074-02-072	1.141393825	0.275971974	2.17881283	NO	YES
17	0074-03-041	1	0.325053	2.039513	NO	YES
18	0074-03-042	NO DIFFERENCE BETWEEN S_{AB} and S_{PT}			NO	YES
19	0074-05-094	2.496150883	0.023858231	2.119905299	YES	3224-2048 August
20	0074-06-222	2.379154757	0.025301823	2.059538553	YES	YES
21	0086-19-030	NO DIFFERENCE BETWEEN S_{AB} and S_{PT}			NO	YES
22	0100-07-045	0.426401433	0.681057161	2.306004135	NO	YES
23	0101-01-066	1.363636364	0.184835996	2.059538553	NO	YES
24	0101-05-035	NO DIFFERENCE BETWEEN S_{AB} and S_{PT}			NO	YES
25	0254-01-137	1	0.335561278	2.160368656	NO	YES
26	0101-03-082	NO DIFFERENCE BETWEEN S_{AB} and S_{PT}			NO	YES
27	0101-04-108	1	0.373900966	2.776445105	NO	YES
28	0254-01-130	NO DIFFERENCE BETWEEN S_{AB} and S_{PT}			NO	YES
29	0348-06-023	1.426565007	0.15906635	2.001717484	NO	YES
30	0371-02-066	NO DIFFERENCE BETWEEN S_{AB} and S_{PT}			NO	YES

Model 2 Results

NO.	PROJECT	MODEL 2				
		S_{AB} VS S_{PT} (t Stat)	P(T<=t) two-tail	t Critical two-tail	SIGNIFICANT DIFFERENCE	$\frac{S_{PH}}{S_{AB}} > 1$
1	0371-03-114	4.019363072	0.003020958	2.262157163	YES	
2	0371-07-006	NO DIFFERENCE BETWEEN S_{AB} and S_{PT}			NO	YES
3	0371-04-056	2.432227444	0.030204393	2.160368656	YES	
4	0371-04-061	1.333333333	0.230809409	2.446911851	NO	YES
5	0372-01-093	2.034190511	0.064649446	2.17881283	NO	
6	0373-01-098	2.064187386	0.107938822	2.776445105	NO	YES
7	0617-01-074	3.263520498	0.004314915	2.10092204	YES	
8	0617-01-0180	1.471960144	0.164823445	2.160368656	NO	YES
9	0617-02-063	1.802254228	0.096660779	2.17881283	NO	YES
10	0738-03-028	NO DIFFERENCE BETWEEN S_{AB} and S_{PT}			NO	YES
11	1088-04-023	NO DIFFERENCE BETWEEN S_{AB} and S_{PT}			NO	YES
12	1093-01-027	2.024440825	0.056486162	2.085963447	NO	YES
13	1193-03-016	1.751387311	0.088165983	2.026192463	NO	YES
14	1557-01-035	NO DIFFERENCE BETWEEN S_{AB} and S_{PT}			NO	YES
15	2343-01-030	1	0.323636084	2.024394164	NO	YES
16	0074-02-072	2.408040224	0.033030667	2.17881283	YES	
17	0074-03-041	2.745565424	0.009962883	2.039513446	YES	
18	0074-03-042	3.627381251	0.004632631	2.228138852	YES	
19	0074-05-094	3.869322928	0.001358832	2.119905299	YES	
20	0074-06-222	3.426241444	0.002123265	2.059538553	YES	
21	0086-19-030	1.995217211	0.057027027	2.059538553	NO	YES
22	0100-07-045	3.1920955	0.012763109	2.306004135	YES	
23	0101-01-066	2.236067977	0.034511337	2.059538553	YES	
24	0101-05-035	1	0.334281943	2.144786688	NO	YES
25	0254-01-137	1.846574143	0.087693257	2.160368656	NO	YES
26	0101-03-082	1	0.363217468	2.570581836	NO	YES
27	0101-04-108	1.632993162	0.177807808	2.776445105	NO	
28	0254-01-130	2.132007164	0.054360123	2.17881283	NO	
29	0348-06-023	2.912828767	0.005078221	2.001717484	YES	
30	0371-02-066	1.490711985	0.166889596	2.228138852	NO	YES

Comparison between Estimated and Actual Duration by Activities

NO.	PROJECT	ACTUAL VS ESTIMATED			
		S_{AB} VS S_{TX} (t Stat)	P(T<=t) two-tail	t Critical two-tail	SIGNIFICANT DIFFERENCE
1	0371-03-114	-2.417990086	0.025819394	2.093024054	YES
2	0371-07-006	SAMPLE SIZE LESS THAN 10			
3	0371-04-056	2.045758193	0.067989259	2.228138852	NO
4	0371-04-061	SAMPLE SIZE LESS THAN 10			
5	0372-01-093	1.444444444	0.179206711	2.228138852	NO
6	0373-01-098	SAMPLE SIZE LESS THAN 10			
7	0617-01-074	SAMPLE SIZE LESS THAN 10			
8	0617-01-0180	SAMPLE SIZE LESS THAN 10			
9	0617-02-063	3.002599232	0.012023852	2.20098516	YES
10	0738-03-028	1.999943782	0.076559763	2.262157163	NO
11	1088-04-023	3.303627323	0.005707748	2.160368656	YES
12	1093-01-027	3.721727769	0.002277246	2.144786688	YES
13	1193-03-016	2.334890381	0.03132978	2.10092204	YES
14	1557-01-035	1.36414704	0.205658103	2.262157163	NO
15	2343-01-030	2.808289332	0.013950803	2.144786688	YES
16	0074-02-072	SAMPLE SIZE LESS THAN 10			
17	0074-03-041	2.161004957	0.056014422	2.228138852	NO
18	0074-03-042	SAMPLE SIZE LESS THAN 10			
19	0074-05-094	SAMPLE SIZE LESS THAN 10			
20	0074-06-222	-0.628251599	0.538704355	2.119905299	NO
21	0086-19-030	3.724625131	0.001843945	2.119905299	YES
22	0100-07-045	SAMPLE SIZE LESS THAN 10			
23	0101-01-066	-5.31972417	1.85356E-05	2.063898562	YES
24	0101-05-035	-0.128671253	0.902633256	2.570581836	NO
25	0254-01-137	2.000555573	0.076484282	2.262157163	NO
26	0101-03-082	1.960732935	0.08154828	2.262157163	NO
27	0101-04-108	SAMPLE SIZE LESS THAN 10			
28	0254-01-130	1.464469204	0.173782835	2.228138852	NO
29	0348-06-023	2.543735095	0.029175705	2.228138852	YES
30	0371-02-066	3.221369926	0.010466383	0.010466383	YES

APPENDIX 4.4

STATISTICAL ANALYSIS RESULTS BY PROJECTS

S_{AB} vs S_{PT}					
Ballesteros-Perez et Al Model			Apipattanavis et Al. Model		
t-Test: Paired Two Sample for Means			t-Test: Paired Two Sample for Means		
	S_{AB}	S_{PT}		S_{AB}	S_{PT}
Mean	40.366667	36.866667	Mean	40.366667	31.03333333
Variance	524.1023	501.77471	Variance	524.1023	401.6195402
Observations	30	30	Observations	30	30
Pearson Correlation	0.9757105		Pearson Correlation	0.952625	
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
df	29		df	29	
t Stat	3.8222142		t Stat	7.1159659	
P(T<=t) one-tail	0.0003234		P(T<=t) one-tail	3.937E-08	
t Critical one-tail	1.699127		t Critical one-tail	1.699127	
P(T<=t) two-tail	0.0006469		P(T<=t) two-tail	7.875E-08	
t Critical two-tail	2.0452296		t Critical two-tail	2.0452296	

S_{PH} vs S_{AB}					
Ballesteros-Perez et Al Model			Apipattanavis et Al. Model		
t-Test: Paired Two Sample for Means			t-Test: Paired Two Sample for Means		
	S_{PH}	S_{AB}		S_{PH}	S_{AB}
Mean	81.5	40.36667	Mean	62.63333	40.36666667
Variance	2083.776	524.1023	Variance	1052.24	524.1022989
Observations	30	30	Observations	30	30
Pearson Correlation	0.651467		Pearson Correlation	0.771364	
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
df	29		df	29	
t Stat	6.38191		t Stat	5.876733	
P(T<=t) one-tail	2.81E-07		P(T<=t) one-tail	1.12E-06	
t Critical one-tail	1.699127		t Critical one-tail	1.699127	
P(T<=t) two-tail	5.62E-07		P(T<=t) two-tail	2.23E-06	
t Critical two-tail	2.04523		t Critical two-tail	2.04523	

S_{TX} vs S_{PT}					
Ballesteros-Perez et Al Model			Apipattanavis et Al. Model		
t-Test: Paired Two Sample for Means			t-Test: Paired Two Sample for Means		
	S_{PH}	S_{TX}		S_{TX}	S_{PH}
Mean	81.5	78.33333	Mean	78.33333	62.63333333
Variance	2083.776	2087.678	Variance	2087.678	1052.24023
Observations	30	30	Observations	30	30
Pearson Correlation	0.235096		Pearson Correlation	0.431335	
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
df	29		df	29	
t Stat	0.307055		t Stat	1.993194	
P(T<=t) one-tail	0.380498		P(T<=t) one-tail	0.027862	
t Critical one-tail	1.699127		t Critical one-tail	1.699127	
P(T<=t) two-tail	0.760996		P(T<=t) two-tail	0.055723	
t Critical two-tail	2.04523		t Critical two-tail	2.04523	

S_{TX} vs S_{AB}		
t-Test: Paired Two Sample for Means		
	S_{TX}	S_{AB}
Mean	78.33333333	40.36667
Variance	2087.678161	524.1023
Observations	30	30
Pearson Correlation	0.337876365	
Hypothesized Mean Difference	0	
df	29	
t Stat	4.764568763	
P(T<=t) one-tail	2.4394E-05	
t Critical one-tail	1.699127027	
P(T<=t) two-tail	4.8788E-05	
t Critical two-tail	2.045229642	

APPENDIX 5.1

SUMMARY STATISTICS AND ANALYSIS RESULTS FOR WEATHER CONDITIONS

Items with Some Significant Results (10 Items)										
ID	**Item**	**N**	**Summary Stats of PR** **V.N**				**Non-Parametric Comparison test**	**Post Hoc test**	**Regression** **V.N**	
				Clear	**Cloudy**	**MildSevere**				**Results**
1	0432-2039	97	92	N=26 Mean=101.14 Median=51.2 SD=212.77 Min=2 Max=1107	N=45 Mean=31.06 Median=14.64 SD=43.64 Min=0.15 Max=174	N=21 Mean=74.8 Median=20 SD=90.64 Min=5.56 Max=246	H_a: Medians are not all equal Kruskal-Wallis χ^2_2 = 7.7 p=0.02*	H_a: $m_{cle}>m_{cloudy}$ W=784 p=0.009** 95% CI for $m_{cle}-m_{clo}$: (1.9, 61) H_a: $m_{clo}<m_{mildsever}$ W=317.5 p=0.02* 95% CI for $m_{clo}-m_{mildse}$: (-37.6, -1.1)	91	H_a: Means are not all equal $F_{(2, 88)}$ =4.3 p=0.02* β_{cloudy}=-29.8 (95% CI: -60.1, 0.4) $\beta_{mildsever}$=13.9 (95% CI: -22, 49.8) $\mu_{clo}-\mu_{mildsev}$=-43.7 (95% CI for $\mu_{clo}-\mu_{mildsev}$: -86.7, -0.8)
2	0644-2060	71	61	N=21 Mean=24.9 Median=11 SD=27.15 Min=1 Max=101	N=40 Mean=13.05 Median=7 SD=20.12 Min=1 Max=111	NA	H_a: $m_{clear}>m_{cloudy}$ W=571 p=0.01* 95% CI for $m_{cle}-m_{cloudy}$: (1, 14)	NA	59	H_a: $\beta_{cloudy}\neq0$ $F_{(1, 57)}$ =5.75 p=0.02* β_{cloudy}=-10.6 (95% CI: -19.4, -1.7)
3	0420-2004	80	77	N=19 Mean=53.53 Median=18.84 SD=74.66 Min=2 Max=313.57	N=48 Mean=22.91 Median=18.44 SD=16.48 Min=4.98 Max=66.1	N=10 Mean=16.44 Median=11.67 SD=15.85 Min=3.2 Max=56.64	H_a: Medians are not all equal Kruskal-Wallis χ^2_2 = 4.54 p=0.1	NA	66	H_a: $\beta_{cloudy}\neq0$ $F_{(1, 64)}$ =5.25 p=0.03* β_{cloudy}=-16.2 (95% CI: -30.2, -2.1)

4	0467 - 2286	91	89	N=26 Mean=4.15 Median=2 SD=4.9 Min=1 Max=23	N=50 Mean=7.32 Median=4 SD=9.4 Min=1 Max=62	N=13 Mean=10.31 Median=6 SD=9.59 Min=2 Max=28	H_a: Medians are not all equal Kruskal-Wallis x_2^2 = 10.84 p=0.004**	H_a: m_{cle}<m_{cloudy} W=401 p=0.002* 95% CI for m_{cle}-m_{clo}: (-3, -6.2e-05) H_a: m_{clear}<$m_{mildsever}$ W=81 p=0.003** 95% CI for m_{cle}-m_{mildse}: (-6, -7.9e-05)	75	H_a: β_{cloudy}≠0 $F_{(1, 73)}$ =2.78 p=0.1 β_{cloudy}=2.1 (95% CI: -0.4, 4.5)
5	0672 - 2012	71	56	N=25 Mean=116.76 Median=60 SD=164.75 Min=8 Max=687	N=31 Mean=169.65 Median=111 SD=164.95 Min=14 Max=681	NA	H_a: m_{clear}<m_{cloudy} W=268 p=0.02* 95% CI for m_{cle}-m_{cloudy}: (-97, -7.8e-05)	NA	53	H_a: β_{cloudy}≠0 $F_{(1, 51)}$ =7.0 p=0.01* β_{cloudy}=80.7 (95% CI: 19.7, 141.7)
6	0316 - 6002	93	80	N=23 Mean=103.95 Median=42 SD=217.46 Min=7 Max=1078	N=57 Mean=172.4 Median=89 SD=261.37 Min=3 Max=1120.5	NA	H_a: m_{clear}<m_{cloudy} W=461 p=0.02* 95% CI for m_{cle}-m_{cloudy}: (-63, -3.5E-05)	NA	76	H_a: β_{cloudy}≠0 $F_{(1, 74)}$ =3.3 p=0.07* β_{cloudy}=63.8 (95% CI: -5.8, 133.4)
7	0316 - 6001	92	82	N=32 Mean=2055.66 Median=1350 SD=1732.55 Min=20 Max=6000	N=50 Mean=5616.56 Median=2310 SD=7821.7 Min=4 Max=32656	NA	H_a: m_{clear}<m_{cloudy} W=520 p=0.004** 95% CI for m_{cle}-m_{cloudy}: (-2370, -270)	NA	79	H_a: β_{cloudy}≠0 $F_{(1, 77)}$ =5.1 p=0.03* β_{cloudy}=1998.6 (95% CI: 233, 3764.2)
8	0316 - 2594	69	59	N=20 Mean=333.1 Median=255.5 SD=254.19 Min=28 Max=931	N=39 Mean=216.9 Median=141.12 SD=259.3 Min=3 Max=1204	NA	H_a: m_{clear}>m_{cloudy} W=518 p=0.02* 95% CI for m_{cle}-m_{cloudy}: (6, 214.8)	NA	57	H_a: β_{cloudy}≠0 $F_{(1, 55)}$ =10.4 p=0.002** β_{cloudy}=-166.9 (95% CI: -270.9, -63)
9		85	75	N=40	N=35	NA	H_a: m_{clear}<m_{cloudy}	NA	72	H_a: β_{cloudy}≠0

	0247 - 6041			Mean=946.49 Median=583.71 SD=1320.01 Min=30.5 Max=7123.7	Mean=1334.65 Median=810.05 SD=1531.54 Min=37 Max=5636.02		W=638.5 p=0.3 95% CI for m_{cle}-m_{cloudy}: (-452.5, 190.6)			$F_{(1, 70)}$ =5 p=0.03* β_{cloudy}=532.4 (95% CI: 58.9, 1005.9)
10	0275 - 6001	9 1	88	N=45 Mean=59.54 Median=50.17 SD=19.97 Min=25.07 Max=144.21	N=32 Mean=96.7 Median=74.7 SD=92.03 Min=12.4 Max=465.69	N=11 Mean=60.4 Median=50.01 SD=38.2 Min=14.74 Max=164.66	H_a: Medians are not all equal Kruskal-Wallis [illegible] = 5 p=0.08	NA	75	H_a: β_{cloudy}≠0 $F_{(1, 73)}$ =5.4 p=0.02* β_{cloudy}=16.3 (95% CI: 2.3, 30.3)
Items with Non-Significant Results (29 Items)										
1	0500 - 6001	9 9	72	N=28 Mean=0.27 Median=0.08 SD=0.3 Min=0.02 Max=0.9	N=34 Mean=0.43 Median=0.29 SD=0.37 Min=0.03 Max=0.9	N=10 Mean=0.3 Median=0.2 SD=0.28 Min=0.05 Max=0.9	H_a: Medians are not all equal Kruskal-Wallis [illegible] = 4.1 p=0.13	NA	62	H_a: β_{cloudy}≠0 $F_{(1, 60)}$ =3.5 p=0.07 β_{cloudy}=0.16 (95% CI: -0.01, 0.34)
2	0496 - 2007	9 1	86	N=34 Mean=95.91 Median=52.5 SD=125.79 Min=12 Max=556	N=52 Mean=120.58 Median=51.5 SD=225.91 Min=4 Max=1259	NA	H_a: m_{clear}>m_{cloudy} W=898.5 p=0.45 95% CI for m_{cle}-m_{cloudy}: (-15, 22)	NA	83	H_a: β_{cloudy}≠0 $F_{(1, 81)}$ =1.2 p=0.28 β_{cloudy}=-24.97 (95% CI: -71, 21)
3	0542 - 2002	6 5	55	N=15 Mean=2.53 Median=2 SD=1.88 Min=1 Max=8	N=40 Mean=3.23 Median=2 SD=3.1 Min=1 Max=14	NA	H_a: m_{clear}<m_{cloudy} W=286 p=0.4 95% CI for m_{cle}-m_{cloudy}: (-1, 1)	NA	54	H_a: β_{cloudy}≠0 $F_{(1, 52)}$ =0.32 p=0.58 β_{cloudy}=0.42 (95% CI: -1.1, 1.9)
4	0677 - 2001	8 1	71	N=18 Mean=4664.94 Median=1619 SD=6196.67 Min=75	N=53 Mean=5671.75 Median=2274 SD=11646.27 Min=4	NA	H_a: m_{clear}<m_{cloudy} W=497 p=0.61 95% CI for m_{cle}-m_{cloudy}: (-1064, 1397)	NA	69	H_a: β_{cloudy}≠0 $F_{(1, 67)}$ =0.4 p=0.53 β_{cloudy}=-965.4 (95% CI: -4016.7, 2086)

				Max=22228	Max=69490					
5	3224 - 2008	65	62	N=27 Mean=963.43 Median=762.82 SD=779.32 Min=45.72 Max=2560.84	N=35 Mean=904.81 Median=828.57 SD=700.36 Min=12 Max=2609.19	NA	H_a: $m_{clear}<m_{cloudy}$ W=487 p=0.58 95% CI for $m_{cle}-m_{cloudy}$: (-318.6, 431.8)	NA	62	H_a: $\beta_{cloudy}\neq0$ $F_{(1, 60)}=0.1$ p=0.76 β_{cloudy}=-58.6 (95% CI: -435.5, 318.3)
6	0668 - 2106	85	84	N=33 Mean=10.03 Median=4 SD=14.26 Min=1 Max=60	N=41 Mean=9.02 Median=7 SD=8.63 Min=1 Max=43	N=10 Mean=10.6 Median=9 SD=6.88 Min=4 Max=22	H_a: Medians are not all equal Kruskal-Wallis x_2^2 = 2.87 p=0.24	NA	70	H_a: $\beta_{cloudy}\neq0$ $F_{(1, 68)}=2.09$ p=0.15 β_{cloudy}=2.2 (95% CI: -0.8, 5.3)
7	0668 - 2116	77	75	N=31 Mean=6.71 Median=4 SD=7.8 Min=1 Max=39	N=33 Mean=6.42 Median=3 SD=6.16 Min=1 Max=20	N=11 Mean=6.91 Median=6 SD=5.39 Min=1 Max=21	H_a: Medians are not all equal Kruskal-Wallis x_2^2 = 1.13 p=0.57	NA	63	H_a: $\beta_{cloudy}\neq0$ $F_{(1, 61)}=0.31$ p=0.58 β_{cloudy}=0.79 (95% CI: -2.1, 3.7)
8	0160 - 2003	72	59	N=11 Mean=56543.5 Median=5333.33 SD=105256.3 Min=98 Max=271672.8	N=48 Mean=47820.47 Median=10937.06 SD=155108.1 Min=128.22 Max=1061656	NA	H_a: $m_{clear}<m_{cloudy}$ W=271 p=0.56 95% CI for $m_{cle}-m_{cloudy}$: (-11661, 9043)	NA	47	NA
9	0310 - 2005	67	62	N=24 Mean=2240.31 Median=1691.25 SD=2075.69 Min=0 Max=7070	N=38 Mean=1498.51 Median=1500 SD=1064.45 Min=150 Max=4485	NA	H_a: $m_{clear}>m_{cloudy}$ W=516 p=0.19 95% CI for $m_{cle}-m_{cloudy}$: (-335, 1250)	NA	61	H_a: $\beta_{cloudy}\neq0$ $F_{(1, 59)}=2.05$ p=0.16 β_{cloudy}=-531.8 (95% CI: -1275, 211)
10	0618 - 2018	65	64	N=13	N=39	N=12	H_a: Medians are not all equal	NA	63	H_a: Means are not all equal

				Mean=613.11 Median=451 SD=675.59 Min=10 Max=2480	Mean=530.71 Median=131 SD=691.16 Min=18 Max=2500	Mean=661.75 Median=293 SD=1146.47 Min=32 Max=4112	Kruskal-Wallis χ^2 = 0.25 p=0.88			$F_{(2, 60)}$ =0.53 p=0.59 β_{cloudy}=-82.4 (95% CI: -497, 332) $\beta_{mildsevere}$=-265 (95% CI: -795. 265)
11	0662 - 2001	9 5	85	N=36 Mean=1541.75 Median=760 SD=2036.51 Min=130 Max=10220	N=49 Mean=2095.49 Median=950 SD=2636.52 Min=50 Max=11080	NA	H_a: m_{clear},m_{cloudy} W=824 p=0.30 95% CI for m_{cle}-m_{cloudy}: (-460, 200)	NA	82	H_a: $\beta_{cloudy}\neq0$ $F_{(1, 80)}$ =1.25 p=0.27 β_{cloudy}=446.1 (95% CI: -347, 1239)
12	0432 - 2001	9 4	94	N=26 Mean=57.76 Median=28.75 SD=71 Min=0.42 Max=273.31	N=52 Mean=36.95 Median=11.04 SD=54.39 Min=0.47 Max=252.77	N=16 Mean=68.14 Median=43.13 SD=127.15 Min=0.61 Max=534.81	H_a: Medians are not all equal Kruskal-Wallis χ^2 = 2.06 p=0.36	NA	91	H_a: Means are not all equal $F_{(2, 88)}$ =1.05 p=0.36 β_{cloudy}=-16.4 (95% CI: -39, 6.2) $\beta_{Mildsevere}$=-12.1 (95% CI: -42.4, 18.1)
13	0666 - 2003	6 8	63	N=21 Mean=6292.52 Median=2850 SD=7802.29 Min=146 Max=27050	N=30 Mean=4448.03 Median=1872.5 SD=5007.47 Min=20 Max=19500	N=12 Mean=3085.58 Median=2542 SD=2893.27 Min=110 Max=9526	H_a: Medians are not all equal Kruskal-Wallis χ^2 = 0.91 p=0.63	NA	61	H_a: Means are not all equal $F_{(2, 58)}$ =0.4 p=0.67 β_{cloudy}=231 (95% CI: -2410, 2872) $\beta_{Mildsevere}$=-1131 (95% CI: -4453, 2191)
14	0666 - 2111	6 7	54	N=23 Mean=15639.67 Median=7820 SD=18500.25	N=31 Mean=17382.02 Median=6882 SD=21935.27	NA	H_a: m_{clear}>m_{cloudy} W=361 p=0.47 95% CI for	NA	53	H_a: $\beta_{cloudy}\neq0$ $F_{(1, 51)}$ =0.0 p=0.94 β_{cloudy}=-381.6

				Min=111 Max=61714	Min=66 Max=81101		m_{cle}-m_{cloudy}: (-6061, 5966)			(95% CI: -10767, 10004)
15	1122 - 2037	7 7	72	N=32 Mean=972.69 Median=617.5 SD=1043.74 Min=39 Max=4960.64	N=40 Mean=653.58 Median=304 SD=1214.38 Min=24 Max=5555	NA	H_a: m_{clear}>m_{cloudy} W=770 p=0.07 95% CI for m_{cle}-m_{cloudy}: (-47, 462)	NA	69	H_a: $\beta_{cloudy} \neq 0$ $F_{(1, 67)}$ =1.12 p=0.29 β_{cloudy}=-199 (95% CI: -575, 177)
16	3268 - 2008	9 2	84	N=38 Mean=1007.17 Median=799.15 SD=779.21 Min=11.24 Max=2995.84	N=46 Mean=742.14 Median=484.63 SD=696.74 Min=4.99 Max=2756.41	NA	H_a: m_{clear}>m_{cloudy} W=1051 p=0.06 95% CI for m_{cle}-m_{cloudy}: (-37.3, 540.7)	NA	84	H_a: $\beta_{cloudy} \neq 0$ $F_{(1, 82)}$ =2.7 p=0.10 β_{cloudy}=-265 (95% CI: -585.6, 55.5)
17	3268 - 2047	7 9	78	N=23 Mean=1820.89 Median=1445.67 SD=1344.47 Min=53.1 Max=4971	N=38 Mean=1244.46 Median=1425.37 SD=841.66 Min=9.5 Max=3355.45	N=17 Mean=1389.46 Median=1227.08 SD=962.67 Min=430.36 Max=3355.45	H_a: Medians are not all equal Kruskal-Wallis χ^2 = 2.4 p=0.30	NA	75	H_a: Means are not all equal $F_{(2, 72)}$ =1.06 p=0.35 β_{cloudy}=-282.4 (95% CI: -725, 160) $\beta_{Mildsevere}$=-345.5 (95% CI: -886, 195)
18	0662 - 6111	6 6	62	N=21 Mean=699.62 Median=505 SD=791.75 Min=40 Max=3555	N=41 Mean=748.73 Median=362 SD=1170.34 Min=40 Max=6812	NA	H_a: m_{clear}>m_{cloudy} W=469.5 p=0.28 95% CI for m_{cle}-m_{cloudy}: (-127, 265)	NA	61	H_a: $\beta_{cloudy} \neq 0$ $F_{(1, 59)}$ =0.29 p=0.59 β_{cloudy}=-102.5 (95% CI: -484, 279)
19	0465 - 2001	6 3	60	N=16 Mean=1.8 Median=0.75 SD=2.32 Min=0.5 Max=9	N=44 Mean=1.93 Median=1 SD=1.95 Min=0.25 Max=8	NA	H_a: m_{clear}<m_{cloudy} W=314 p=0.26 95% CI for m_{cle}-m_{cloudy}: (-0.5, 0.25)	NA	58	H_a: $\beta_{cloudy} \neq 0$ $F_{(1, 56)}$ =0.9 p=0.35 β_{cloudy}=0.47 (95% CI: -0.52, 1.46)
20		6 5	54	N=23	N=31	NA	H_a: m_{clear}>m_{cloudy}	NA	53	H_a: $\beta_{cloudy} \neq 0$

	8251 - 2017			Mean=17271.57 Median=12915 SD=16590.76 Min=185 Max=58711	Mean=10709.97 Median=5994 SD=10412.72 Min=505 Max=38059		W=431 p=0.1 95% CI for m_{cle}-m_{cloudy}: (-1332, 11748)			$F_{(1, 51)}$ =1.9 p=0.17 β_{cloudy}=-4678 (95% CI: -11470, 2114)
21	0341 - 6042	79	68	N=14 Mean=2003.21 Median=1183.26 SD=2489.86 Min=46.41 Max=9249.8	N=54 Mean=940.04 Median=1052.09 SD=457.25 Min=1.68 Max=1543.86	NA	H_a: m_{clear}>m_{cloudy} W=445 p=0.16 95% CI for m_{cle}-m_{cloudy}: (-160, 776)	NA	54	NA
22	0247 - 2366	67	60	N=14 Mean=1268.13 Median=1161.94 SD=1135.94 Min=38.86 Max=3722.45	N=46 Mean=2592.03 Median=935.39 SD=7111.24 Min=62.69 Max=47909	NA	H_a: m_{clear}>m_{cloudy} W=312 p=0.57 95% CI for m_{cle}-m_{cloudy}: (-661, 705)	NA	45	NA
23	0316 - 2015	60	53	N=17 Mean=2511.65 Median=2960 SD=1955.34 Min=360 Max=5850	N=36 Mean=1938.89 Median=1240 SD=1564.95 Min=190 Max=6945	NA	H_a: m_{clear}>m_{cloudy} W=352 p=0.19 95% CI for m_{cle}-m_{cloudy}: (-400, 1920)	NA	52	H_a: β_{cloudy}≠0 $F_{(1, 50)}$ =2.42 p=0.13 β_{cloudy}=-715.8 (95% CI: -1640, 208.4)
24	0530 - 2017	65	54	N=19 Mean=1387.33 Median=888.89 SD=1324.26 Min=200.3 Max=3952	N=35 Mean=2006 Median=1750.16 SD=2086.28 Min=17.33 Max=7889.65	NA	H_a: m_{clear}<m_{cloudy} W=292.5 p=0.24 95% CI for m_{cle}-m_{cloudy}: (-1287, 350)	NA	53	H_a: β_{cloudy}≠0 $F_{(1, 51)}$ =0.86 p=0.36 β_{cloudy}=445.6 (95% CI: -520, 1411)
25	0531 - 2004	73	61	N=21 Mean=69.68 Median=51.66 SD=52.27 Min=3.07 Max=188.15	N=40 Mean=84.42 Median=42.45 SD=106.43 Min=1.75 Max=508.78	NA	H_a: m_{clear}>m_{cloudy} W=466.5 p=0.24 95% CI for m_{cle}-m_{cloudy}: (-22.5, 31.1)	NA	59	H_a: β_{cloudy}≠0 $F_{(1, 57)}$ =0.04 p=0.84 β_{cloudy}=-3.52 (95% CI: -38.2, 31.2)
26	0341 - 6076	80	72	N=33 Mean=719.59 Median=843.12	N=39 Mean=823.31 Median=914.35	NA	H_a: m_{clear}<m_{cloudy} W=530 p=0.1	NA	70	H_a: β_{cloudy}≠0 $F_{(1, 68)}$ =1.19 p=0.28

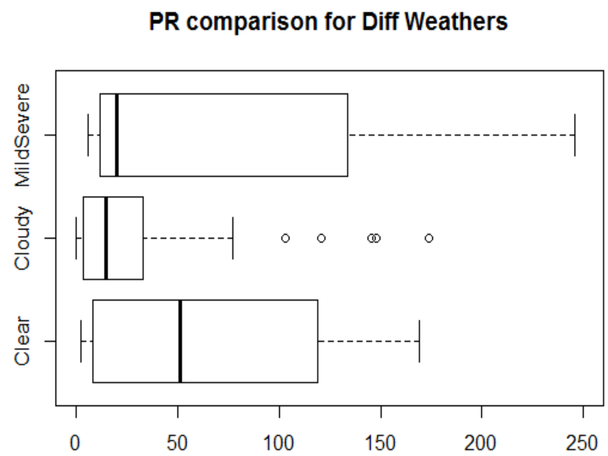
				SD=416.63 Min=25.62 Max=2073.18	SD=512.53 Min=51.9 Max=2282.56		95% CI for m_{cle}-m_{cloudy}: (-318.8, 68)			β_{cloudy}=107.6 (95% CI: -89, 304)
27	0341-6008	62	55	N=22 Mean=1457.68 Median=1100.51 SD=1371.15 Min=92.06 Max=7030.54	N=21 Mean=1068.54 Median=968.49 SD=755 Min=46.73 Max=2447.65	N=12 Mean=928.42 Median=835.06 SD=604.95 Min=100 Max=2103.89	H_a: Medians are not all equal Kruskal-Wallis χ^2_2 = 2.01 p=0.37	NA	54	H_a: Means are not all equal $F_{(2, 51)}$ =0.62 p=0.54 β_{cloudy}=-123.8 (95% CI: -534.1, 286.6) $\beta_{Mildsever}$=-263.9 (95% CI: -745, 217)
28	4481-2001	74	60	N=9 Mean=120.45 Median=92.8 SD=75.12 Min=42.6 Max=268.48	N=51 Mean=131.26 Median=92.8 SD=79.14 Min=19.47 Max=338.02	NA	H_a: $m_{clear}<m_{cloudy}$ W=217 p=0.40 95% CI for m_{cle}-m_{cloudy}: (-61.3, 28.8)	NA	51	NA
29	2085-2002	61	58	N=17 Mean=69.41 Median=71 SD=28.97 Min=28 Max=127	N=41 Mean=77.06 Median=58 SD=50.93 Min=10 Max=266	NA	H_a: $m_{clear}>m_{cloudy}$ W=348.5 p=0.50 95% CI for m_{cle}-m_{cloudy}: (-21, 21)	NA	57	H_a: $\beta_{cloudy}\neq0$ $F_{(1, 55)}$ =0.07 p=0.79 β_{cloudy}=2.9 (95% CI: -19.3, 25.1)
Items did not allow performing of statistical analysis due to small sample sizes (1 Items)										
1	3224-2042	68	63	N=3 Mean=1256.92 Median=1012 SD=786.42 Min=622.1 Max=2136.66	N=60 Mean=1178.9 Median=1096.43 SD=773.86 Min=22.65 Max=2583.54	NA	NA	NA	NA	NA

*P-value<0.05, **p-value<0.01, ***p-value<0.001

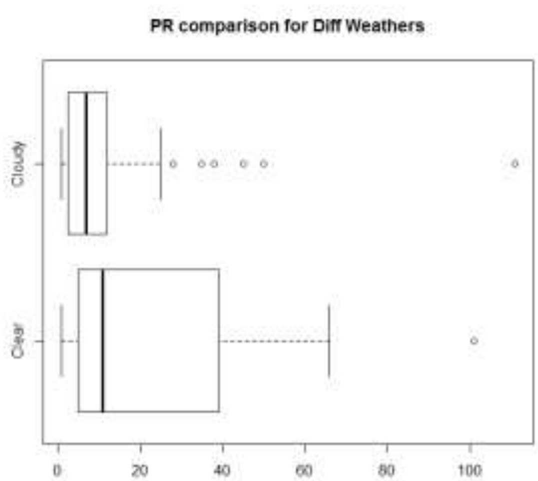
NA indicate no statistical analysis was feasible.

Plots for Descriptive Statistics (Only for Significant Items)

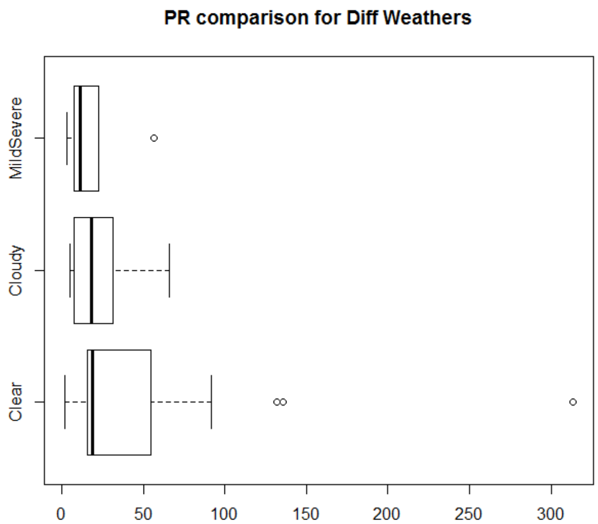
For Item 0432-2039 (Item description is RIPRAP (MOW STRIP) (4 IN))



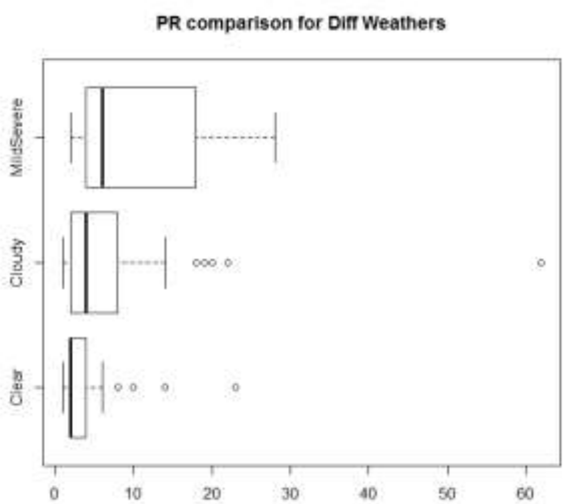
For Item 0644-2060 (Item description is REMOVE SM RD SN SUP & AM)



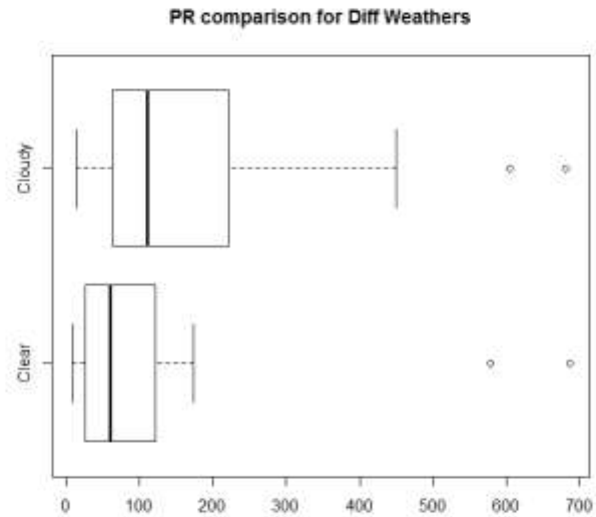
For Item 0420-2004 (Item description is CL C CONC (BENT))



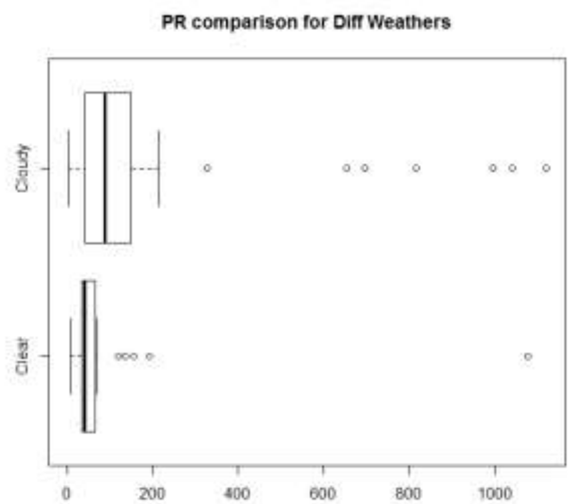
For Item 0467-2286 (Item description is SET (TY II) (18 IN) (RCP) (6:1) (P))



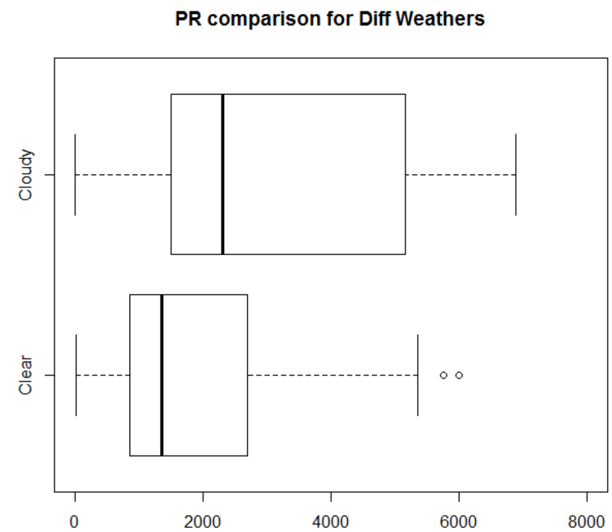
For Item 0672-2012 (Item description is REFL PAV MRKR TY I-C)



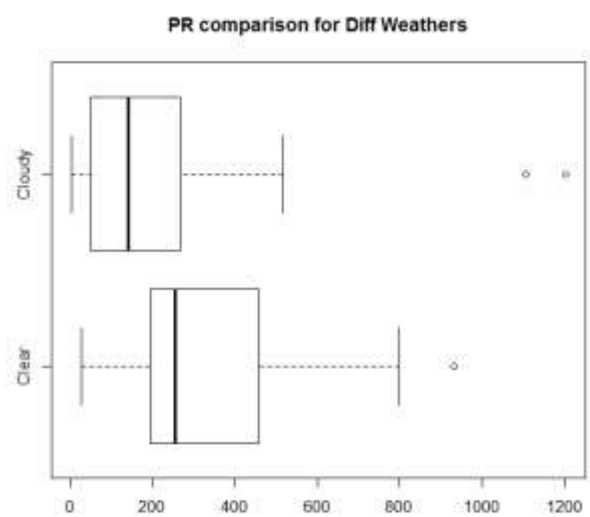
For Item 0316-6002 (Item description is AGGR (MULTI OPTION))



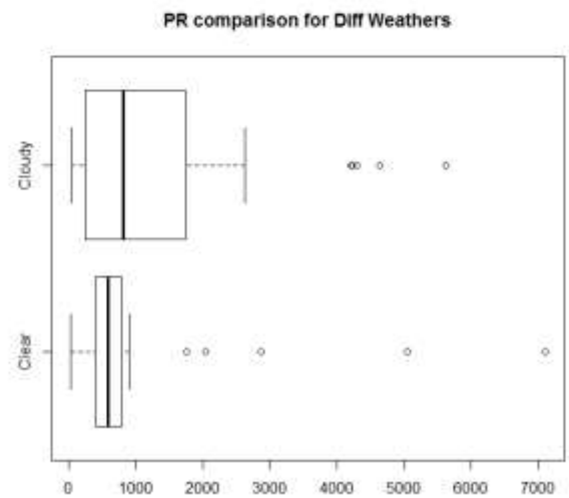
For Item 0316-6001 (Item description is ASPH (MULTI OPTION))



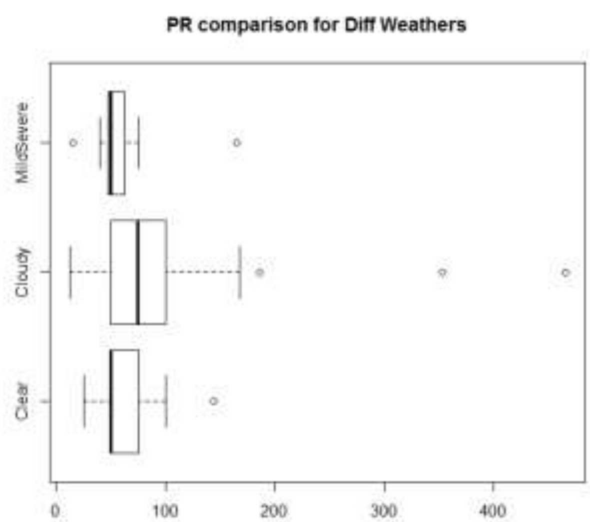
For Item 0316-2594 (Item description is AGGR (TY-PB GR-3 OR TY-PB GR-3S) SAC-B)



For Item 0247-6041 (Item description is FL BS (CMP IN PLC) (TYA GR1-2) (FNAL POS))



For Item 0275-6001 (Item description is CEMENT)



APPENDIX 5.2

SUMMARY STATISTICS AND ANALYSIS RESULTS FOR TEMPERATURE

Items with Some Significant Results (7 Items)									
ID	Item	Raw	Summary Stats of PR/Temp			Correlation Test		Regression	
		N	Valid N	PR	Temp	Cor	p-value	Valid N	Results
1	0432-2039	97	71	N=71 Mean=67.55 Median=16.4 SD=141.27 Min=0.15 Max=1107	N=71 Mean=78.45 Median=78 SD=13.72 Min=46 Max=101	-0.35	0.004**	65	Ha: β ≠ 0 $F_{(1, 63)}$ =8.9 p= 0.004** β=-1.9 (95% CI: -3.18, -0.63)
2	0420-2004	80	59	N=59 Mean=34.25 Median=22.48 SD=45.02 Min=2 Max=313.57	N=59 Mean=86.41 Median=88 SD=13.54 Min=57 Max=106	0.32	0.01*	56	Ha: β ≠ 0 $F_{(1, 54)}$ =10.25 p= 0.002** β=0.83 (95% CI: 0.31, 1.35)
3	0662-2001	95	62	N=62 Mean=1870.52 Median=725 SD=2429.4 Min=50 Max=10220	N=62 Mean=75.35 Median=75 SD=13.73 Min=29 Max=103	0.48	<0.001***	57	Ha: β ≠ 0 $F_{(1, 55)}$ =15.83 p= <0.001*** β=81.48 (95% CI: 40.4, 122.5)
4	3268-2008	92	17	N=17 Mean=567.71 Median=388.43 SD=539.99 Min=20.69 Max=1607.85	N=17 Mean=80.71 Median=86 SD=11.52 Min=59 Max=97	-0.63	0.006**	16	Ha: β ≠ 0 $F_{(1, 14)}$ =5.06 p= 0.04* β=-23.99 (95% CI: -48.87, -1.11)
5	0341-6042	79	68	N=68 Mean=1130.48 Median=1074.31 SD=1204.27 Min=30.53 Max=9249.8	N=68 Mean=79.96 Median=80 SD=10.86 Min=57 Max=100	0.34	0.005**	64	Ha: β ≠ 0 $F_{(1, 62)}$ =8.34 p= 0.005** β=22.64 (95% CI: 6.97, 38.32)
6	0316-6002	93	79	N=79 Mean=129.26 Median=60 SD=223.78 Min=3 Max=1120.5	N=79 Mean=73.89 Median=71 SD=10.48 Min=54 Max=94	0.46	<0.001***	71	Ha: β ≠ 0 $F_{(1, 69)}$ =9.84 p= 0.003** β=3.66 (95% CI: 1.33, 5.98)

7	0316-6001	92	84	N=84 Mean=3659.99 Median=1900 SD=5700.9 Min=4 Max=32656	N=84 Mean=73 Median=71 SD=10.76 Min=48 Max=100	0.46	<0.001***	76	Ha: β ≠ 0 $F_{(1, 74)}$ =19.57 p= <0.001*** β=131.85 (95% CI: 72.5, 191.2)
Items with Non-Significant Results (33 Items)									
1	0500-6001	99	40	N=40 Mean=0.38 Median=0.34 SD=0.31 Min=0.02 Max=0.9	N=40 Mean=82.28 Median=84 SD=10.45 Min=55 Max=98	0.24	0.13	36	Ha: β ≠ 0 $F_{(1, 34)}$ =2.74 p=0.11 β=0.01 (95% CI: -0.003, 0.03)
2	0496-2007	91	68	N=68 Mean=124.9 Median=53.5 SD=224.63 Min=4 Max=1259	N=68 Mean=82.56 Median=84 SD=13.53 Min=45 Max=105	0.11	0.35	63	Ha: β ≠ 0 $F_{(1, 61)}$ =0.10 p=0.76 β=0.36 (95% CI: -1.93, 2.65)
3	0542-2002	65	38	N=38 Mean=2.92 Median=2 SD=2.8 Min=1 Max=14	N=38 Mean=86.53 Median=89.5 SD=10.12 Min=60 Max=100	0.09	0.58	33	Ha: β ≠ 0 $F_{(1, 31)}$ =1.01 p=0.32 β=0.06 (95% CI: -0.06, 0.18)
4	0644-2060	71	42	N=42 Mean=11.64 Median=6 SD=15.41 Min=1 Max=66	N=42 Mean=80.1 Median=77.5 SD=14.15 Min=40 Max=100	0.12	0.46	38	Ha: β ≠ 0 $F_{(1, 36)}$ =0.34 p=0.56 β=0.09 (95% CI: -0.22, 0.39)
5	0677-2001	81	58	N=58 Mean=4789.43 Median=1365.5 SD=10719.37 Min=4 Max=69490	N=58 Mean=82.5 Median=85 SD=15 Min=45 Max=103	0.0004	1	54	Ha: β ≠ 0 $F_{(1, 52)}$ =0.17 p=0.68 β=15.19 (95% CI: -58.5, 88.9)
6	3224-2008	65	63	N=63 Mean=975.73 Median=860.92 SD=743.08 Min=12 Max=2609.19	N=63 Mean=84.13 Median=86 SD=12.34 Min=51 Max=100	-0.01	0.93	60	Ha: β ≠ 0 $F_{(1, 58)}$ =0.02 p=0.89 β=-1.17 (95% CI: -18.3, 15.9)
7	0668-2106	85	29	N=29 Mean=6.97 Median=4 SD=6.66 Min=1 Max=25	N=29 Mean=6.97 Median=83 SD=11.47 Min=60 Max=101	-0.15	0.42	28	Ha: β ≠ 0 $F_{(1, 26)}$ =1.44 p=0.24 β=-0.14 (95% CI: -0.39, 0.10)

8	0668-2116	77	31	N=31 Mean=5.77 Median=4 SD=4.98 Min=1 Max=20	N=31 Mean=83.68 Median=83 SD=11.01 Min=60 Max=101	-0.09	0.6	29	Ha: β ≠ 0 $F_{(1, 27)}$ =0.2 p=0.66 β=-0.03 (95% CI: -0.19, 0.13)
9	0160-2003	72	43	N=43 Mean=42067.55 Median=3371 SD=163879.5 Min=98 Max=1061656	N=43 Mean=78.6 Median=80 SD=15.18 Min=35 Max=101	-0.05	0.72	39	Ha: β ≠ 0 $F_{(1, 37)}$ =0.05 p=0.83 β=125.1 (95% CI: -1044.5, 1294.7)
10	0310-2005	67	29	N=29 Mean=2091.97 Median=1827.5 SD=1640.54 Min=210 Max=6150	N=29 Mean=80.86 Median=80 SD=13.42 Min=55 Max=100	-0.1	0.59	28	Ha: β ≠ 0 $F_{(1, 26)}$ =0.80 p=0.38 β=-22.54 (95% CI: -74.26, 29.2)
11	0467-2286	91	53	N=53 Mean=6.3 Median=4 SD=9.61 Min=1 Max=62	N=53 Mean=82.58 Median=81 SD=11.4 Min=63 Max=102	-0.15	0.28	50	Ha: β ≠ 0 $F_{(1, 48)}$ =0.83 p=0.37 β=-0.07 (95% CI: -0.22, 0.08)
12	0618-2018	65	56	N=56 Mean=594.24 Median=193.5 SD=817.43 Min=10 Max=4112	N=56 Mean=80.23 Median=82.5 SD=14.84 Min=43 Max=100	0.18	0.19	52	Ha: β ≠ 0 $F_{(1, 50)}$ =4.03 p=0.05 β=14.74 (95% CI: -3.8e-03, 29.5)
13	0672-2012	71	29	N=29 Mean=107.49 Median=83 SD=81.21 Min=8 Max=347.25	N=29 Mean=83.48 Median=84 SD=14.61 Min=49 Max=103	-0.07	0.71	26	Ha: β ≠ 0 $F_{(1, 24)}$ =0.26 p=0.62 β=-0.58 (95% CI: -2.95, 1.79)
14	0432-2001	94	58	N=58 Mean=42.42 Median=10.39 SD=59.77 Min=0.42 Max=252.77	N=58 Mean=79.03 Median=78 SD=13.16 Min=54 Max=103	0.02	0.88	53	Ha: β ≠ 0 $F_{(1, 51)}$ =0.003 p=0.95 β=-0.04 (95% CI: -1.28, 1.21)
15	0666-2003	68	23	N=23 Mean=4818.17 Median=2580 SD=6055.6 Min=20	N=23 Mean=87.78 Median=91 SD=11.17 Min=65	-0.35	0.1	21	Ha: β ≠ 0 $F_{(1, 19)}$ =1.12 p=0.30 β=-102.8 (95% CI: -305.6, 100)

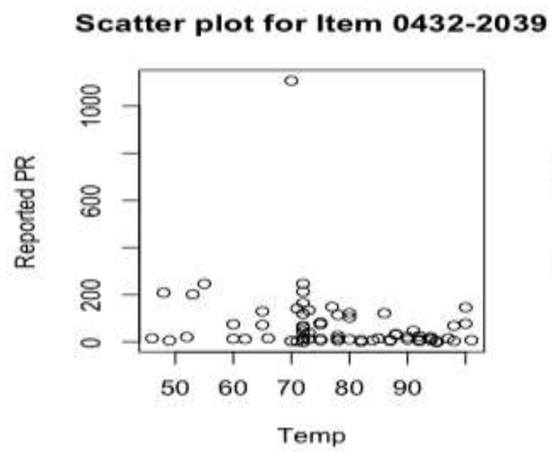
				Max=24970	Max=101				
16	0666-2111	67	25	N=25 Mean=17428.52 Median=12445 SD=20555.01 Min=66 Max=81101	N=25 Mean=89.12 Median=91 SD=10.05 Min=65 Max=101	-0.07	0.75	23	Ha: β ≠ 0 $F_{(1, 21)}$ =0.72 p=0.41 β=-329.4 (95% CI: -1137, 478)
17	1122-2037	77	31	N=31 Mean=672.32 Median=278 SD=1086.32 Min=35 Max=5555	N=31 Mean=82.23 Median=83 SD=12.89 Min=51 Max=101	-0.07	0.7	29	Ha: β ≠ 0 $F_{(1, 27)}$ =2.79 p=0.11 β=16.32 (95% CI: -3.72, 36.36)
18	3268-2047	79	40	N=40 Mean=1252.72 Median=1314.22 SD=959.94 Min=9.5 Max=4971	N=40 Mean=94.28 Median=99 SD=11.99 Min=55 Max=103	0.06	0.73	34	Ha: β ≠ 0 $F_{(1,32)}$ =0.25 p=0.62 β=34.94 (95% CI: -107, 177)
19	0662-6111	66	31	N=31 Mean=821.81 Median=384 SD=1305.82 Min=77 Max=6812	N=31 Mean=88.71 Median=91 SD=8.13 Min=70 Max=100	0.14	0.44	28	Ha: β ≠ 0 $F_{(1, 26)}$ =0.69 p=0.41 β=16.19 (95% CI: -23.93, 56.31)
20	0465-2001	63	54	N=54 Mean=1.75 Median=1 SD=1.98 Min=0.25 Max=9	N=54 Mean=79.39 Median=80.5 SD=15.08 Min=48 Max=105	0.08	0.58	50	Ha: β ≠ 0 $F_{(1, 48)}$ =0.85 p=0.36 β=-0.01 (95% CI: -0.04, 0.02)
21	3224-2042	68	25	N=25 Mean=738.59 Median=564 SD=672.45 Min=22.65 Max=2136.66	N=25 Mean=93.36 Median=97 SD=7.86 Min=74 Max=103	-0.06	0.76	23	Ha: β ≠ 0 $F_{(1, 21)}$ =0.02 p=0.89 β=-3.37 (95% CI: -54.48, 47.74)
22	8251-2017	65	27	N=27 Mean=12845.11 Median=9449 SD=11865.6 Min=256 Max=38059	N=27 Mean=87.22 Median=90 SD=9.81 Min=61 Max=101	0.09	0.65	26	Ha: β ≠ 0 $F_{(1, 24)}$ =1.51 p=0.23 β=341.2 (95% CI: -231.2, 913.6)
23	0247-2366	67	53	N=53 Mean=1488.89 Median=986.84	N=53 Mean=80.09 Median=81	0.06	0.68	48	Ha: β ≠ 0 $F_{(1, 46)}$ =0.008 p=0.93

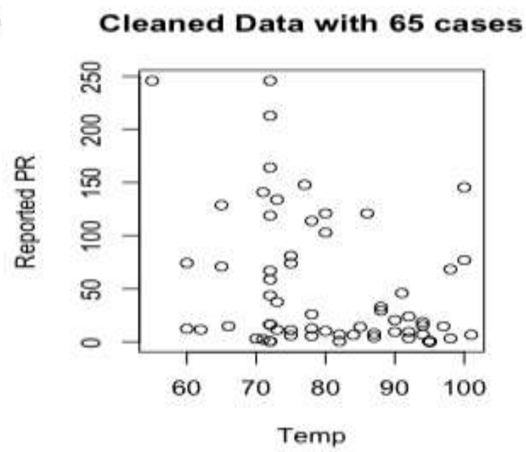
				SD=1830.93 Min=38.86 Max=9255	SD=12.09 Min=52 Max=98				β=-1.68 (95% CI: -40.66, 37.29)
24	0316-2015	60	48	N=48 Mean=2036.56 Median=1425 SD=1727.7 Min=190 Max=7475	N=48 Mean=87 Median=89 SD=8.36 Min=69 Max=102	0.002	1	42	Ha: β ≠ 0 $F_{(1, 40)}$ =1.04 p=0.31 β=32.12 (95% CI: -31.61, 95.85)
25	0316-2594	69	38	N=38 Mean=316.16 Median=260.5 SD=294.13 Min=10 Max=1204	N=38 Mean=87.16 Median=89 SD=9.47 Min=68 Max=105	-0.07	0.67	33	Ha: β ≠ 0 $F_{(1, 31)}$ =2.61 p=0.12 β=-7.49 (95% CI: -16.94, 1.97)
26	0530-2017	65	23	N=23 Mean=1171.75 Median=808 SD=1147.76 Min=45 Max=3934	N=23 Mean=89.26 Median=90 SD=9.22 Min=72 Max=103	0.33	0.12	21	Ha: β ≠ 0 $F_{(1, 19)}$ =2.45 p=0.13 β=51.71 (95% CI: -17.38, 120.8)
27	0247-6041	85	37	N=37 Mean=1046.3 Median=667 SD=1184.54 Min=30.5 Max=5059.5	N=37 Mean=83.35 Median=84 SD=5.95 Min=69 Max=94	0.06	0.72	31	Ha: β ≠ 0 $F_{(1, 29)}$ =0.45 p=0.51 β=22.28 (95% CI: -45.66, 90.21)
28	0531-2004	73	25	N=25 Mean=116.97 Median=93.44 SD=124.45 Min=1.75 Max=508.78	N=25 Mean=70.24 Median=71 SD=16.55 Min=43 Max=97	0.1	0.65	24	Ha: β ≠ 0 $F_{(1, 22)}$ =0.04 p=0.85 β=0.24 (95% CI: -2.28, 2.76)
29	0341-6076	80	74	N=74 Mean=768.35 Median=858.13 SD=475.42 Min=25.62 Max=2282.56	N=74 Mean=77.59 Median=79.5 SD=8.67 Min=60 Max=92	-0.1	0.37	67	Ha: β ≠ 0 $F_{(1, 65)}$ =1.55 p=0.22 β=-9.25 (95% CI: -24.1, 5.6)
30	0341-6008	62	56	N=56 Mean=1180.53 Median=928.46 SD=1028.17 Min=46.73 Max=7030.54	N=56 Mean=80.2 Median=82 SD=10.92 Min=52 Max=98	-0.08	0.57	53	Ha: β ≠ 0 $F_{(1, 51)}$ =0.002 p=0.96 β=-0.42 (95% CI: -19.4, 18.6)
31		74	70	N=70	N=70	-0.18	0.13	64	Ha: β ≠ 0

	4481- 2001			Mean=134.16 Median=92.8 SD=85.86 Min=19.47 Max=460.8	Mean=79.74 Median=83.5 SD=17.4 Min=35 Max=104				$F_{(1, 62)}$ =0.02 p=0.88 β=0.11 (95% CI: -1.33, 1.54)
32	0275- 6001	91	45	N=45 Mean=85.49 Median=50.14 SD=84.56 Min=12.4 Max=465.69	N=45 Mean=80.29 Median=82 SD=9.75 Min=53 Max=95	-0.11	0.48	40	Ha: β ≠ 0 $F_{(1, 38)}$ =0.004 p=0.95 β=-0.05 (95% CI: -1.79, 1.69)
33	2085- 2002	61	61	N=61 Mean=74.73 Median=62 SD=44.6 Min=10 Max=266	N=61 Mean=87.21 Median=90 SD=10.95 Min=59 Max=101	-0.03	0.79	56	Ha: β ≠ 0 $F_{(1, 54)}$ =0.31 p=0.58 β=-0.3 (95% CI: -1.4, 0.79)

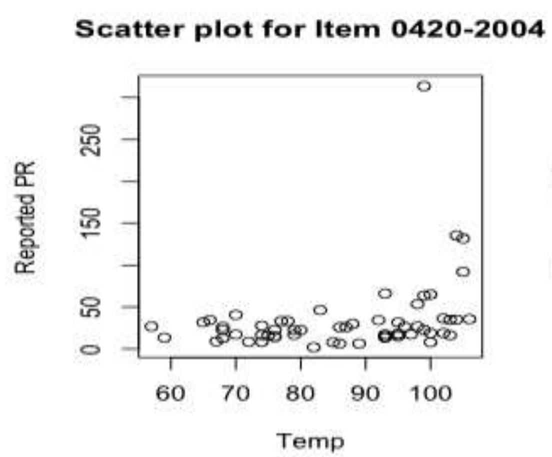
Scatterplots for Temperature vs Reported PR (only for Significant Items)

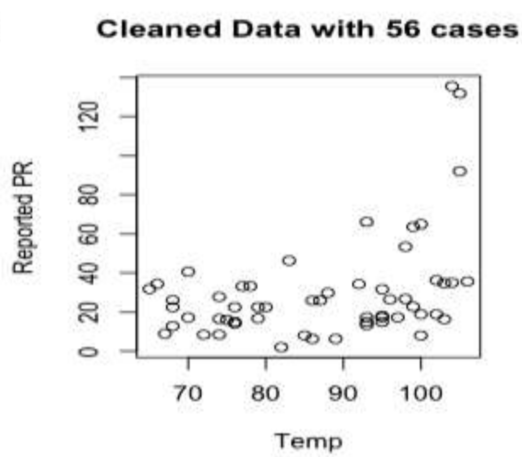
For Item 0432-2039 (Item description is RIPRAP (MOW STRIP) (4 IN))



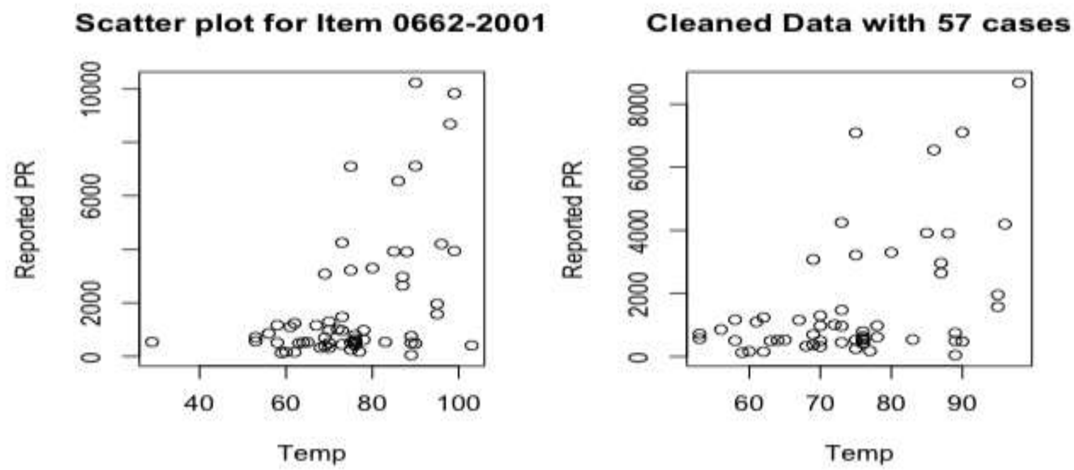


For Item 0420-2004 (Item description is CL C CONC (BENT))

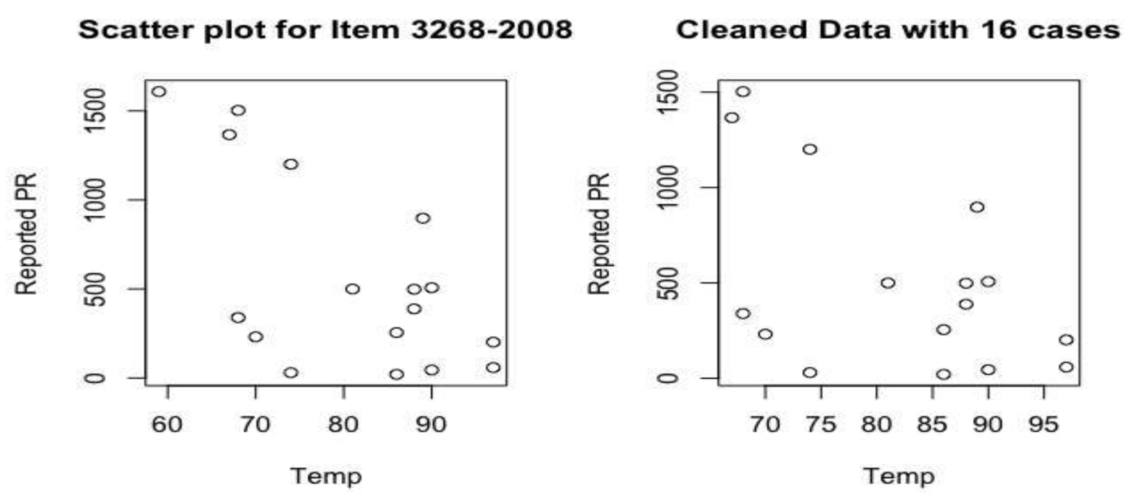




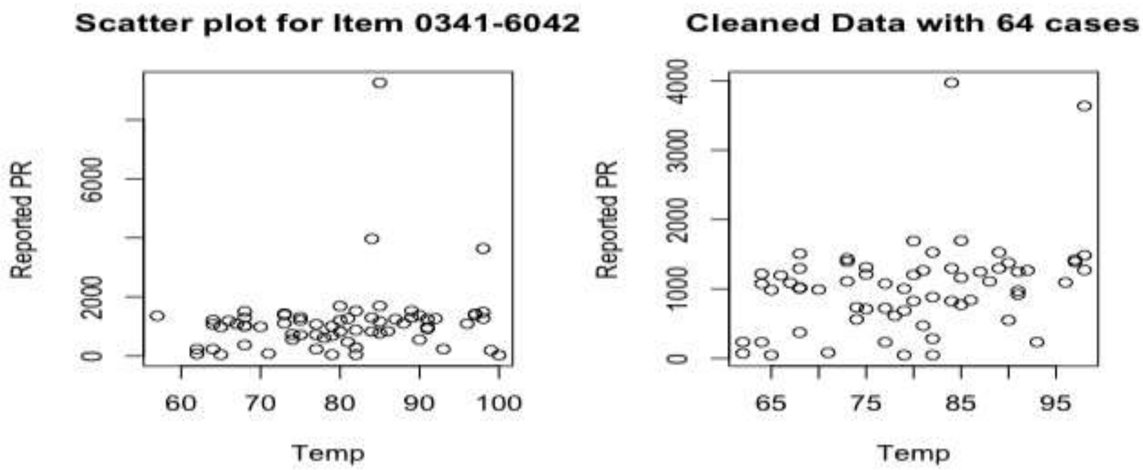
For Item 0662-2001 (Item description is WK ZN PAV MRK NON-REMOV (W) 4" (BRK))



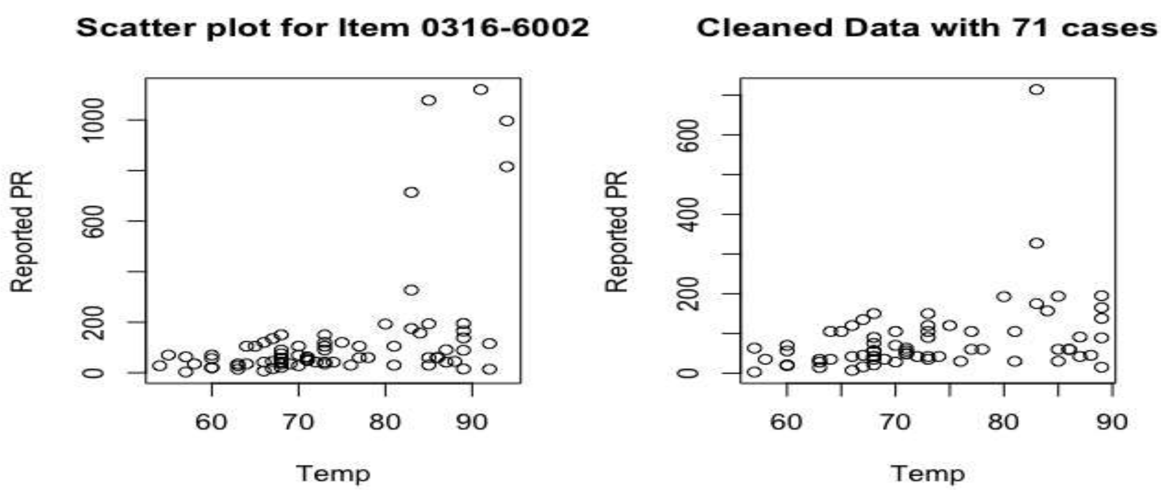
For Item 3268-2008 (Item description is D-GR HMA TY-B PG64-22)



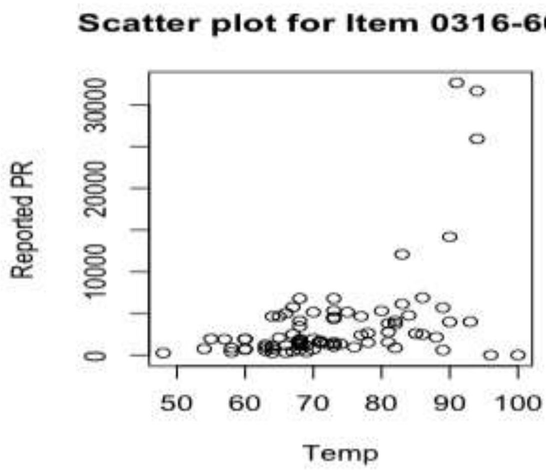
For Item 0341-6042 (Item description is D-GR HMA TY-D SAC-B PG70-22)

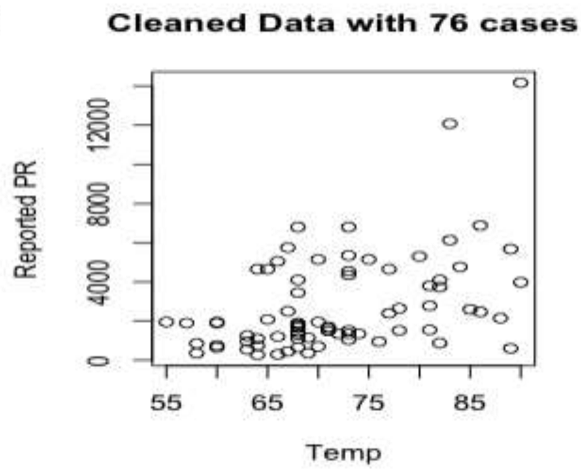


For Item 0316-6002 (Item description is AGGR (MULTI OPTION))



For Item 0316-6001 (Item description is ASPH (MULTI OPTION))


Scatter plot for Item 0316-6001
Reported PR
0
10000
20000
30000
50
60
70
80
90
100
Temp


Cleaned Data with 76 cases
Reported PR
0
4000
8000
12000
55
65
75
85
Temp

APPENDIX 5.3.

SUMMARY STATISTICS AND ANALYSIS RESULTS FOR LOCATION (URBAN/RURAL)

Items with Some Significant Results (16 Items)								
ID	**Item**	**Raw N**	**Summary Stats of PR**			**Non-parametric Comparison test**	**Regression Results**	
			Valid N	**Rural**	**Urban**		**Valid N**	**Results**
1	0496-2007	91	91	N=60 Mean=80.58 Median=32 SD=153.72 Min=4 Max=984	N=31 Mean=197.61 Median=97 SD=274.36 Min=20 Max=1259	H_a: m_r<m_u W=421 p<0.001*** 95% CI for m_r-m_u: (-80, -26)	88	H_a: $\beta_{urban}\neq0$ $F_{(1, 86)}$ =7.58 p=0.007** β_{urban}=75.42 (95% CI: 20.97, 129.87)
2	0677-2001	81	81	N=55 Mean=3742.93 Median=1214 SD=6656.75 Min=50 Max=42434	N=26 Mean=7997.23 Median=4493 SD=14329.59 Min=4 Max=69490	H_a: m_r>m_u W=531 p=0.03* 95% CI for m_r-m_u: (-3890, 46)	79	H_a: $\beta_{urban}\neq0$ $F_{(1, 77)}$ =4.01 p=0.04 β_{urban}=2511.1 (95% CI: 14.18, 5008)
3	0668-2116	77	77	N=53 Mean=5.91 Median=4 SD=6.6 Min=1 Max=39	N=24 Mean=8.21 Median=5 SD=6.58 Min=1 Max=20	H_a: m_r<m_u W=497 p=0.06 95% CI for m_r-m_u: (-5, 0)	76	H_a: $\beta_{urban}\neq0$ $F_{(1, 74)}$ =4.89 p=0.03* β_{urban}=2.94 (95% CI: 0.29, 5.59)
4	0160-2003	72	72	N=42 Mean=11948.71 Median=3321 SD=16862.98 Min=8.01 Max=66870.75	N=30 Mean=86774.84 Median=22390.98 SD=199095.9 Min=138.89 Max=1061656	H_a: m_r<m_u W=336 p<0.001*** 95% CI for m_r-m_u: (-35365, -3504)	71	H_a: $\beta_{urban}\neq0$ $F_{(1, 69)}$ =11.29 p=0.001** β_{urban}=41210 (95% CI: 16743, 65675)
5	0310-2005	67	67	N=20 Mean=1053.6 Median=650 SD=928.24	N=47 Mean=3716.22 Median=1800 SD=11139.68	H_a: m_r<m_u W=262 p=0.002** 95% CI for m_r-m_u:	66	H_a: $\beta_{urban}\neq0$ $F_{(1, 64)}$ =7.217 p=0.009** β_{urban}=1055.1

				Min=150 Max=2875	Min=0 Max=7766.16	(-1548, -263)		(95% CI: 270, 1840)
6	0420-2004	80	80	N=32 Mean=13.46 Median=7.8 SD=11.77 Min=0.43 Max=46.3	N=48 Mean=39.23 Median=22.48 SD=49.35 Min=4.98 Max=313.57	H_a: $m_r<m_u$ W=306 P<0.001*** 95% CI for m_r-m_u: (-20, -9)	79	H_a: $\beta_{urban}\neq0$ $F_{(1, 77)}$ =13.91 P<0.001*** β_{urban}=19.94 (95% CI: 9.29, 30.58)
7	0467-2286	91	91	N=30 Mean=11.07 Median=6 SD=11.62 Min=1 Max=62	N=61 Mean=4.72 Median=4 SD=4.02 Min=1 Max=22	H_a: $m_r>m_u$ W=1247 p=0.002** 95% CI for m_r-m_u: (0, 4)	90	H_a: $\beta_{urban}\neq0$ $F_{(1, 88)}$ =12.55 P<0.001*** β_{urban}=-4.59 (95% CI: -7.16, -2.01)
8	0618-2018	65	65	N=33 Mean=243.55 Median=64.5 SD=352.9 Min=10 Max=1200	N=32 Mean=893.88 Median=687.5 SD=945.35 Min=18 Max=4112	H_a: $m_r<m_u$ W=236.5 P<0.001*** 95% CI for m_r-m_u: (-754, -125)	64	H_a: $\beta_{urban}\neq0$ $F_{(1, 62)}$ =14.1 P<0.001*** β_{urban}=546.5 (95% CI: 255.54, 837.50)
9	0662-2001	95	95	N=43 Mean=2835.77 Median=1633.75 SD=2930.79 Min=130 Max=11080	N=52 Mean=1010.71 Median=585 SD=1210.78 Min=50 Max=6550	H_a: $m_r>m_u$ W=1609.5 P<0.001*** 95% CI for m_r-m_u: (370, 1750)	92	H_a: $\beta_{urban}\neq0$ $F_{(1, 90)}$ =12.84 P<0.001*** β_{urban}=-1259.7 (95% CI: -1958, -561)
10	0432-2001	94	94	N=44 Mean=13.38 Median=6.8 SD=19.74 Min=0.42 Max=97.71	N=50 Mean=78.49 Median=56.27 SD=92.44 Min=0.68 Max=534.81	H_a: $m_r<m_u$ W=375 p<0.001*** 95% CI for m_r-m_u: (-64, -26)	93	H_a: $\beta_{urban}\neq0$ $F_{(1, 91)}$ =29.45 p<0.001*** β_{urban}=55.79 (95% CI: 35.37, 76.22)
11	3268-2008	92	92	N=39 Mean=410.27 Median=388.43 SD=380.43 Min=4.99 Max=1554.86	N=53 Mean=1152.19 Median=1203.68 SD=782.05 Min=59.35 Max=2995.84	H_a: $m_r<m_u$ W=432 p<0.001*** 95% CI for m_r-m_u: (-1059, -370)	91	H_a: $\beta_{urban}\neq0$ $F_{(1, 89)}$ =29.25 p<0.001*** β_{urban}=706.47 (95% CI: 447, 966)
12	0465-2001	63	63	N=45 Mean=1.27	N=18 Mean=3.5	H_a: $m_r<m_u$ W=116	60	H_a: $\beta_{urban}\neq0$ $F_{(1, 58)}$ =52.42

				Median=0.75 SD=1.58 Min=0.25 Max=8	Median=3.75 SD=2.11 Min=0.5 Max=9	p<0.001*** 95% CI for m_r-m_u: (-3, -1)		p<0.001*** β_{urban}=2.21 (95% CI: 1.60, 2.82)
13	0316-6002	93	93	N=57 Mean=250.38 Median=120 SD=305.33 Min=14 Max=1120.5	N=36 Mean=39.47 Median=42 SD=18.69 Min=3 Max=70	H_a: m_r>m_u W=1845.5 p<0.001*** 95% CI for m_r-m_u: (63, 112)	89	H_a: $\beta_{urban}\neq0$ $F_{(1, 87)}$ =17.38 p<0.001*** β_{urban}=-149.87 (95% CI: -221.33, -78.41)
14	0316-6001	92	92	N=58 Mean=5658.86 Median=3940 SD=7224.87 Min=4 Max=32656	N=34 Mean=1277.35 Median=1325 SD=491.19 Min=300 Max=1950	H_a: m_r>m_u W=1592 p<0.001*** 95% CI for m_r-m_u: (1700, 3350)	87	H_a: $\beta_{urban}\neq0$ $F_{(1, 85)}$ =24.8 p<0.001*** β_{urban}=-2371.3 (95% CI: -3318, -1424)
15	0247-2366	67	67	N=50 Mean=2674.84 Median=1322.6 SD=6810.71 Min=38.86 Max=47909	N=17 Mean=836.75 Median=508.08 SD=900.17 Min=62.69 Max=3722.45	H_a: m_r>m_u W=568 p=0.02* 95% CI for m_r-m_u: (8.87, 1065.86)	66	H_a: $\beta_{urban}\neq0$ $F_{(1, 64)}$ =3.42 p=0.07 β_{urban}=-914.9 (95% CI: -1904, 74)
16	0530-2017	65	65	N=38 Mean=2487.93 Median=2071 SD=1987.13 Min=17.33 Max=7889.65	N=27 Mean=580.43 Median=334.83 SD=633.38 Min=45 Max=2335.84	H_a: m_r>m_u W=865.5 p<0.001*** 95% CI for m_r-m_u: (878, 2144)	64	H_a: $\beta_{urban}\neq0$ $F_{(1, 62)}$ =23.73 p<0.001*** β_{urban}=-1761.5 (95% CI: -2482, -1038)
Items with Non-Significant Results (10 Items)								
1	0500-6001	99	99	N=81 Mean=0.28 Median=0.1 SD=0.3 Min=0.02 Max=0.9	N=18 Mean=0.33 Median=0.07 SD=0.4 Min=0.03 Max=0.9	H_a: m_r>m_u W=732 p=0.49 95% CI for m_r-m_u: (-0.04, 0.04)	81	NA (Only rural left)
2	0542-2002	65	62	N=50 Mean=2.7 Median=2 SD=2.67 Min=1	N=12 Mean=3.17 Median=1 SD=3.13 Min=1	H_a: m_r>m_u W=322 p=0.34 95% CI for m_r-m_u: (-1, 1)	48	NA (Only rural left)

				Max=14	Max=8			
3	0644-2060	71	71	N=46 Mean=17.8 Median=6.5 SD=25.93 Min=1 Max=111	N=25 Mean=11.76 Median=9 SD=10.95 Min=1 Max=45	H_a: $m_r<m_u$ W=529.5 p=0.29 95% CI for m_r-m_u: (-5, 3)	69	H_a: $\beta_{urban}\neq0$ $F_{(1, 67)}$ =0.26 p=0.61 β_{urban}=-2.03 (95% CI: -9.95, 5.88)
4	3224-2008	65	65	N=24 Mean=744.93 Median=779.91 SD=482.31 Min=12 Max=1752.77	N=41 Mean=1065.24 Median=911.29 SD=851.87 Min=0.02 Max=2609.19	H_a: $m_r<m_u$ W=402 p=0.11 95% CI for m_r-m_u: (-759.61, 142.85)	65	H_a: $\beta_{urban}\neq0$ $F_{(1, 63)}$ =2.85 p=0.1 β_{urban}=320.3 (95% CI: -59, 699)
5	0668-2106	85	85	N=61 Mean=8.97 Median=6 SD=11.19 Min=1 Max=60	N=24 Mean=10.96 Median=10 SD=10.23 Min=1 Max=43	H_a: $m_r<m_u$ W=622.5 p=0.14 95% CI for m_r-m_u: (-6, 1)	81	H_a: $\beta_{urban}\neq0$ $F_{(1, 79)}$ =3.07 p=0.08 β_{urban}=2.75 (95% CI: -0.37, 5.88)
6	0672-2012	71	71	N=54 Mean=184.74 Median=96.5 SD=297.94 Min=7 Max=1938	N=17 Mean=121.53 Median=97 SD=99.94 Min=8 Max=298	H_a: $m_r<m_u$ W=485.5 p=0.64 95% CI for m_r-m_u: (-53, 61)	55	NA (Only rural left)
7	0666-2003	68	68	N=58 Mean=4459.83 Median=2306 SD=5640.89 Min=9 Max=27050	N=10 Mean=6836.2 Median=5917 SD=7399.86 Min=580 Max=24970	H_a: $m_r<m_u$ W=204 p=0.07 95% CI for m_r-m_u: (-5329, 731)	57	NA (Only rural left)
8	0666-2111	67	67	N=56 Mean=16287.32 Median=7476 SD=19884.61 Min=66 Max=81101	N=11 Mean=12307.45 Median=10099 SD=11384.21 Min=79 Max=32980	H_a: $m_r<m_u$ W=315 p=0.55 95% CI for m_r-m_u: (-7019, 8056)	45	NA (Only rural left)
9	1122-2037	77	77	N=33 Mean=945.82 Median=528 SD=1266.85	N=44 Mean=928.27 Median=518 SD=1047.18	H_a: $m_r>m_u$ W=707 p=0.58 95% CI for m_r-m_u:	75	H_a: $\beta_{urban}\neq0$ $F_{(1, 73)}$ =0.02 p=0.88 β_{urban}=32.72

				Min=35 Max=5555	Min=24 Max=4960.64	(-280, 206)		(95% CI: -389, 454)
10	8251-2017	65	65	N=51 Mean=14984.08 Median=9488 SD=15830.02 Min=33 Max=62053	N=14 Mean=9939.86 Median=9884 SD=8085.75 Min=256 Max=25059	H_a: m_r<m_u W=399 p=0.75 95% CI for m_r-m_u: (-4140, 9541)	49	NA (Only rural left)
Items did not allow performing of statistical analysis due to small sample sizes (14 Items)								
1	0432-2039	97	97	N=94 Mean=58.08 Median=15.7 SD=126.09 Min=0.02 Max=1107	N=3 Mean=53.1 Median=74.3 SD=39.08 Min=8 Max=77	NA	NA	NA
2	3268-2047	79	79	N=79 Mean=1441.04 Median=1387.4 SD=1048.75 Min=9.5 Max=4971	NA	NA	NA	NA
3	0662-6111	66	66	N=58 Mean=641.74 Median=307.5 SD=1017.25 Min=40 Max=6812	N=8 Mean=1399.12 Median=1358.5 SD=1117.17 Min=161 Max=3555	NA	NA	NA
4	3224-2042	68	68	N=68 Mean=1142.67 Median=1064.32 SD=784.46 Min=0.52 Max=2583.54	NA	NA	NA	NA
5	0341-6042	79	79	N=79 Mean=1136.35 Median=1073.62 SD=1215.16 Min=1.68 Max=9294.8	NA	NA	NA	NA
6	0316-2015	60	60	N=52 Mean=2089.71	N=8 Mean=2519.75	NA	NA	NA

				Median=1240 SD=1823.36 Min=190 Max=7475	Median=2215 SD=1383.57 Min=400 Max=4344			
7	0316-2594	69	69	N=63 Mean=249.86 Median=186 SD=262.49 Min=3 Max=1204	N=6 Mean=166.67 Median=181.42 SD=82.08 Min=23.8 Max=268.24	NA	NA	NA
8	0247-6041	85	85	N=85 Mean=1063.7 Median=619 SD=1362.06 Min=30.5 Max=7123.7	NA	NA	NA	NA
9	0531-2004	73	73	N=73 Mean=75.52 Median=47.8 SD=86.52 Min=0.04 Max=508.78	NA	NA	NA	NA
10	0341-6076	80	80	N=80 Mean=771.07 Median=853.69 SD=461.45 Min=25.62 Max=2282.56	NA	NA	NA	NA
11	0341-6008	62	62	N=62 Mean=1143.02 Median=886.02 SD=1012.05 Min=46.73 Max=7030.45	NA	NA	NA	NA
12	4481-2001	74	74	N=74 Mean=129.06 Median=86.85 SD=86.52 Min=5.48 Max=460.8	NA	NA	NA	NA
13		91	91	N=91	NA	NA	NA	NA

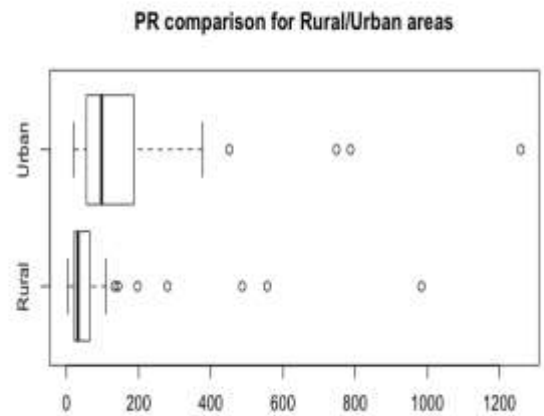
	0275-6001			Mean=74.3 Median=50.67 SD=61.18 Min=12.4 Max=465.69				
14	2085-2002	61	61	N=61 Mean=74.73 Median=62 SD=44.6 Min=10 Max=266	NA	NA	NA	NA

*P-value<0.05, **p-value<0.01, ***p-value<0.001

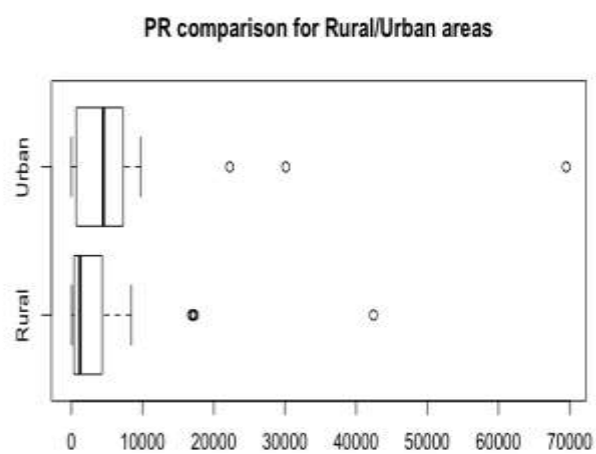
NA indicate no statistical analysis was feasible.

Plots for Descriptive Statistics (only for Significant Items)

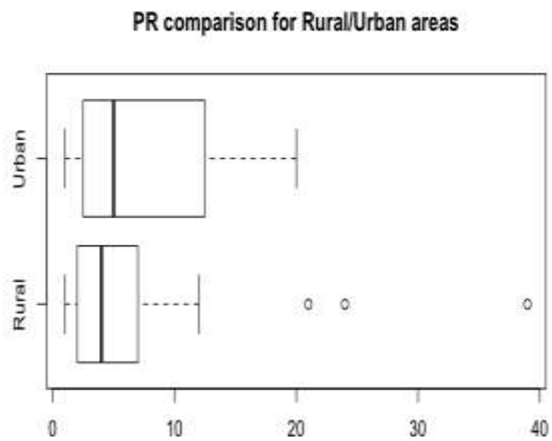
For Item 0496-2007 (Item description is REMOV STR (PIPE))



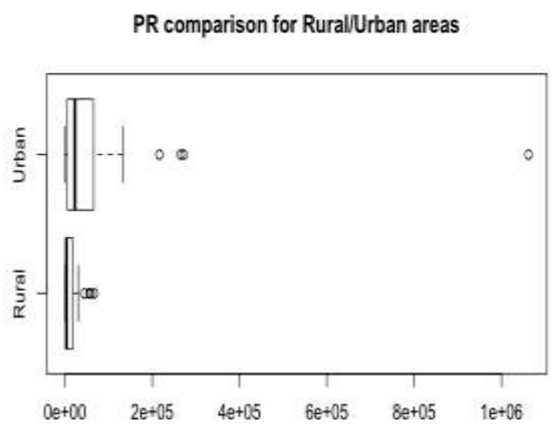
For Item 0677-2001 (Item description is ELIM EXT PAV MRK & MRKS (4"))



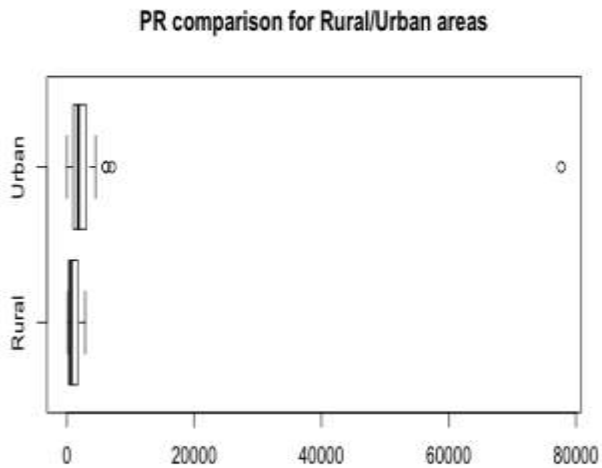
For Item 0668-2116 (Item description is PREFAB PAV MRK TY C (W) (WORD))



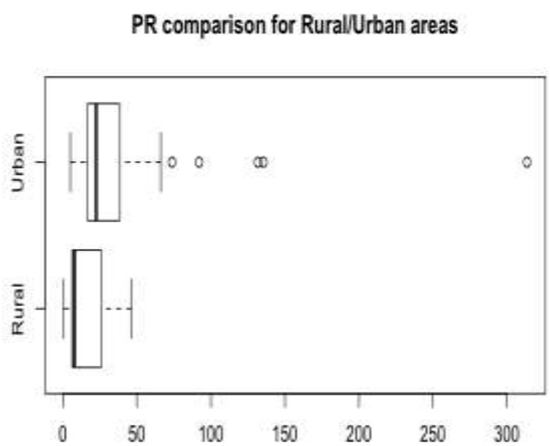
For Item 0160-2003 (Item description is FURNISHING AND PLACING TOPSOIL (4"))



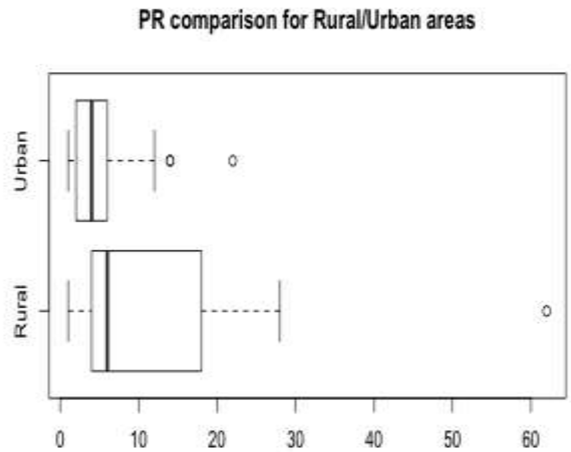
For Item 0310-2005 (Item description is PRIME COAT (MC-30 OR AE-P))



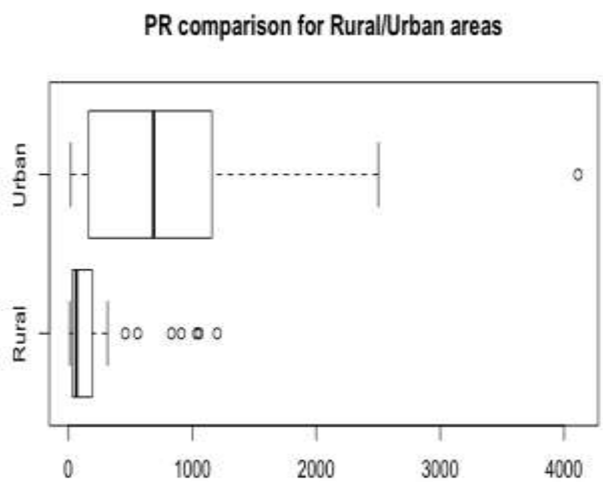
For Item 0420-2004 (Item description is CL C CONC (BENT))



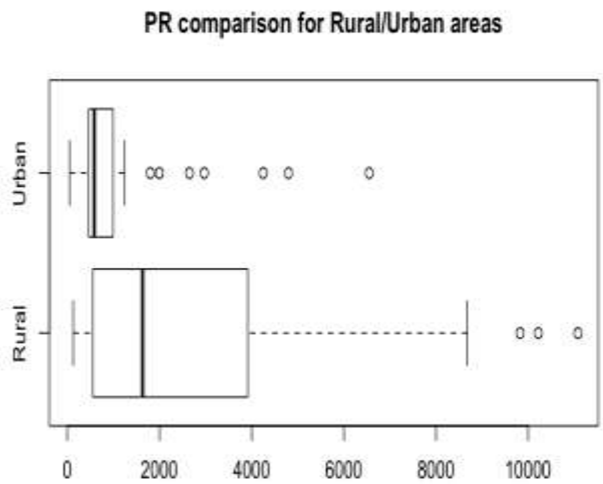
For Item 0467-2286 (Item description is SET (TY II) (18 IN) (RCP) (6:1) (P))



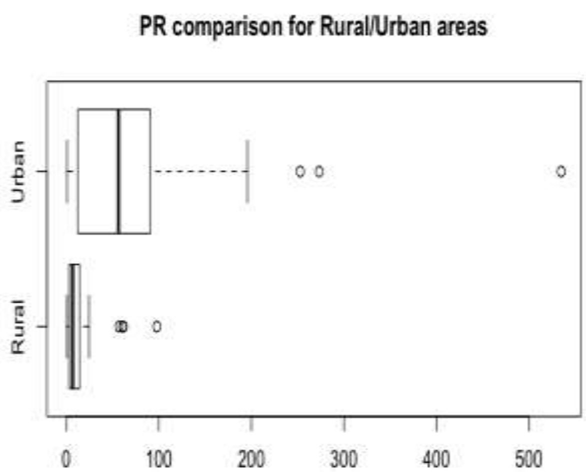
For Item 0618-2018 (Item description is CONDT (PVC) (SCHD 40) (2"))



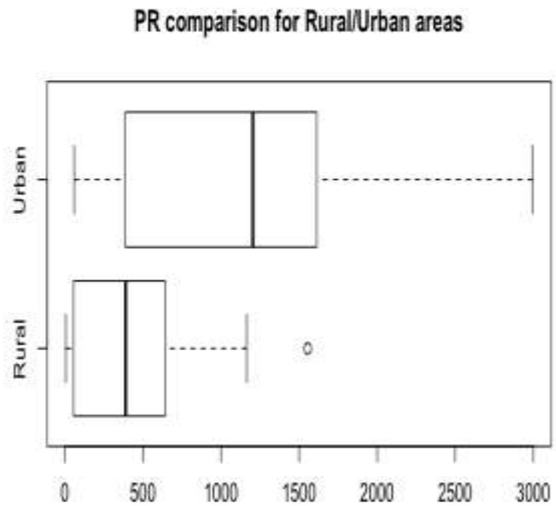
For Item 0662-2001 (Item description is WK ZN PAV MRK NON-REMOV (W) 4" (BRK))



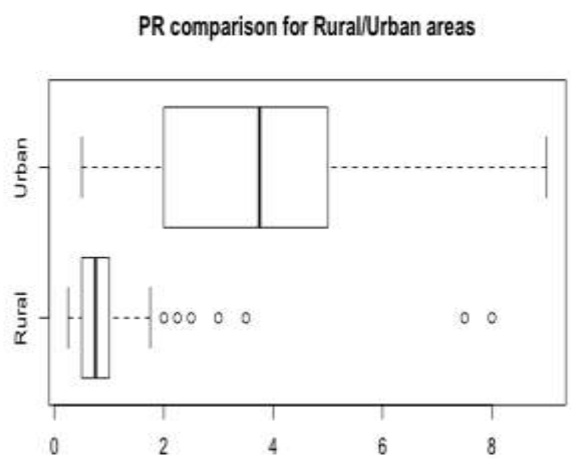
For Item 0432-2001 (Item description is RIPRAP (CONC) (4 IN))



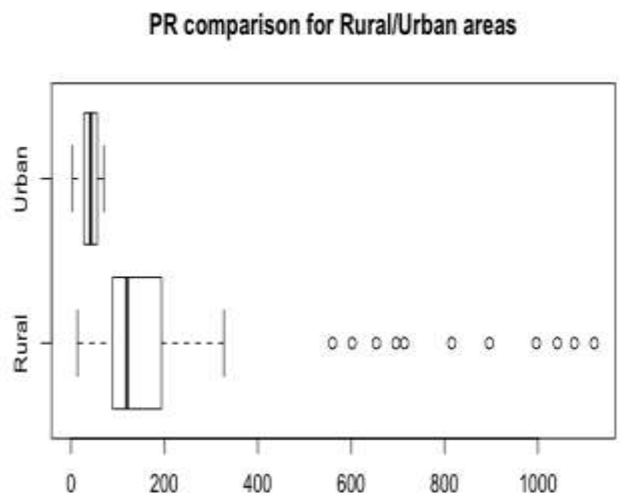
For Item 3268-2008 (Item description is D-GR HMA TY-B PG64-22)



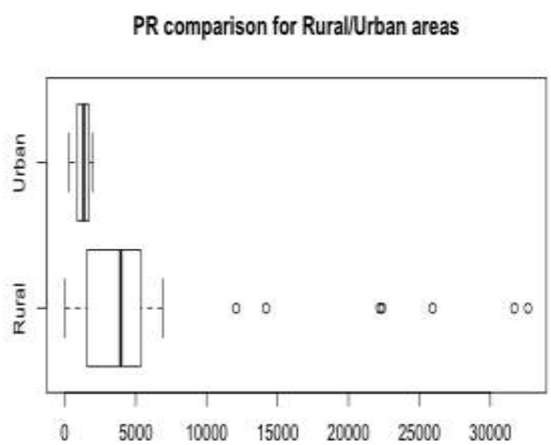
For Item 0465-2001 (Item description is INLET (COMPL) (TY C))



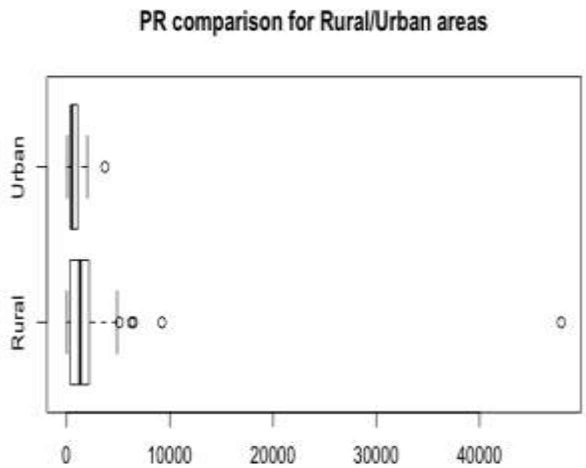
For Item 0316-6002 (Item description is AGGR (MULTI OPTION))



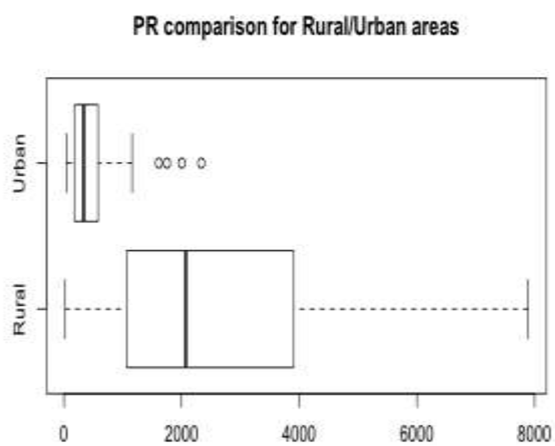
For Item 0316-6001 (Item description is ASPH (MULTI OPTION))



For Item 0247-2366 (Item description is FL BS (CMP IN PLC) (TY A GR 5) (FNAL POS))



For Item 0530-2017 (Item description is TURNOUTS (ACP))



APPENDIX 5.4

SUMMARY STATISTICS AND ANALYSIS RESULTS OF DAY OR NIGHT

Items with Some Significant Results (3 Items)								
ID	Item	RawN	Summary Stats of PR			Non-Parametric Comparison test	Regression Results	
			Valid N	Night	Day		Valid N	Results
1	0662-2001	95	62	N=29 Mean=894 Median=540 SD=1228.42 Min=180 Max=7096	N=33 Mean=2728.67 Median=1580 SD=2882.12 Min=50 Max=10220	Ha: $m_n<m_d$ W=315.5 p=0.01* 95% CI for m_n-m_d: (-2520, -50)	60	Ha: $\beta_{day}\neq0$ $F_{(1, 58)}$ =8.3 p=0.005** $\beta_{day=}$ 1364.2 (95% CI: 416.6, 2311.8)
2	0316-6002	93	83	N=35 Mean=40.49 Median=42 SD=17.93 Min=3 Max=70	N=48 Mean=228.6 Median=110.25 SD=296.88 Min=14 Max=1120.5	Ha: $m_n<m_d$ W=206.5 p<0.001*** 95% CI for m_n-m_d: (-99, -50)	79	Ha: $\beta_{day}\neq0$ $F_{(1, 77)}$ =14.7 p<0.001*** $\beta_{day=}$ 115.92 (95% CI: 55.72, 176.11)
3	0316-6001	92	85	N=37 Mean=1200 Median=1250 SD=539.52 Min=250 Max=1950	N=48 Mean=5561.23 Median=4050 SD=6979.73 Min=4 Max=32656	Ha: $m_n<m_d$ W=251.5 p<0.001*** 95% CI for m_n-m_d: (-3500, -2030)	82	Ha: $\beta_{day}\neq0$ $F_{(1, 80)}$ =34.68 p<0.001*** $\beta_{day=}$ 2725.8 (95% CI: 1804.6, 3647)
Items did not allow performing of statistical analysis due to small sample sizes (37 Items)								
1	0432-2039	97	71	NA	N=71 Mean=67.55 Median=16.4 SD=141.27 Min=0.15 Max=1107	NA	NA	NA
2	0500-6001	99	41	N=1 Mean=0.8 Median=0.8 SD=NA	N=40 Mean=0.36 Median=0.29 SD=0.3	NA	NA	NA

				Min=0.8 Max=0.8	Min=0.02 Max=0.9			
3	0496-2007	91	68	N=1 Mean=99 Median=99 SD=NA Min=99 Max=99	N=67 Mean=125.28 Median=52 SD=226.31 Min=4 Max=1259	NA	NA	NA
4	0542-2002	65	38	N=1 Mean=2 Median=2 SD=NA Min=2 Max=2	N=37 Mean=2.95 Median=2 SD=2.84 Min=1 Max=14	NA	NA	NA
5	0644-2060	71	42	NA	N=42 Mean=11.64 Median=6 SD=15.41 Min=1 Max=66	NA	NA	NA
6	0677-2001	81	58	N=2 Mean=7510 Median=7510 SD=1516.04 Min=6438 Max=8582	N=56 Mean=4692.27 Median=1265.5 SD=10897.83 Min=4 Max=69490	NA	NA	NA
7	3224-2008	65	63	NA	N=63 Mean=975.73 Median=860.92 SD=743.08 Min=12 Max=2609.19	NA	NA	NA
8	0668-2106	85	29	N=4 Mean=10.25 Median=7 SD=10.4 Min=2 Max=25	N=25 Mean=6.44 Median=4 SD=6.01 Min=1 Max=22	NA	NA	NA
9	0668-2116	77	31	N=4 Mean=7 Median=6 SD=6 Min=2 Max=14	N=27 Mean=5.59 Median=4 SD=4.92 Min=1 Max=21	NA	NA	NA
10	0160-2003	72	43	NA	N=43 Mean=42067.55 Median=3371 SD=163879.5 Min=98 Max=1061656	NA	NA	NA
11	0310-2005	67	29	NA	N=29 Mean=2091.97 Median=1827.5	NA	NA	NA

					SD=1640.54 Min=210 Max=6150			
12	0420-2004	80	59	N=1 Mean=40.6 Median=40.6 SD=NA Min=40.6 Max=40.6	N=58 Mean=34.14 Median=22.48 SD=45.42 Min=2 Max=313.57	NA	NA	NA
13	0467-2286	91	53	NA	N=53 Mean=6.3 Median=4 SD=9.61 Min=1 Max=62	NA	NA	NA
14	0618-2018	65	56	N=2 Mean=698.5 Median=698.5 SD=350.02 Min=451 Max=946	N=54 Mean=590.38 Median=178 SD=831.07 Min=10 Max=4112	NA	NA	NA
15	0672-2012	71	29	N=3 Mean=109.33 Median=97 SD=44.79 Min=72 Max=159	N=26 Mean=107.28 Median=82.5 SD=85 Min=8 Max=347.25	NA	NA	NA
16	0432-2001	94	58	NA	N=58 Mean=42.42 Median=10.39 SD=59.77 Min=0.42 Max=252.77	NA	NA	NA
17	0666-2003	68	23	N=7 Mean=9123 Median=6279 SD=8842.47 Min=990 Max=24970	N=16 Mean=2934.81 Median=1615 SD=3174.25 Min=20 Max=9508	NA	NA	NA
18	0666-2111	67	25	N=5 Mean=20696.4 Median=26213 SD=12304.45 Min=3460 Max=32980	N=20 Mean=16611.55 Median=7351.5 SD=22322.82 Min=66 Max=81101	NA	NA	NA
19	1122-2037	77	31	N=1 Mean=278 Median=278 SD=NA Min=278 Max=278	N=30 Mean=638.97 Median=273 SD=1103.22 Min=35 Max=5555	NA	NA	NA
20	3268-2008	92	17	N=5 Mean=1181.76	N=12 Mean=311.85	NA	NA	NA

				Median=1366.42 SD=552.77 Min=231.39 Max=1607.85	Median=297.4 SD=264.99 Min=20.69 Max=897.27			
21	3268-2047	79	40	N=5 Mean=1179.82 Median=1139.38 SD=562.21 Min=546.62 Max=2030.04	N=35 Mean=1263.13 Median=1397.57 SD=1009.41 Min=9.5 Max=4971	NA	NA	NA
22	0662-6111	66	33	NA	N=33 Mean=780 Median=366 SD=1275.38 Min=77 Max=6812	NA	NA	NA
23	0465-2001	63	54	NA	N=54 Mean=1.75 Median=1 SD=1.98 Min=0.25 Max=9	NA	NA	NA
24	3224-2042	68	25	NA	N=25 Mean=738.59 Median=564 SD=672.45 Min=22.65 Max=2136.66	NA	NA	NA
25	8251-2017	65	27	N=2 Mean=12657.5 Median=12657.5 SD=17538.37 Min=256 Max=25059	N=25 Mean=12860.12 Median=9449 SD=11819.71 Min=600 Max=38059	NA	NA	NA
26	0341-6042	79	69	NA	N=69 Mean=1116.86 Median=1073.62 SD=1200.72 Min=30.53 Max=9249.8	NA	NA	NA
27	0247-2366	67	53	NA	N=53 Mean=1488.89 Median=986.84 SD=1830.93 Min=38.86 Max=9255	NA	NA	NA
28	0316-2015	60	48	NA	N=48 Mean=2036.56 Median=1425 SD=1727.7 Min=190 Max=7475	NA	NA	NA
29		69	38	NA	N=38	NA	NA	NA

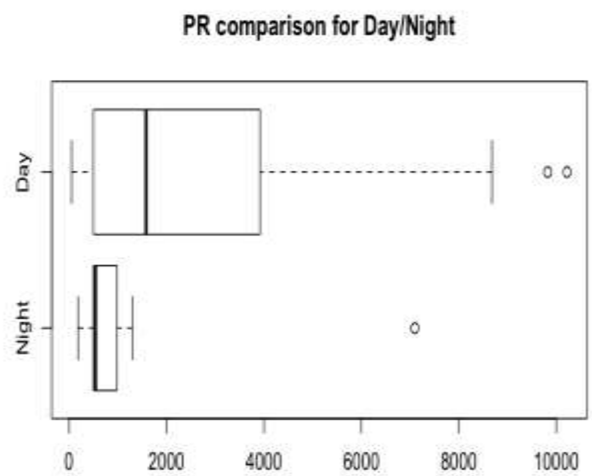
	0316-2594				Mean=316.16 Median=260.5 SD=294.13 Min=10 Max=1204			
30	0530-2017	65	23	NA	N=23 Mean=1171.75 Median=808 SD=1147.76 Min=45 Max=3934	NA	NA	NA
31	0247-6041	85	37	NA	N=37 Mean=1046.3 Median=667 SD=1184.54 Min=30.5 Max=5059.5	NA	NA	NA
32	0531-2004	73	25	NA	N=25 Mean=116.97 Median=93.44 SD=124.45 Min=1.75 Max=508.78	NA	NA	NA
33	0341-6076	80	74	NA	N=74 Mean=768.35 Median=858.13 SD=475.42 Min=25.62 Max=2282.56	NA	NA	NA
34	0341-6008	62	62	NA	N=62 Mean=1143.02 Median=886.02 SD=1012.05 Min=46.73 Max=7030.54	NA	NA	NA
35	4481-2001	74	70	N=6 Mean=172.37 Median=172.9 SD=59.81 Min=76.2 Max=235	N=64 Mean=130.58 Median=86.85 SD=87.39 Min=19.47 Max=460.8	NA	NA	NA
36	0275-6001	91	46	NA	N=46 Mean=84.17 Median=50.14 SD=84.1 Min=12.4 Max=465.69	NA	NA	NA
37	2085-2002	61	61	NA	N=61 Mean=74.73 Median=62 SD=44.6 Min=10 Max=266	NA	NA	NA

*P-value<0.05, **p-value<0.01, ***p-value<0.001

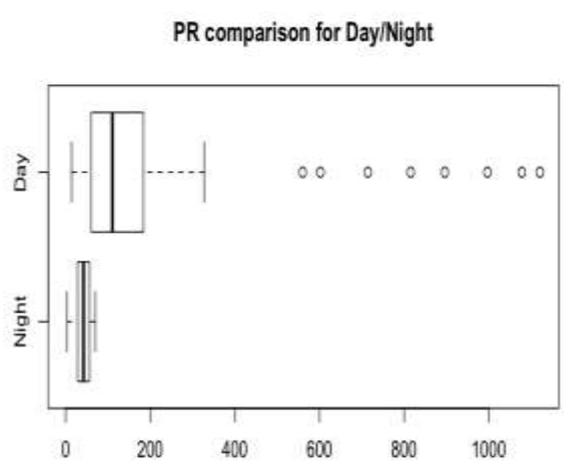
NA indicate no statistical analysis was feasible

Plots for Descriptive Statistics (only for significant Items)

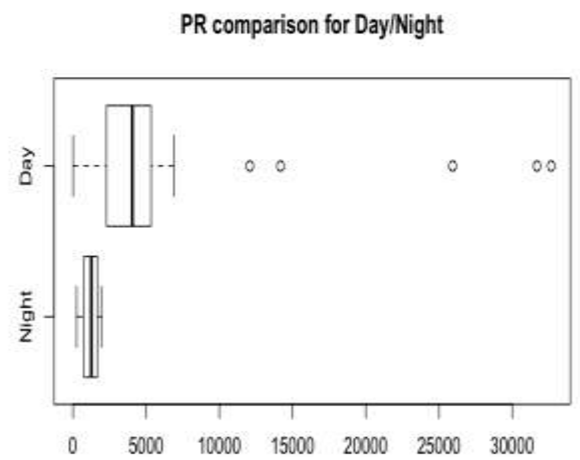
For Item 0662-2001 (Item description is WK ZN PAV MRK NON-REMOV (W) 4" (BRK))



For Item 0316-6002 (Item description is AGGR (MULTI OPTION))



For Item 0316-6001 (Item description is ASPH (MULTI OPTION))



BIOGRAPHICAL SKETCH

Angelica M. Neira was born in Barranquilla, Colombia. She received a Bachelor of Science with a major in Civil Engineering from University of Texas Rio Grande Valley in December 2016. Since January 2017, she has been with the Department of Civil Engineering, where she was employed as a Graduate Research Assistant. Her research interests lie in the field of Highway Construction Management, she is currently focusing on the assessment of the contract time determination systems used in Texas, and the factors affecting construction projects' schedule. Angelica is an active member of the American Society of Civil Engineers and the Honor Society.

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