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Analyzing cost and schedule growth in public works projects

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ANALYZING COST AND SCHEDULE GROWTH

IN PUBLIC WORKS PROJECTS

by

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ABSTRACT

Analyzing Cost and Schedule Growth in Public Works Projects

by

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The final cost of a Public Works project can directly affect the number of projects that can be accomplished during a fiscal year. Many of the factors that determine the final cost of a project are not under the control of the Project Engineer. For example, there is the Contractor's productivity and manning levels, the weather, the price of materials, and the price of labor. Those items that are under the control of the Engineer are the quality of the drawings and specifications. Likewise, the time required to complete the project is dependent on complexity and quantity of work, site conditions, weather, and the clearly stated statement of work required.

This study analyzed three types of Public Works projects, transportation, flood control, and utility, using one-way ANOVA to determine if the mean cost and schedule growth were significantly different from each other. The results were summarized and conclusions drawn on the tests performed.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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CHAPTER 1

INTRODUCTION

1.1 Purpose of this Study

Cost and schedule growth on Public Works projects in any economic climate are not the best use of taxpayer money, however, in the current economic downturn where tax revenues are lagging, they are particularly detrimental. In the Public sector, money spent on project change orders and increased construction time reduces the number and size of the projects which can be completed during any given fiscal year.

Competitive bidding is frequently used to procure public works contracts. This method of procurement typically uses lump sum or unit price contracts, with the lowest responsive bidder selected to perform the work. The completed cost of a competitively bid project is subject to change as a result of additions to the original work brought about by an unforeseen site condition, omission during the design phase, modifications to the work due to design errors or changes or owner changes.

Decisions on which projects to put out for bids are based not only on the need for improvement in a current facility or construction of a new facility, which is certainly the most important consideration, but also on the Engineer's estimated cost and construction time.

Previous research has shown that the time in the life of a project when the biggest impact on the total cost of a project can be influenced the most is during the pre-project planning phase prior to project authorization. Proper planning in the beginning reduces or eliminates the need for most changes after construction begins. If the designer has not spent the appropriate time commensurate with the complexity of the project at the beginning then it is likely the cost and schedule estimates will not reflect the true requirements of the construction phase.

A project estimate that is excessively low may result in the decision to put that project out for competitive bid and could keep another project with a higher, possibly more accurate estimate and of equal priority from going out to bid.

Inaccurate estimates frequently result in change orders which increase cost and time of delivery. These changes in the cost and time required to complete the work are always higher than it would have been if it had been included in the original bid. Projects that are needed to help ease traffic congestion, increase pedestrian and traffic safety, or mitigate flood water damage cannot be constructed because the funds are tied up on a project that should not have gone out to bid in its present form.

Underestimating the construction time is equally detrimental because another important project may be delayed from going to bid until the current project is completed. Many Public projects are extensions of a previous project.

Without accuracy in estimating project cost and construction time, the proper sequencing of related projects or phasing within projects may not take place delaying much needed improvements.

Both time and cost estimates developed during the early phases of the design process are typically based on a limited scope of work and under severe time restraints. Sometimes it can be the result of a request for "just a rough estimate" for the boss to pass up the chain. Unfortunately, these early estimates may become the basis for deciding which projects go to design should continue on and which should be placed "on the shelf" for a later time. As the process continues, the estimates will be reviewed and revised. However, within some agencies the norm tends to be a philosophy of inflating the estimates to address any errors or omissions. There may also be those that will just "throw a number at it" because the time-line from when the need arises to the end of the design phase and consequently the bid date, is very short. Although in Clark County, this short time line would probably only happen with emergency repair projects. Typical timelines for regular projects in Clark County are two to five years from identifying the need to the project going out to bid.

Other possible reasons for issuing projects with inaccurate cost and time estimates include urgent pressure from local politicians to "do something in my district" or the result of an emergency repair brought on by an extreme weather event. The Designer may believe that the design schedule does not allow sufficient time to go to the project site and do a thorough investigation of the requirements or evaluate site conditions that will be encountered during construction in order to make the appropriate allowances for them in the design. Other times it may be that the client does not believe that it is necessary for the Designer to perform the above mentioned work and is not willing to reimburse the Designer. Regardless of the reason, inaccurate estimates for project cost and time are not in the public's best interest, particularly in an urban area with the rate of growth experienced in Clark County, Nevada.

The process for taking a project from inception to completion in Clark County Public Works is typical of the method utilized by many public agencies. To begin the process, a need is identified by the cities within Clark County, the Regional Transportation Commission (RTC), and the Regional Flood Control District (RFCD), etc. These requirements are then prioritized by each entity and then assigned to an in-house Public Works Engineer or a consultant engineering firm which is selected through an interview process, and design work begins. The time spent in design depends on many factors including the scope of the project, but a project of medium size ($500,000 - $5 million) and moderate complexity could spend two to three years in the design phase. It is reviewed three or four times at various stages of completion (35, 60, and 100 percent) for changes and comments from the various utilities and undergoes a constructability review within the Construction Management Division for omissions that could cause change orders and delays during construction. During this period, there are other activities that are concurrently in progress that can affect the project timeline. Examples of these activities include obtaining Right-of-Way (ROW), where necessary, processing any permits that may be required for working on Nevada Department of Transportation (NDOT) facilities or within their ROW, or permits and permissions for constructing projects over, under or near the Union Pacific Railroad (UPRR) facilities. Once a design reaches the 90 percent level, the Designer will commence to securing the funding from either RTC or RFCD depending on who the ultimate owner will be. Once the funds are secured, it is forwarded for approval signatures within the Department of Public Works and outside agencies such as the Las Vegas Valley Water District, NV Energy, Southwest Gas Corp, and Clark County Water Reclamation District. The project is then sent to the Purchasing Office to be advertised for bids. The advertising period varies, but the minimum period of advertisement is approximately two weeks and can be extended if there are changes in the scope of work or the specification prior to the established bid opening date at which time addendums will be issued. The Purchasing Office will schedule a pre-bid meeting for all prospective bidders to ask any questions they might have on the specifications and drawings prior to bidding. They may also arrange for a site visit if there is enough interest among the bidders in order that all bidders have an opportunity to be shown the exact project location and see existing site conditions to assist them, in hopefully, preparing a more accurate bid. On bid opening day, interested parties gather in one of the Clark County conference rooms, typically the closest to the Purchasing Office, to witness bid opening. The lowest responsive bidder is identified after all bid packages have been verified to contain the required documents and the bidding documents have be checked for accuracy. Following the identification and verification of the lowest responsive bidder, the recommendation for award is placed on the Board of County Commissioner (BCC) Agenda for approval. BCC meetings take place the first Tuesday of the month for new project award approval. The approval process sometimes requires up to three months, but can also be completed in as little as two or three weeks, depending on the number of items already waiting to be placed on the agenda for the current meeting. After the BCC has approved awarding the project to the Contractor, Purchasing will issue the Contractor a letter requesting the submission of bonds and insurance documentation stipulated in the project General Conditions. Typically they are the performance, material, and labor bonds, and the proof of liability and workmen's compensation insurance. When the Purchasing Office receives the requested documentation, they will issue an award letter and advise the Contractor to contact the Construction Management Division to start the process of constructing the project which begins with a preconstruction meeting. This is the meeting where the Supervising Construction Management Inspector, as the project manager for Clark County, goes over the requirements of the contract, explains what will be expected of the Contractor, and discusses other pertinent requirements of the contract. They will introduce the key personnel for both Clark County Public Works and the Contractor's project personnel. The Construction Management Division personnel are divided into four teams. Each team consists of a Supervising Construction Management Inspector, a Senior Construction Management Inspector and between three and six Construction Management Inspectors. The key Construction Management Division personnel for a particular project are the Construction Management Inspector, the Senior Construction Management Inspector, and the Supervising Construction Management Inspector. Each project will have one Construction Management Inspector assigned. The function of the Senior Construction Manager is to assist both the Supervising Construction Management Inspector and the Construction Management Inspectors with project inspection, material submittals, overseeing progress meetings, and filling in as the project manager during periods when the Supervising Construction Management Inspector is on vacation or otherwise not available.

Normally, the Contractor is asked to provide the submittals necessary to start the project at the preconstruction meeting. These submittals include a Storm Water Prevention and Protection Plan (SWPPP), the Air Quality Permit (Dust Permit), the preliminary progress schedule, the Quality Control Plan (QCP), traffic control plans (TCP), 24-hour emergency contact list for Contractor personnel, and any materials that will be required to start which also includes any items with long delivery periods. They will also be asked if they would like to request a Notice to Proceed (NTP) date. Once the preliminary submittals are approved, the Construction Management Project Manager will issue the NTP and the construction can begin. Clark County assigns an Inspector full time to each project to not only ensure the work is done according to the project specifications and drawings, but also to try to anticipate problems and start solving issues before they impact either the cost or the schedule of a project. There are times when all that can be done is get a resolution started early to minimize the impact.

This study will examine the difference between the award and final costs of projects constructed by Clark County Public Works, Clark County, Nevada from 1991 to 2007. The differences between them are presented as a cost growth which is a percentage increase of the award cost. Three types of construction projects were evaluated to determine if there were significant differences between the cost growths of the three project types. Likewise, construction time of these projects was evaluated to determine if there were significant differences between the schedule growths within the three types of project.

1.2 Research Hypotheses

There are many hypotheses that could be written based on the data collected, however, for this study, the scope is restricted to analyzing the cost and schedule growth for the transportation, utility, and flood control construction projects. The specific hypotheses for this research are:

1. Research Hypothesis - The mean cost growth of utilities, transportation, and flood control projects are significantly different from each other

Null Hypotheses:

A. The mean utility cost growth is equal to the mean transporation cost growth.

B. The mean utility cost growth is equal to the mean flood control cost growth.

C. The mean transportation cost growth is equal to the mean flood control cost growth.

2. Research Hypothesis - The mean schedule growth of utilities, transportation, and flood control projects are significantly different from each other.

Null hypotheses:

A. The mean utility schedule growth is equal to the mean transpiration schedule growth.

B. The mean utility schedule growth is equal to the mean flood control schedule growth.

C. The mean transportation schedule growth is equal to the mean flood control schedule growth.

1.3 Significance and Sequence of the Study

The research began with a literature review of studies completed within the last 10 years on similar sets of project data with similar purposes. Chapter 2 presents the literature review. The studies that have made an effort to evaluate the difference between estimated and actual construction time and award versus final cost of Public Works projects are not numerous. The opportunity to build on the previous studies as related to Clark County Public Works is significant and can only increase the ability of the Organization to make the best use of the taxpayer money.

In difficult economic times, carefully managing project cost and schedule is imperative to being a good steward of public money while still delivering the services and new facilities the public has come to expect and the growing population requires.

In the Las Vegas Valley, the three most important types of projects for Public Works departments are transportation, flood control, and utilities. The utilities are traffic signals, street lighting, and the traffic signal interconnect system to monitor and expedite traffic through the city by controlling the signal sequence and timing. For this reason, these three categories of construction projects were the focal point of this study.

Chapter 3 of this paper will discuss the methodology used to analyze the data to arrive at the conclusions drawn from this study. The data collection and processing is discussed.

Chapter 4 presents the results of the statistical analyses of the data. The findings from the data analyses are presented and discussed.

Chapter 5 presents the conclusions of this research recommendations for further studies.

CHAPTER 2

REVIEW OF RELEVANT LITERATURE

2.1 General Literature Review Information

Interest in cost and schedule is not confined to the United States, although many of the published research papers identified for review in this research are domestic in origin. All literature reviewed for this research did not specifically address the cost and schedule growth issue of this research. However, all the literature reviewed did contribute to the overall knowledge required to accomplish this research.

2.2 Specific Literature Reviewed

Oberlender and Trost (2001) investigated the development of a method of scoring an estimate to determine its accuracy by comparing it to the final cost of a project. They worked under the premise that the accuracy of an early estimate depends on four determinants: (1) who was involved in preparing the estimate; (2) how the estimate was prepared; (3) what was known about the project; and (4) other factors considered while preparing the estimate. The estimate scoring system they developed consists of 45 elements. For their research, they collected quantitative data from completed projects around the world. Respondents were asked to assign a one-to-five Likert scale, with one being the best possible score, to each of the 45 potential drivers of estimate accuracy. The 45 elements were then separated into

11 factor categories. The categories were formal estimating process, basic process design, bidding and labor climate, site requirements, team experience and cost information, money issues, technology issues, contingency and reviews, team alignment, time allowed to prepare the estimate, and owner's cost. They collected data from 67 projects, representing $5.6 billion in total installed costs. The percentages by project type were 29.9 percent chemical manufacturing, 13.4 percent each for electrical generation and oil refining, 16.4 percent each for pulp and paper manufacturing and miscellaneous, and the remaining 10.5 percent made up of consumer products manufacturing, mineral refining pharmaceuticals and water/wastewater projects. Statistical analyses determined the relative influence of the 45 elements, based on collected project data. The results of the scoring system showed there was a significant correlation between the estimate score and the accuracy of the estimate. The estimate scoring system developed as a result of this study can predict the amount of contingency funds that should be added to an estimate based on a desired confidence level. This study is pertinent because contingency funds are included in cost estimates to account for unforeseen and unanticipated events, inaccuracies in the estimate, and other unknowns. The contingency funds if properly estimated should prevent project cost growth. Public Works projects in Las Vegas include contingency funds for this reason.

The statistical relationship between actual and estimated costs of road construction was investigated by Odeck (2004). He used data from the Norwegian equivalent of the Department of Transportation road construction program over the years 1992 to 1995 to develop a regression model to explore the project cost growth experienced by the Norwegian agency. His model revealed four findings not evident from previous studies.

First, he showed that cost growth is more predominant in smaller projects than larger ones. The author categorized the projects as very small, small, median and large based on the total project cost. The very small project comprised of projects costing less than 15 million Norwegian Krone (NOK). One US dollar is equivalent to 7 NOK. The small, median and large project comprised of projects costing between 15 million to 100 million NOK, 100 million to 350 million NOK, and greater than 300 million NOK respectively. The total project sample size was 620 projects. The data analysis showed that the average cost growth for the sample was 7.9 percent. Secondly, as the size of the estimated cost of the project increased, the cost growth appeared to decrease suggesting that there may have been better management in medium and large projects than in small projects. His third observation was that the growth increases with completion time up to medium sized projects and then decreases. He postulated that this may indicate that a longer construction schedule offers opportunity for adjustments that may help control costs. His final observation was that there were indications that there were regional differences with respect to the magnitude of cost growth. He suggested that this could be due to work load, skill level, and different management styles.

Neither the type of project nor the type of work force used to construct the project appeared to make a significant difference in the amount of cost growth experienced.

Many of the projects completed in Clark County Public Works are of a smaller nature. The projects selected for this study are less than $1.5 million in value.

Based on the study findings that smaller projects tend to have larger growth, Odeck (2004) suggested that possibly there was less accuracy in the cost estimation and that there could have been less ability of the Agency to provide oversight and control over the short period of construction. The projects from this study were selected with Odeck's observations in mind. While most of the projects included in this study are within the Las Vegas metropolitan area there are some from the outlying areas of Clark County as well. Clark County Public Works utilizes project management teams for the construction management phase of a project and the projects used in this study were managed by four different teams.

One of the reasons for cost and schedule growth is disputes. Disputes occur because Contractors and Construction Managers disagree on what the contract requirements are. Ambiguities in the contract documents can lead to confusion and adversarial relationships. Disputes can be minor in nature and settled through communication, end in arbitration, or a more formal judgment scenario. As construction projects became more complex in India, claims and disputes became a burden on the Indian judicial system with most disputes requiring five to fifteen years to settle. The back log in the judicial system topped two million in the High Court system and over 200,000 in the Supreme Court of India. Iyer, et al (2008), developed a rule-based expert system to assist contract administrators in determining the merit of a claim before taking it to litigation saving time and money for the parties involved. Recent advances in computer artificial intelligence have made it possible to simulate human reasoning with computer systems. This is known as an Expert system. Each expert system develops a knowledge base through user queries and derived solutions. Iyer, et al, noted several such systems developed for Civil Engineering, but found there were none for construction disputes. Their work was to construct a rule-based expert system to assist contract administrators in handling delay related claims. Rule based expert systems are a set of rules developed using knowledge from several experts and rule interpreter. When a new problem is posed to the system, the rule interpreter decides which rules to apply. Solutions to each problem are stored along with the inputs from the user adding to the knowledge base for future queries.

Many disputes are the result of misinterpretation of the contract documents. Disputes can also arise over contradictory clauses in the contract. Iyer, et al (2008), suggested that better training in contract interpretation and management may produce greater results in assisting Construction Management professionals in understanding the construction contract. The expert system should be considered a handy tool for both construction administrators and the judiciary to come to appropriate conclusions in less time.

In many Engineering Departments, projects are assigned by areas of expertise. This research will explore three areas of expertise, transportation, utility, and flood control and three different sets of specifications making the Iyer, et al (2008), study pertinent to this research.

It is a well known and continuously studied issue, that problems of cost and schedule growth are common occurrences on construction projects and have persisted for decades. Numerous advances, both technological and knowledge based, have failed to eliminate them. Various techniques in project management have been developed to help cope with the problem. Among them are the program evaluation and review technique (PERT) and the critical path method (CPM). Millions of dollars are made each year selling the latest and greatest project management software, which employ PERT and CPM, but none seem capable of controlling the dynamic nature of construction projects. Individual project schedules and budget performance are a function of the feedback processes built in to any project. Those processes include: the rework cycle, changes in productivity and work quality, to name a few. According to the work of Semple, et al (1994), all projects are subject to these dynamic processes, which result in cycles of revisions to work products. The number and duration of these cycles control the project's completion and ultimate cost. One of the factors affecting labor productivity is temperature. The Las Vegas Valley experiences a wide range of temperatures from 20° F to as much as an occasional 120° F. At either end of the temperature spectrum, productivity decreases. These extremes in temperature could also be a factor in the other processes mentioned by Semple, et al (1994).

Research performed by Vidalis and Najafi (2002), investigated cost and schedule growth. In their work, they investigated different causes for cost and schedule growth in Florida Department of Transportation highway projects, constructed between 1999 and 2001 with a combined original contract amount of over $1.9 billion. The combined cost growth for the projects was $200 million. The schedule growth for these projects was 17 percent. Among the reasons they identified were utility conflicts and weather damage delays which can cause enormous increases in the costs of a construction project and extend project schedule. They also looked at the specific causes of cost and schedule growth due to design or differing site conditions and discussed ways that can help control cost and schedule extension on projects. Their findings indicated that cost and schedule growth, expressed as a percentage of the original contract amount are mostly caused by designs and changed conditions. As a result of their work, they developed a checklist to assist highway officials in their design, overall planning, scheduling, and project implementation prior to project commencement. Projects constructed in the Las Vegas Valley are frequently plagued by these same issues.

In many nations of the world, building industries have embraced the need for more efficient use of money and time in their construction programs. The key to controlling time and money is understanding the reasons these two aspects of construction increase as the project progresses towards completion. Chan and Kumaraswamy (1996) investigated the primary factors for delays in the Hong Kong building industry were evaluated. Clients, consultants, and contractor groups were surveyed to determine their perception of different factors responsible for construction delays and their level of impact on cost and schedule and relative importance to the different participants involved in the industry.

The authors developed a survey with delay factors, which they previously identified, broken into eight major groups. They received similar responses from approximately 94 percent of the client and consultant groups suggesting that construction site management and contractor caused delays were high on the list of delay factors. This was not supported by the contractor groups. The survey responses receiving the highest level of significance when it came to construction delays include poor construction site management, differing site conditions and the slow decision making involving all parties in the project. The clients and consultants tended to believe that much of the fault lies with inexperienced contractor planning and execution of the project while contractors contend that the fault lies in the shortcomings of the designer's product.

Using the survey results, the authors developed some guidelines to assist in reducing the impact of construction delays. They recommended using a system of pre-qualifying bidders in hopes of finding the more qualified contractors. Hong Kong Public Works projects are often given to those contractors registered to do government work based on their categorized specialty experience and past project size. They also recommended that contractors invest in their management and supervisory personnel to insure they have the proper training and skill level to handle the projects they are assigned. The design phase of the project should be provided enough time and resources to do a thorough site investigation and ensure the designs reflect what is expected in construction phase.

Poorly prepared contract documents, ineffective communication within the construction team, and suspicious relationships between owners and constructors often result in delays. Clear and comprehensive drawings and specifications ensure the designer's intent is clearly communicated to the contractor. Clearly defined roles coupled with specific levels of authority and responsibility between all project participants will define the levels necessary to expedite decision-making throughout the project duration. The owner should allow sufficient time for the work they request. And finally, minimizing changes to the design initiated by the owner or their representative during the construction period.

Hsieh, et al (2004), investigated the cause-effect relationship of change orders. Their work included 90 public works projects in Taipei, Taiwan during the years 1991 to 2000. Each project had a construction value in excess of $2 million that required change orders during construction. Related literature and experience tells us that there are many causes for change orders. The authors assigned the change orders to nine categories: (1) planning and design, (2) underground conditions, (3) safety considerations, (4) natural incidents such as weather events, (5) changes in work rules / regulations, (6) changes in decision-making authority, (7) special needs for beneficial occupancy and commissioning, (8) special requirements dictated by the neighborhood of the project site, and (9) miscellaneous changes. Most owners and some owner representatives are ill-equipped to handle the different types of changes that can occur resulting in poor change management and cost and time overruns on their projects. The Hsieh, et al (2004), research examines minimizing or avoiding the mismanagement of change orders through understanding the causes of change orders and establishing a prescribed way of handling changes within the project management framework. Even though the study was performed in Taiwan, the lessons learned can be applied in many countries. Regardless of where construction is taking place in the world, the causes behind change orders and therefore cost and schedule increases are very similar. The study examined the relationship among project characteristics and the frequency of change orders. It also examined the cost variances associated with each cause. To analyze their data, the authors grouped the projects into five categories. The project types were: (1) building construction, (2) road construction, (3) bridge and culvert construction, (4)flood control construction and (5) subway tunnel construction. The subway tunneling projects showed the highest frequency of change orders. Underground work frequently encounters utility conflicts and unforeseen soil conditions. Building construction was next highest, possibly reflecting the complexity of trying to sequence the construction in a urban environment where storage space for materials is always at a premium and delivery of large items can be challenging. They found that bridge and culvert work was most sensitive to changes followed by flood control and road construction.

Two significant findings of this study are that most change orders are the result of problems in the planning and design phase of construction and that the type of construction undertaken is correlated to the causes of change orders. Therefore, having a strategy in place to handle various types of change orders that might be encountered based on the type of project should be a standard operating procedure for the project management.

Lowe, et al (2006), attempted to develop a robust regression cost model to predict the final construction cost of a building. According to Lowe, et al (2006), linear regression analysis has, in the past, been performed by using raw cost as the dependent variable. This choice requires several assumptions in the choice of this variable. First, the standard deviation in the error associated with the dependent variable (cost) remains constant throughout the domain. Next, this error is normally distributed, and finally, the effect of any variable is always expressed in terms of a fixed cost increase or decrease, regardless of project size or type.

The authors showed that the first assumption, that the standard deviation of error is constant, is false by producing a scatter plot of the actual cost versus the error in project cost increases. Therefore the raw project cost must be rejected as a suitable predictor for a regression model.

In all, the authors developed six models that ranged between eight and fourteen variables in each model. The variables were: (1) Gross internal floor area, (2) function (log), (3) function, (4) duration (log), (5) duration, (6) mechanical installations, (7) pilings, (8) internal wall finishes, (9) Frame, (10) site access, (11) Protective installations, (12) internal walls, (13) substructure, (14) wall/floor ratio, (15) special installations, (16) external walls, (17) floor finishes, (18) height (log), (19) units, and (20) electrical installations.

They found that regression models appeared to be slightly less accurate than neural networks. All of the models developed tended to underestimate the cost of very large, expensive projects, but underestimate the small, inexpensive projects.

Their work is significant in that their cost model outperforms human estimators when it comes to estimating the final cost of a project. The model they developed is a valuable tool because it provides a benchmark others can use to develop neural network models and has identified variables that have been shown to have a strong linear relationship with project costs.

Gransberg, et al (2007), tried to identify a relationship between the design fee charged for a transportation project and the overall quality of the design. Their findings were that the more money spent on design, the less money spent in changes during construction and vice versa. To many this may seem self-evident, but typically, the design and planning phase of construction receives the smallest percentage of the construction budget, yet has the greatest impact to final project cost. The general conclusions of this study were: (1) as the estimated cost of a construction project increases, the design fee expressed as a percentage of the construction cost should decrease, (2) that as the design fee decreases, the absolute percentage of construction cost growth from the engineer's early estimate increases, (3) complex design such as bridges, should command a higher design fee that less complex design work, and (4) there is a point where increasing the design fee no longer impacts design quality.

In summary, it has been shown that there is continuing interest in this subject of cost and schedule growth. The specific causes of cost and time growth are beyond the scope of this paper, however, the methodology used by the authors of the literature reviewed was influential in the processing of data for this study. The focus will be to analyze the cost and schedule growth of transportation, flood control, and utility projects completed by Clark County Public Works in Clark County, Nevada.

CHAPTER 3

METHODOLOGY

3.1 Research Methodology Flowchart

Figure 1 shows the research methodology adopted for this research. The previous chapters have covered the first two steps shown in Figure 1 and this chapter begins the explanation of data collection and processing.

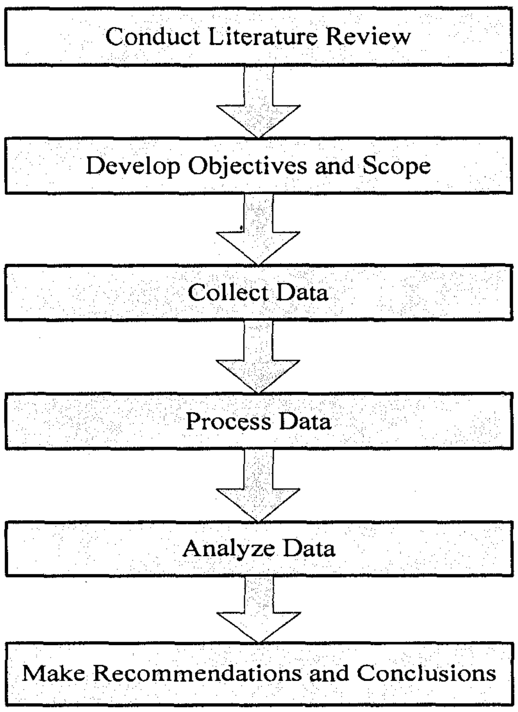

Figure 1. Research methodology flowchart.

3.2 Data Collecting

The data for this study are from the projects completed by Clark County Public Works during the period 1991 to 2007. The project information used for this study is contained in the County archives and considered public information which is available by request through the proper channels.

To retrieve the data for each project, certain information is required. Clark County uses Global 360 software, formerly known as Kovis, to archive completed project data. Each project is accessed by various number identifiers depending on which division within Public Works is attempting to search for data. Two of the numbers associated with each project include project numbers and bid numbers. For this study, bid numbers were used to retrieve the data through the County intranet system.

When a project is completed and the final settlement affidavit has been signed by the Contractor signifying that the claim of retention has been settled, the document is sent through the Clark County Recorder's Office to provide the legal, public proof of settlement. Once the affidavit has been recorded and official recording stamps have been affixed, a receipt is returned to the Construction Management Division of Public Works to be included in the rest of the project documents and prepared for archiving. Archiving is done by scanning all of the project documents and drawings into the Global 360 database and the paper copies are then disposed of due to physical storage space shortages.

The data retrieved from the database for this study included the Engineer's Estimate with Bid Abstract, the completion memorandum to the Clark County Purchasing Office including the beginning cost, final cost, change order costs, if applicable, the initial construction time and the final construction time, the NTP date and substantial completion date. On the older projects, final pay applications for retention release were substituted for bid abstracts when the abstract could not be found. Every effort was made to keep the type of documents consistent for each project; however, there were exceptions which did not affect the accuracy of the data.

3.3 Processing the Data

3.3.1 Data Description

Once the data was collected, it was entered into an Excel spreadsheet for processing. There were 408 projects which contained enough data to be useful. They were separated by type of work performed and fell into five general categories.

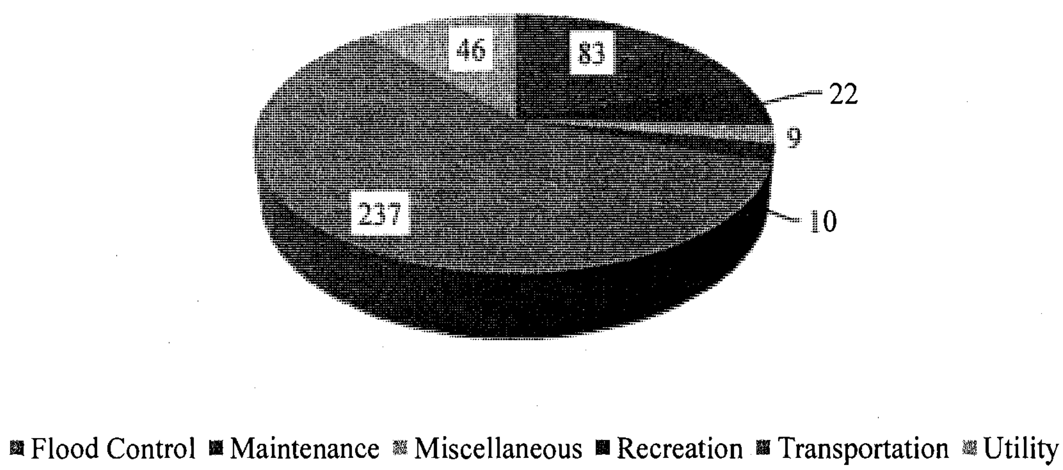

Figure 2. Percentage and number of projects.

The majority of the projects fell into the categories of Transportation (237), Utilities (46), and Flood Control (83). These categories provided the variety of projects, both in scope of work and dollar amount, to be representative of the work performed by Clark

County Public Works. To begin processing the data, it was necessary to remove any contingency funds from the award costs so all cost growth would be reflected in the final cost. Contingency funds are used in the public works project give the project management team a way to pay for additions to the work and omissions to the contract documents without having to write change orders which must have the approval of the Board of County Commissioners (BCC). This can take two to three months for approval depending on the number of items on the Board's agenda. This method of paying for small additions to the work has benefits for both the County and the Contractor. It expedites the payment procedure and allows the additional work or work required, but omitted from the contract documents to be performed in less time.

The data used for this study covered a period of 17 years. Figure 2 shows the histogram of Transportation Projects by Construction Start Year. The following histograms show the breakdown of projects by year construction started. The transportation projects are spread across all years from 1991 to 2007 with the highest number of projects occurring during 1996.

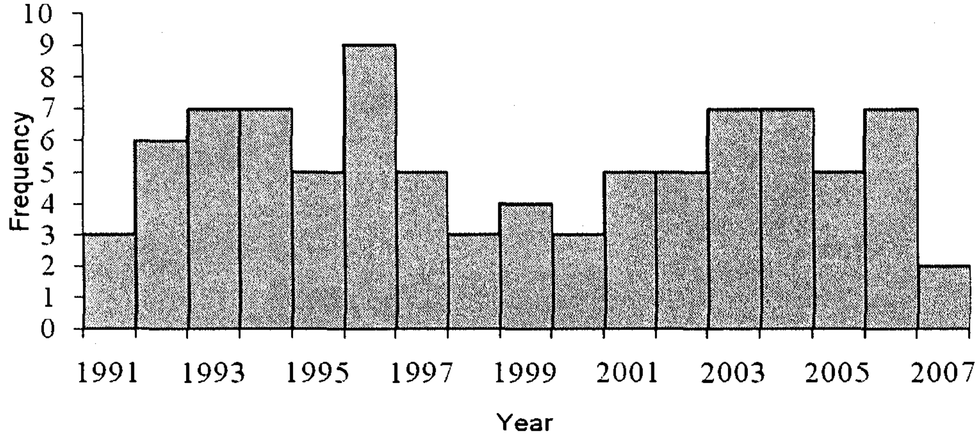

Figure 3. Histogram of transportation projects by year.

The descriptive data for the transportation project cost is shown in Table 1.

Table 1. Transportation final cost descriptive data.

Description	Cost Data
Mean	557,161.63
Standard Error	41,300.81
Median	451,560.09
Mode	#N/A
Standard Deviation	391,813.93

By contrast, the Utility projects were not spread across all years but were more evenly distributed between 1992 and 2004 peaking twice during 1991 and 2005. Figure 3 shows the histogram of utility projects by year.

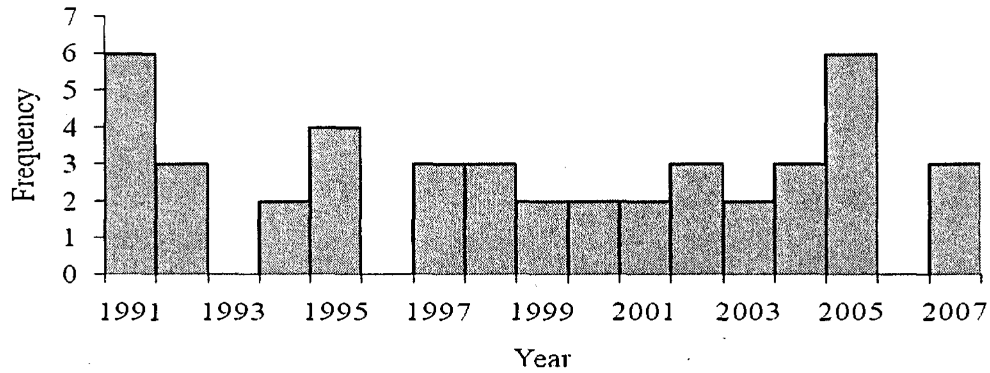

Figure 4. Histogram of utility projects by year.

The descriptive data for the utility project cost is shown in Table 2

Table 2. Utility final cost descriptive data.

Description	Cost Data
Mean	433,748.45
Standard Error	44,695.00
Median	363,480.94
Mode	378,805.10
Standard Deviation	296,473.10

The Flood Control projects reached a peak eight projects during the year 1997 and 2007. Many of the larger projects, such as detention basins, were constructed during this period and were too large for the dollar cap of $1.5 million award cost used for this paper. Figure 4 shows the histogram for Flood Control Projects by Year.

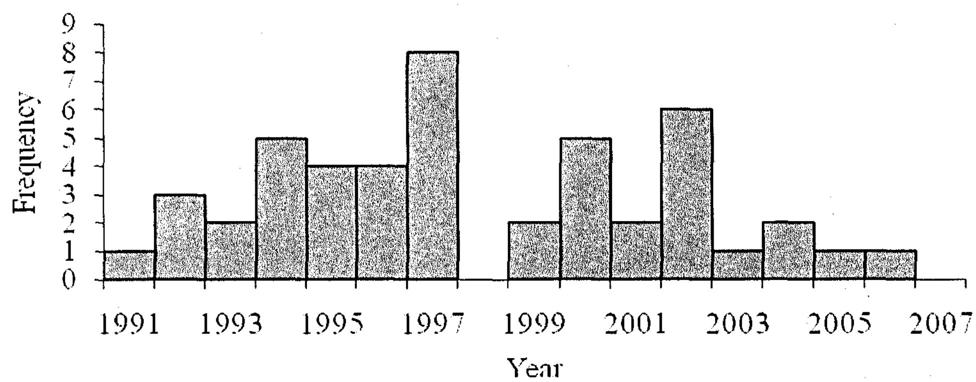

Figure 5. Histogram of flood control projects by year.

The descriptive data for the flood control project cost is shown in Table 3.

Table 3. Flood control final cost descriptive data.

Description	Cost Data
Mean	692,343.99
Standard Error	77,853.80
Median	490,719.96
Mode	#N/A
Standard Deviation	533,738.77

factors were chosen over other published conversion factors such as the Engineer News Record or Federal Highway Administration cost indexes because when contractors bid on a project their estimates contain more than just material costs. They include labor and overhead costs which fluctuate at a different rate than material costs. It was hoped that by using factors similar to the CPI, the impact of these different fluctuation rates would be minimized.

The conversion factors used to adjust all project costs to present value (2007) were from a chart created by Robert Sahr, Professor of Political Science at Oregon State University (http://oregonstate.edu/cla/polisci/faculty-research/sahr/sahr.htm). Table 1 below is the summarized conversion factors used in this study.

Table 4. Conversion Factors.

Year	Conversion Factor	Year	Conversion Factor
1991	0.657	2000	0.831
1992	0.677	2001	0.854
1993	0.697	2002	0.868
1994	0.715	2003	0.888
1995	0.735	2004	0.911
1996	0.757	2005	0.942
1997	0.774	2006	0.973
1998	0.786	2007	1.000
1999	0.804		

To change earlier project costs to 2007 values, the project award and final cost figures were each divided by these factors to arrive at the award and final costs used in the analysis. The equations used for the conversion to 2007 values are:

$$Project\ Award\ cost\ in\ 2007\ values = \frac{Project\ Award\ Cost}{Conversion\ Factor}$$

$$Project\ Final\ cost\ in\ 2007\ values\ = \frac{Project\ Final\ Cost}{Converson\ Factor}$$

These conversion factors were verified against the U.S. Department of Labor, Bureau of Labor (BOL) Statistics Consumer Price Index (CPI) and found to be similar The CPI can be found at the BOL website: (ftp://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt).

The data from each category was analyzed to determine if there were any projects that appeared to be significantly larger than the others within each category. It was determined that the two largest projects within the Utility category were significantly larger than the rest of the projects within that group. The decision was make to cut off the dollar amount of the projects at $1.5 million for all three categories to keep the parameters as close to the same as possible. After establishing the upper limit for projects at $1.5 million, the distribution of projects within the categories was transportation (90), utility (44) and flood control (47). The total cost of the 181 projects was $106,108,857.52.

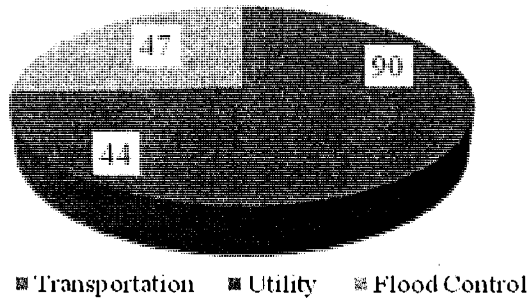

Figure 6. Distribution of projects within catagories

Table 5 presents the final, or total, cost descriptive statistics for this final selection of projects. The table shows that the mean for the three types of projects are similar with the Utility mean being the lowest and Flood Control the highest. The medians for the project types are also similar.

Table 5. Descriptive Statistics of Total Project Cost.

Project Type	Unit	No. of Samples	Total Project Cost				
			Mean	Median	Maximum	Minimum	Standard Deviation
Transportation	$K	90	557.2	451.6	1503.8	71.5	391.8
Utilities	$K	44	433.7	363.5	1411.4	50.9	296.5
Flood Control	$K	47	692.3	490.7	1500.0	36.1	533.7

Figure 7 shows the breakdown of the final costs of the transportation projects.

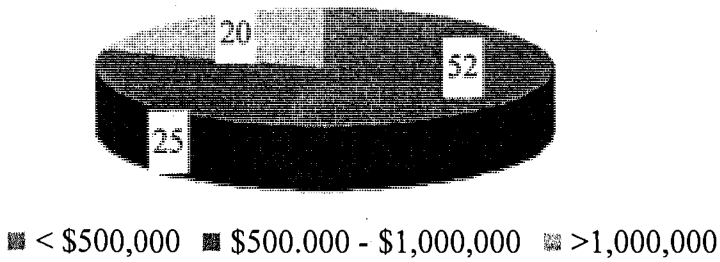

Figure 7. Transportation project breakdown by final cost.

Figure 8 shows the breakdown of the final costs of the utility projects.

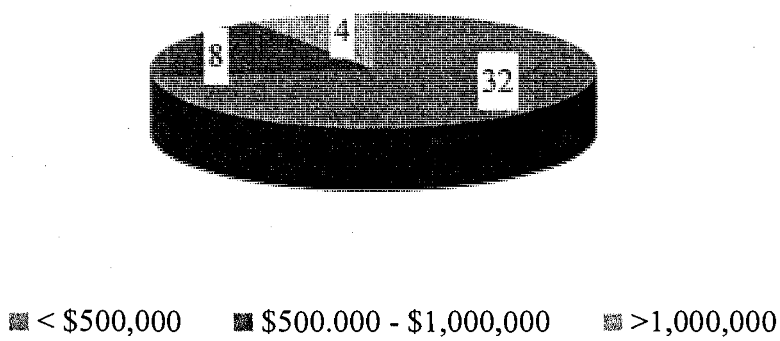

Figure 8. Utility projects by cost ranges.

Figure 9 shows the breakdown of the final costs of the flood control projects.

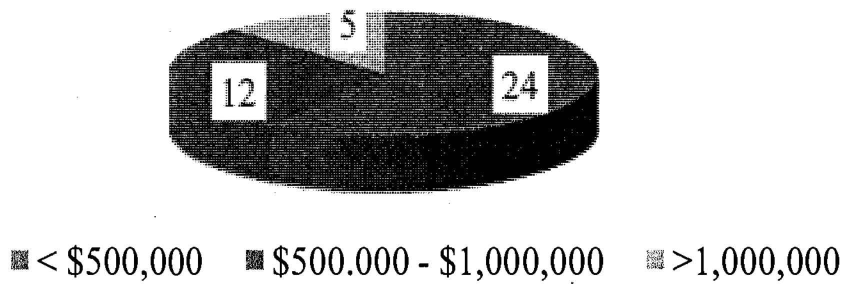

Figure 9. Final cost breakdown for flood control projects.

Figure 10 shows the breakdown of the award costs adjusted to 2007 values for the transportation projects. The majority of the transportation projects were awarded for between $200,000 and $800,000.

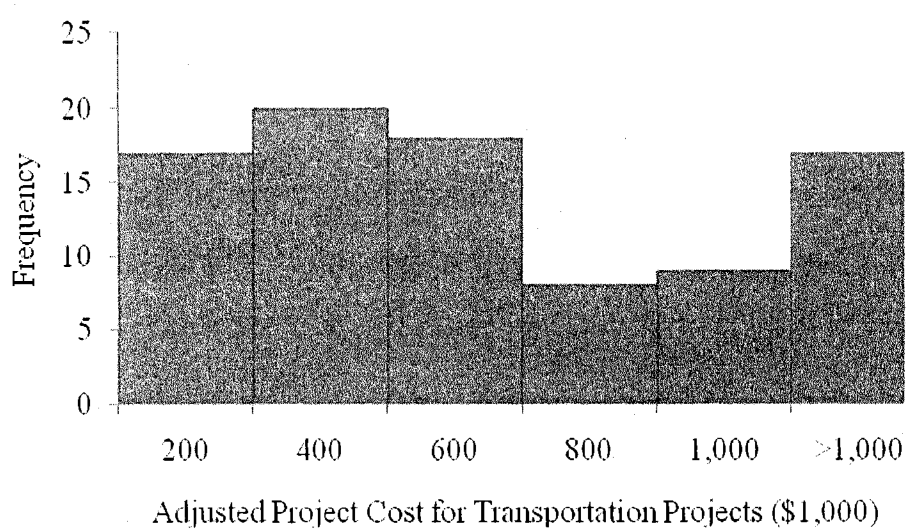

Figure 10. Adjusted project cost histogram of transportation projects.

For the utility projects, most of the projects used for this paper fell between $200,000 and $600,000. This is a significant amount when the type of work performed under this type of project is taken into consideration. Figure 11 shows the histogram of Utility Projects by Adjusted Total Project Cost.

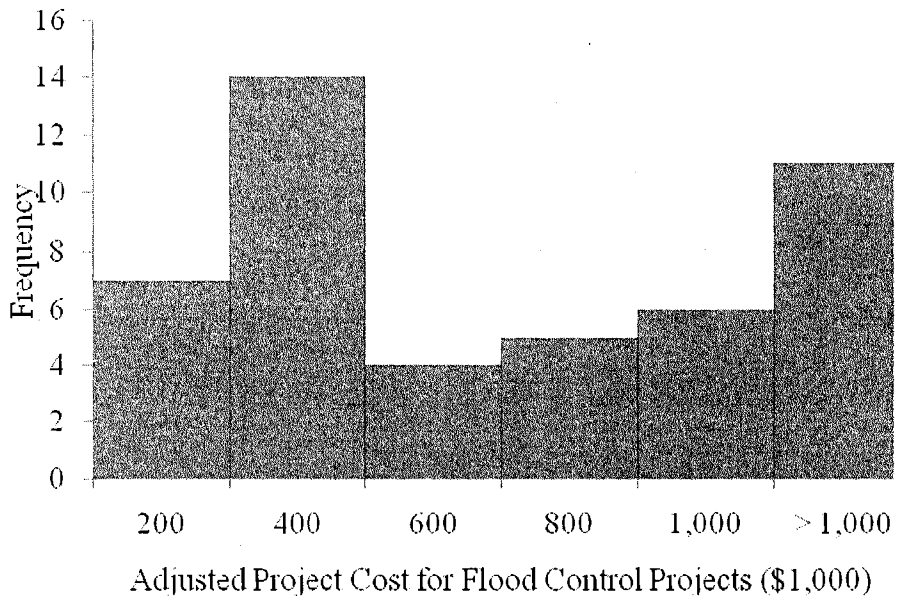

Figure 11. Adjusted total project cost histogram of utility projects.

The majority of flood control projects used for this paper had adjusted award costs at the lower end of the scale with most projects falling around the $400,000 mark. Figure 12 shows the histogram of Flood Control projects by Adjusted Total Project Cost.

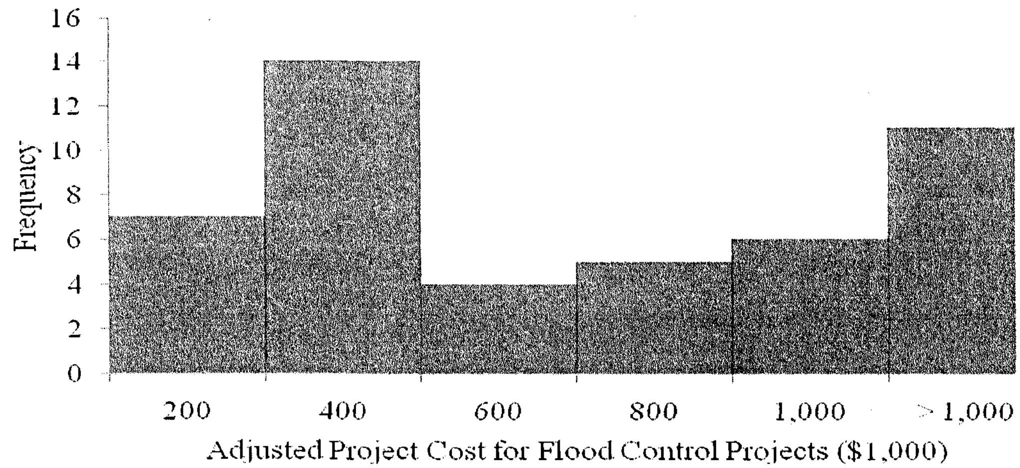

Figure 12: Adjusted Total Project Cost Histogram of Flood Control Projects.

The project schedule data was similarly evaluated and the descriptive statistics are presented in Table 3. This table shows that the mean and median project durations are similar. As the table shows, flood control has the highest duration followed by the Utility projects. These types of projects are frequently disrupted by weather events and underground conflicts. The mean values for the project durations of transportation (72.9 days), utility (96.0 days), and flood control (98.4 days) were close in value as well as the median values for the three types, 60, 89, and 81 days, respectively, indicating that the projects were similar enough in nature to be evaluated. The minimum days for the projects types were close and indicate that the flood control may have been for emergency repair after a weather event while the Transportation could have included small projects to improve air quality in the Las Vegas Valley by paving dirt streets. Durations that short are not typical of work performed for Public Works projects while the maximum appears to be about right for the type of work performed.

Table 6. Descriptive statistics of total project duration.

Project Types	Unit	No. of Samples	Total Project Duration				
			Mean	Median	Maximum	Minimum	Standard Deviation
Transportation	days	90	72.9	60	292	11	50.2
Utilities	days	44	96.0	89	249	15	47.5
Flood Control	days	47	98.4	81	365	18	69.4

The percentage of transportation projects with duration ranges are given in Figure 13.

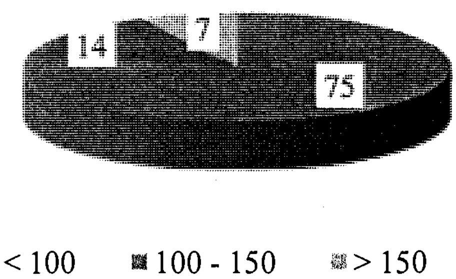

Figure 13: Final transportation project schedule breakdown

The percentages of utility projects with duration ranges are given in Figure 14.

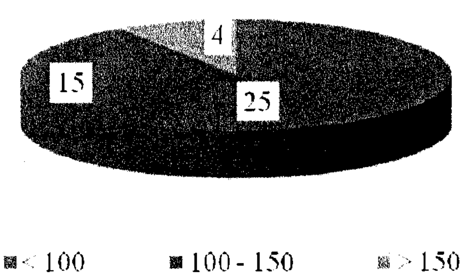

Figure 14. Final utility project schedule breakdown

The percentage of flood control projects with duration ranges are given in Figure 15.

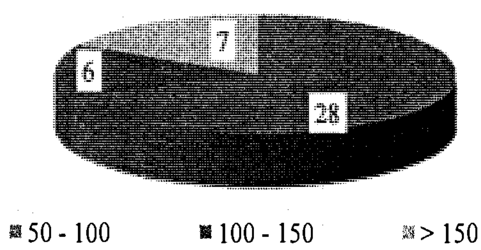

Figure 15. Final flood control project schedule breakdown.

The majority of the transportation projects selected for this paper was between 40 and 120 days in duration. . Figure 16 shows the histogram of transportation projects by total project duration.

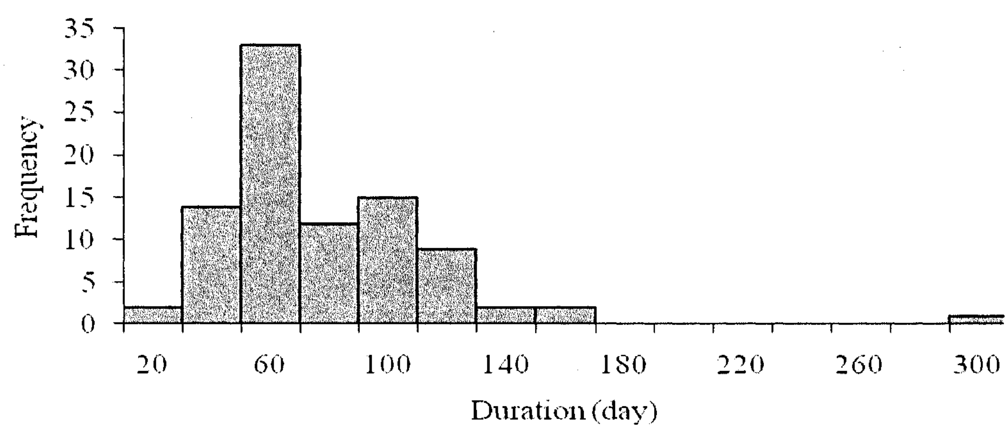

Figure 16. Duration histogram of transportation projects.

The utility project duration was a bit more erratic with 60, 100, and 120 days as the most frequent durations. Figure 17 shows the histogram of utility projects by total project duration.

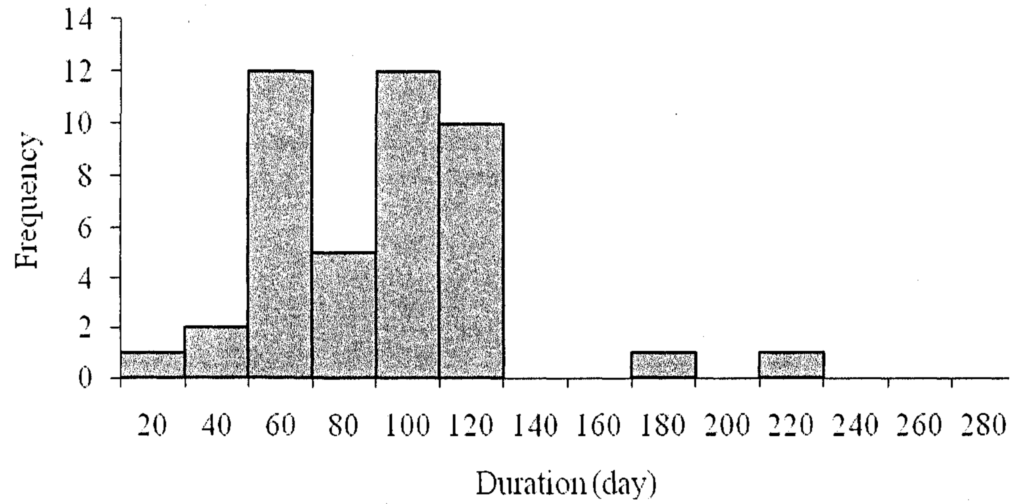

Figure 17. Duration histogram of utility projects.

The flood control projects were mainly between the 60 and 120 day durations with most of the projects at the 60 day duration signifying that the projects in the study were smaller projects possibly maintenance or emergency repair types of work. Figure 18 shows the histogram of flood control projects by total project duration.

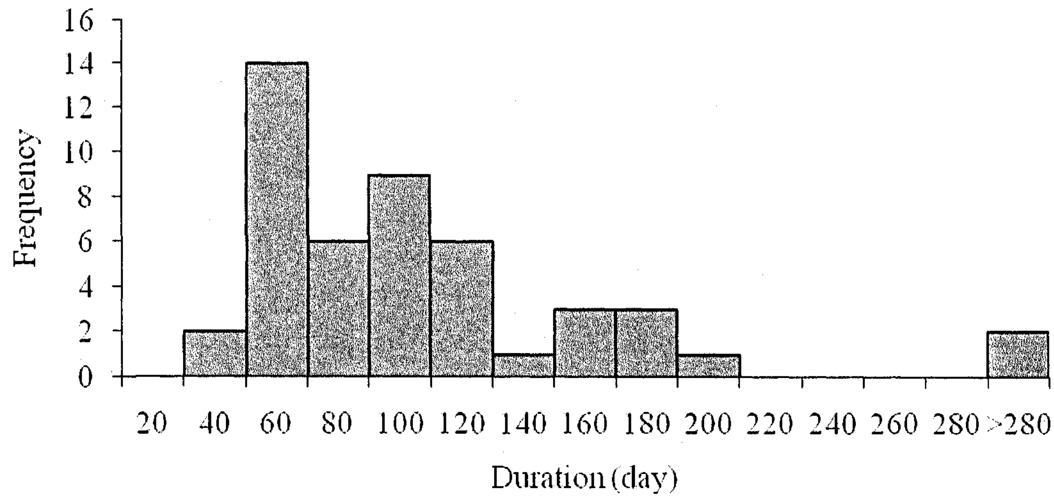

Figure 18. Duration histogram of flood control projects.

3.4 Cost and Schedule Metrics

To arrive at the cost and schedule growth data for the comparisons, the following formulas were used:

$$Cost\ Growth = \frac{Adjusted\ Final\ Project\ Cost - Adjusted\ Estimated\ Cost}{Adjusted\ Estimated\ Cost} \times 100\ \%$$

$$Schedule\ Growth = \frac{Final\ Project\ Duration - Estimated\ Project\ Duration}{Estimated\ Project\ Duration} \times 100\ \%$$

3.5 Statistical Tests

The data was analyzed using one-way ANOVA procedure. To use this procedure, three assumptions must be verified. The first is randomness and independence. This was satisfied by having three completely different types of construction project data sets.

The final group of projects selected, the cost and schedule growth percentage data was checked for normal distribution which began by evaluating the second assumption of the one-way ANOVA– the normality assumption. The third assumption of ANOVA of homogeneity of variance was also checked by conducting the Levene's test.

To begin the analysis, the cost data was checked for within group variation and among group variation. The null hypotheses, represented by H_o, that the means of the cost growth of the three groups are equal were tested against the Alternative hypothesis, represented by H_1, that the means of the cost growth between the three types of projects were significantly different from each other. Because the means of the three data sets are assumed to be equal under the null hypotheses, the total variation between sets is determined by sum of the squared differences between each observation and the overall mean of the three sets of data combined. Total variation (SST) is calculated by the formula:

$$SST = \sum_{j=1}^{c}\sum_{i=1}^{n_j}(X_{ij} - \bar{\bar{X}})^2$$

Where X_{ij} is the ith observation of group j, n_j is the number of observations in group j, n is the total number of observations, and c is the number of groups.

The sum of squares, among (SSA) is calculated using the following formula

$$SSA = \sum_{j=1}^{c} n_j \ (X_{ij} - \bar{\bar{X}})^2$$

Where n_j is the number of observations in group j, $\bar{X}_j$ is the sample mean of group j, and $\bar{\bar{X}}$ is the overall or grand mean.

The within group variation (SSW) is calculated using the following formula:

$$SSW = \sum_{j=1}^{c}\sum_{i=1}^{n_j}(X_{ij} - \bar{X}_j)^2$$

Where: X_{ij} is the ith observations in group j and $\overline{X}_j$ is the sample mean of group j. Once the "within" group variations and "among" group variations are determined, the mean squares for among and within groups can be determined by dividing the sum of squares by the degrees of freedom for that group. The mean of squares among (*MSA*) were calculated using the following formulas:

$$MSA = \frac{SSA}{c-1}$$

Mean Square within (*MSW*) is calculated as follows:

$$MSW = \frac{SSW}{n-c}$$

Mean Square Total (*MST*) is calculated as follows:

$$MST = \frac{SST}{n-1}$$

If we assume that the null hypotheses are true and there are no real differences in the means between sets of data, the three mean square terms, *MSA*, *MSW*, and *MST* will provide the estimated value of the variances inherent in the data. The one-way ANOVA F test statistic is computed using the ratio of the *MSA* and *MSW*.

$$F = \frac{MSA}{MSW}$$

Because the *F* test follows an *F* distribution with c-1 degrees of freedom, a null hypothesis can be rejected if, for a given level of significance, α, the value falls above the critical value, F_U.

Reject H_o if $F > F_U$;

Otherwise do not reject H_o

The results of one-way ANOVA are presented in a summary table and include the Source (Among, Within, Total variance), the degrees of freedom for each source, the sum of squares, the mean square variances, the F statistic, and the *p* value. The *p* value allows the observer to make determinations about the null hypotheses without the use of F distribution tables. If the value is less than the selected level of significance, the null hypothesis can be rejected.

If the null hypotheses are found to be false indicating a significant difference between group means, a multiple comparison procedure will be performed to determine what group or groups are different. The post-hoc procedure that will be used for this study is the Tukey multiple comparison procedure. To perform this test, the first step is to determine the absolute value of the differences between the three data set means. The formula to determine the number of pairs is

$$Number\ of\ pairs = \frac{c(c-1)}{2}$$

Therefore for this data, the number of pairs is 3 for a value of $c=3$. The differences between the means are:

$$Transportation - Utility = |(-2.611) - (-6.625)| = 4.01$$

$$Utility - Flood\ Control = |(-2.611) - (-6.625)| = 3.07$$

$$Transportation - Flood\ Control = |(-2.611) - (-3.559)| = 0.95$$

The three groups of data used for this paper did not have the same number of observations, therefore, to perform the Tukey procedure, a critical range for each set of pairs must be found. This was done using the formula:

$$Critical\ range = Q_u \frac{MSW}{2}\left(\frac{1}{n_j} - \frac{1}{n_{j'}}\right)$$

Where Q_U is equal to the critical value of the upper tail region of the distribution with level of significance $\alpha = 0.05$. The fractions $1/n_j$ and $1/n_{j'}$ are the number of observations for the two groups being compared.

The testing sequence determined, the tests on cost and schedule growth were completed and the results are presented in Chapter 4.

CHAPTER 4

FINDINGS OF THE STUDY

4.1 Analysis of the Data

The data was analyzed using one-way ANOVA procedure. To use this procedure, three assumptions must be verified. The first is randomness and independence. This was satisfied by having three completely different types of construction project data sets.

The raw data was prepared for processing by removing the contingency funds included in nearly every public works project. Once the contingency funds were removed, the project costs were adjusted to 2007 values using the inflation conversion factors. This was done by dividing the award cost and final project cost of each of the projects by the factor for the year the project was awarded. The factors for each year were shown in Table 4.

The project costs were adjusted to 2007 values, the cost growth percentage was calculated and the resulting percentage data was checked for normal distribution which began by evaluating the second assumption of the one-way ANOVA, the normality assumption.

The cost growth data histograms were produced and are included in Figures 19 to 21.

The transportation project follows a normal distribution as seen in Figure 19. The majority of the projects used for the study had a small cost growth percentage with a mean for the projects of 2.93 for the 90 projects.

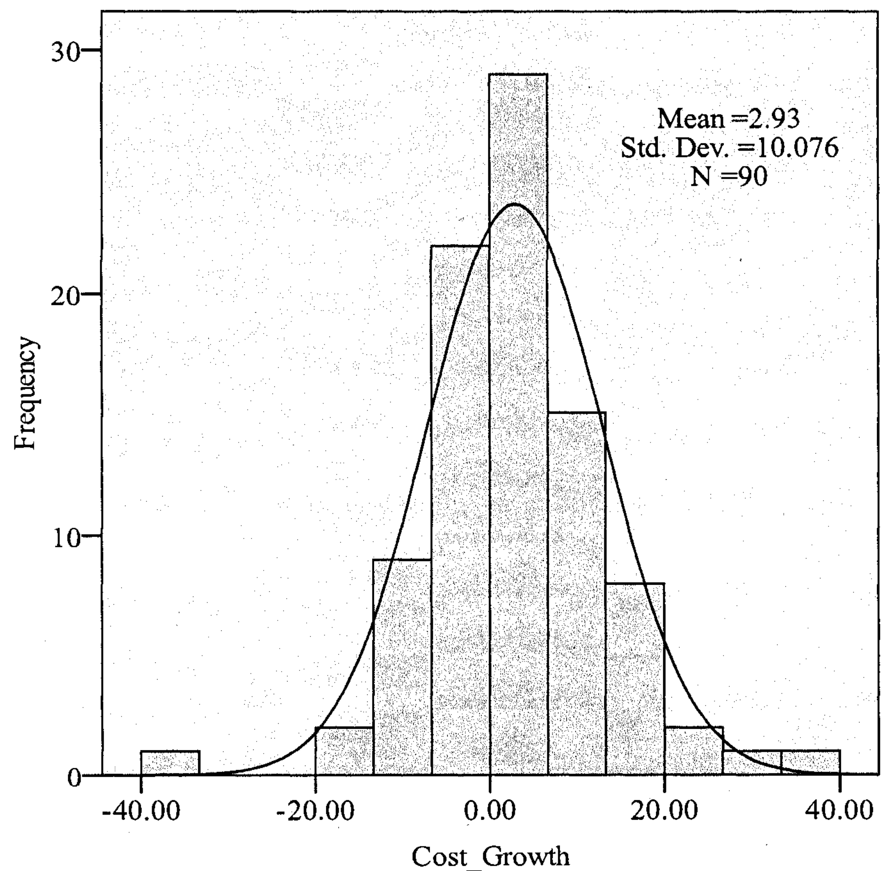

Figure 19: Transportation cost growth normal distribution curve

The utility project cost growth percentages also followed the normal distribution curve with the mean for those projects at 6.52 for the 44 projects, the highest of the three types of projects. Figure 20 shows the histogram and normal distribution curve for the utility project cost growth.

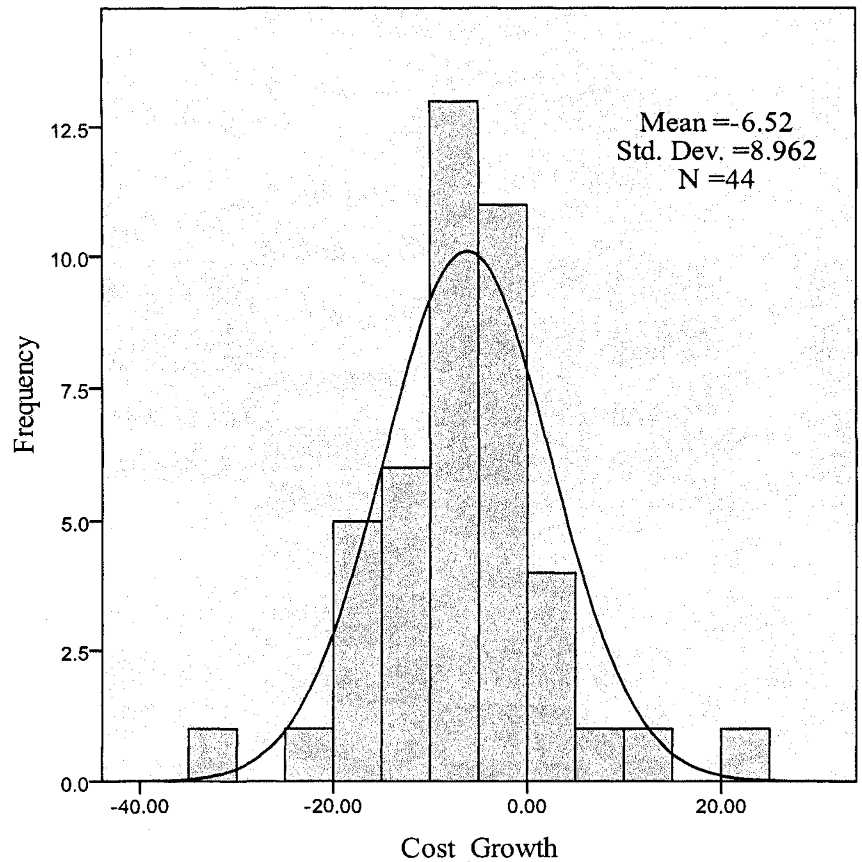

Figure 20: Utility cost growth normal distribution curve.

And finally, the flood control cost growth percentage was in the middle of the other two types of projects with a mean of 2.90 for the 47 projects. Figure 21 shows the histogram and normal distribution curve for the flood control project cost growth.

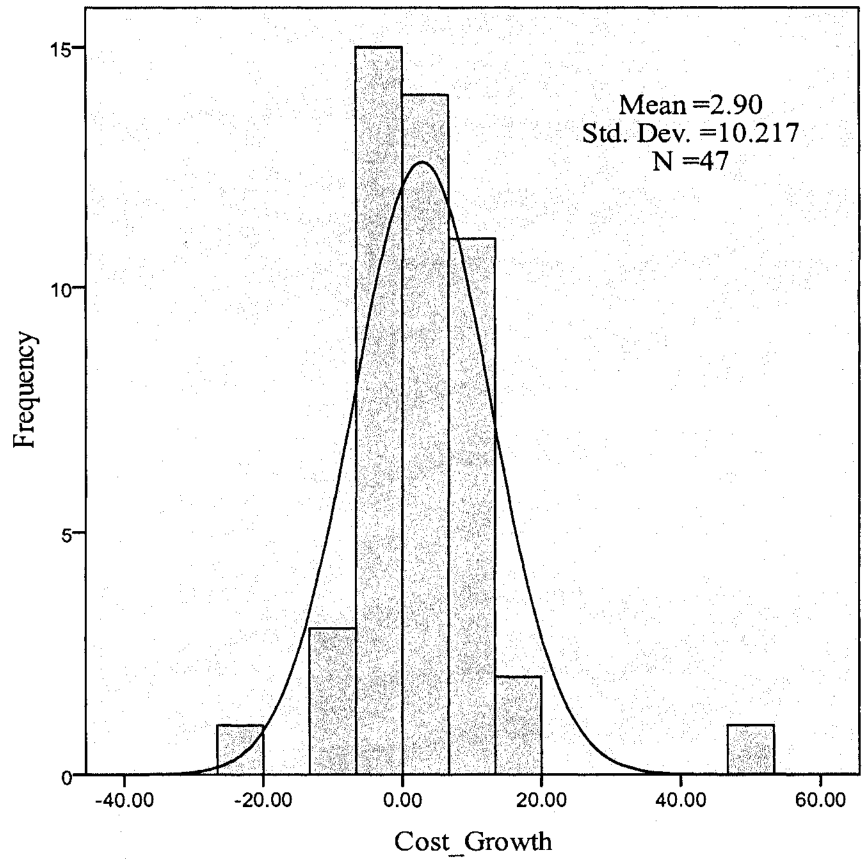

Figure 21. Flood control cost growth normal distribution curve.

As shown in the figures above, the cost data for all project types followed a normal distribution.

Histograms for the schedule growth were produced and are shown in Figures 22 to 24.

The transportation project schedule growth percentages followed a normal distribution curve and were the lowest of the three project types with a mean of 1.19 for the 90 projects. Figure 22 shows the histogram and normal distribution curve for the transportation project schedule growth.

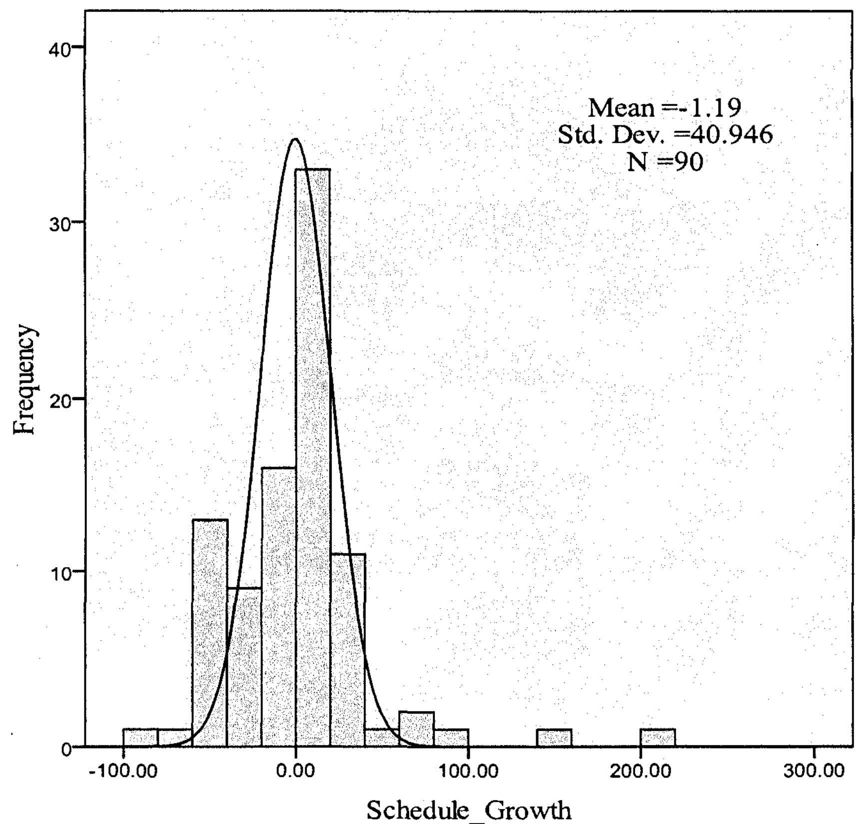

Figure 22. Transportation schedule growth normal distribution curve.

The utility projects also followed a normal distribution and had the highest schedule growth with a mean of 15.25 percentages for the 44 projects. This is to be expected for underground work and reliance on other organizations such as the local electrical utility company for support during construction. It is not unusual for projects to be delayed for several weeks while other utility companies schedule crews in to the project site to move conflicting utility lines or install termination facilities such as a power transformer in support of the project. Figure 23 shows the histogram and normal distribution curve for the utility project schedule growth

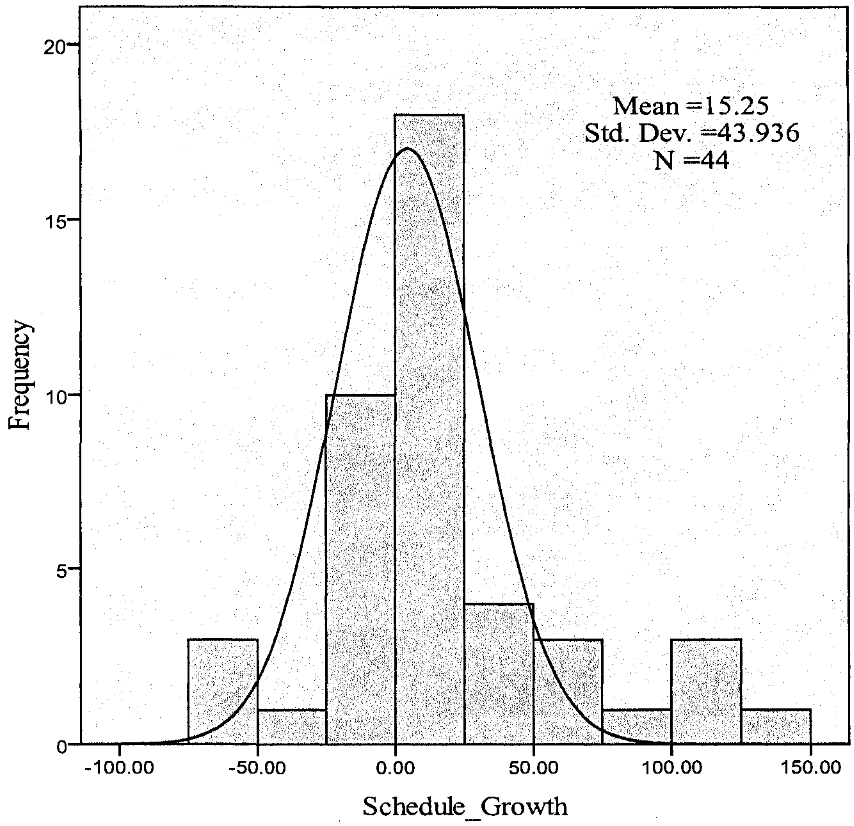

Figure 23. Utility schedule growth normal distribution curve.

Flood control projects were again in the middle with a mean of 7.95 percent of the 47 projects. This could be a result of weather events or the need for additional time to control the ground water at the project site. Figure 24 shows the histogram and normal distribution curve for the flood control project schedule growth.

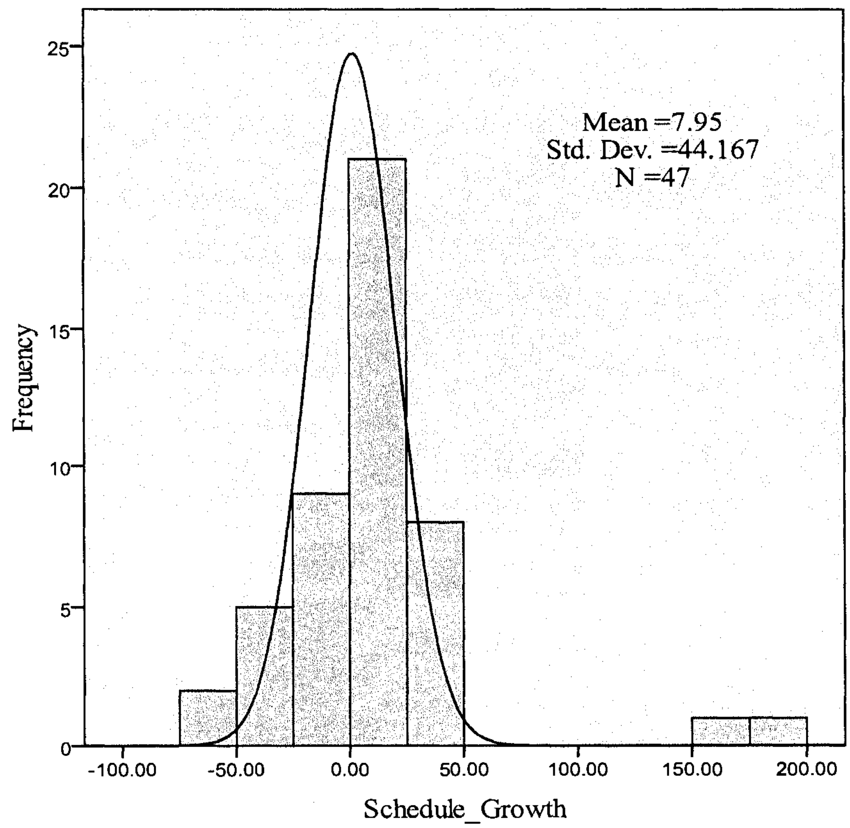

Figure 24. Flood control schedule growth normal distribution curve.

The third assumption, homogeneity of variance, was validated with the Levene test. The Levene test for cost and schedule data results is presented in Table 7. It tests the null hypotheses that the population variances are equal. As indicated by the Significance level of <0.001, there was indication of statistically significant differences within the cost growth data. This means that the differences in the sample variance probably did not occur based on random sampling. Therefore the null hypotheses for the cost growth should be rejected and the assumption made that there is difference between the variances in the population.

There was, however, no indication of significant differences within the schedule growth data as shown by the significance level greater than the level of significance α = 0.05.

Table 7. Test for homogeneity of variance.

Performance Metrics	Levene's Statistics	Significance
Cost Growth	0.268	0.765
Schedule Growth	0.635	0.531

The three assumptions for performing the one-way ANOVA were satisfied and the data was possessed using SPSS Statistics Version 16 software and Microsoft Excel to provide the histograms, box plots, and data result tables.

4.2 Descriptive Statistics

4.2.1 Cost Growth

As described in the previous chapter, the raw data for cost growth for the three types of projects was analyzed and the summaries of values are shown in Table 8. The mean values for transportation and flood control were close producing percentages of 2.93 percent and 2.90 percent respectively. The median cost growth values for the two types of project were within 0.76 percent with transportation median being 2.69 percent and flood control being 1.93 percent. The standard deviation for transportation and flood control types of projects were similar with transportation S = 10.08% and flood control S

= 10.22 percent. The mean, median, and standard deviation percentages for the utility projects were not similar to either the transportation or the flood control percentages.

Table 8. Descriptive statistics of cost growth metric.

Statistics	Unit	Project Types		
		Transportation	Utilities	Flood Control
Mean	%	2.93	-6.52	2.90
Median	%	2.69	-5.96	1.93
Maximum	%	34.33	23.88	47.51
Minimum	%	-36.22	-30.55	-25.22
Standard Deviation	%	10.08	8.96	10.22
No. of Samples	No.	90	44	47

The schedule growth data for the three project types was also processed and provided the following summary data. In Table 9, the mean values indicate that the type of projects with the least schedule growth are the transportation projects. These are followed by the flood control and finally the type with the highest schedule growth is the utility projects. The median schedule growth for all three types of projects was zero percent. Standard deviation values were similar in nature.

Table 9: Descriptive statistics of schedule growth metric

Statistics	Unit	Project Types		
		Transportation	Utilities	Flood Control
Mean	%	1.26	15.91	9.76
Median	%	0	0	0
Maximum	%	289.33	140.00	190.00
Minimum	%	-88	-55.56	-61.11
Standard Deviation	%	50.62	44.83	46.26
No. of Samples	No.	90	44	47

4.3 Inferential Statistics

4.3.1 Cost Growth

The one-way ANOVA test results presented in Table 10 indicates that there are significant differences between the cost means of the three groups, as shown by the *p* value of <0.001 which is less than the level of significance $\alpha = 0.05$ and the *F* value of 15.26 is greater than 1.

Table 10. Single factor ANOVA for cost growth metrics.

Project Types	Unit	No. of Samples	Mean	F-Value	P-Value	F-Critical
Transportation	%	90	2.93			
Utilities	%	44	-6.52	15.264	≤ 0.001	3.0467
Flood Control	%	47	2.90			

To determine in which groups the significant differences were present, the Tukey-Kramer procedure was performed as shown in Table 11 below.

Table 11. Post Hoc analysis for cost growth metrics.

Project Types	Unit	No. of Samples	Mean Difference	P-Value	F-Critical
Transportation Utilities	% %	90 44	9.45	≤0.001	3.44
Transportation Flood Control	% %	90 47	0.33	1.00	3.53
Utilities Flood Control	% %	44 47	-9.41	≤0.001	4.15

The Post Hoc analysis indicated that there is a statistically significant difference between the means of the transportation and utility cost growth and the utility and flood control as shown by the p value < 0.001 and the mean difference values greater distance from zero, but no significant difference between means of the transportation and flood control which produced a mean difference close to zero. The analysis shows that the transportation projects have significantly higher cost growth than utilities projects. Similarly the flood control projects have significantly higher cost growth than utilities projects. However, there is no significant difference of cost growth for transportation and utilities projects. Figure 25 shows the box plot for cost growth of three different types of projects.

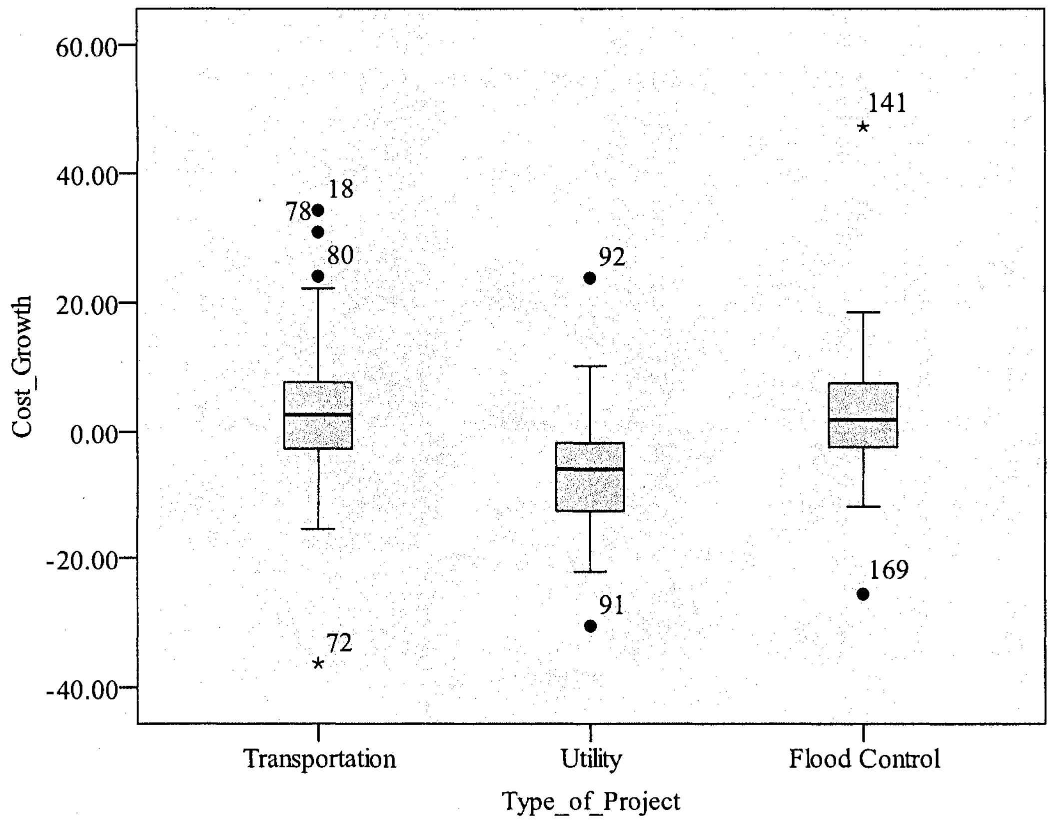

Figure 25. Cost growth box plots.

4.3.2 Schedule Growth

The schedule growth data was tested providing the results shown in Table 9. This data did not indicate any statistical significant difference between any of the groups. The F value is less than the F critical value and p values are greater than the level of significance $\alpha = 0.05$.

Table 12. Single factor ANOVA for schedule growth metrics

Project Types	Unit	No. of Samples	Mean	F-Value	P-Value	F-Critical
Transportation	%	90	-1.19			
Utilities	%	44	15.25	2.342	0.099	3.0467
Flood Control	%	47	7.95			

As the ANOVA test shows that there is no significance difference between any groups. There is no need to conduct Post Hoc analysis, however the test is carried out in conjunction with the ANOVA test in SPSS. Therefore the results of Tukey test are shown in Table 13. The results shows that no group means are significantly different at $\alpha = 0.05$.

Table 13. Post Hoc analysis for schedule growth metrics.

Project Types	Unit	No. of Samples	Mean Difference	P-Value	F-Critical
Transportation Utilities	% %	90 44	-16.44	.111	2.05
Transportation Flood Control	% %	90 47	-914	.702	8.95
Utilities Flood Control	% %	44 47	7.30	1.000	28.38

A box plot of the project schedule growth was plotted and included in Figure 26. As with the cost data, the outlying points were removed and the remaining data tested.

There was no significant difference in the output of the data with the outlying points removed so they were left in the data to be tested for final results.

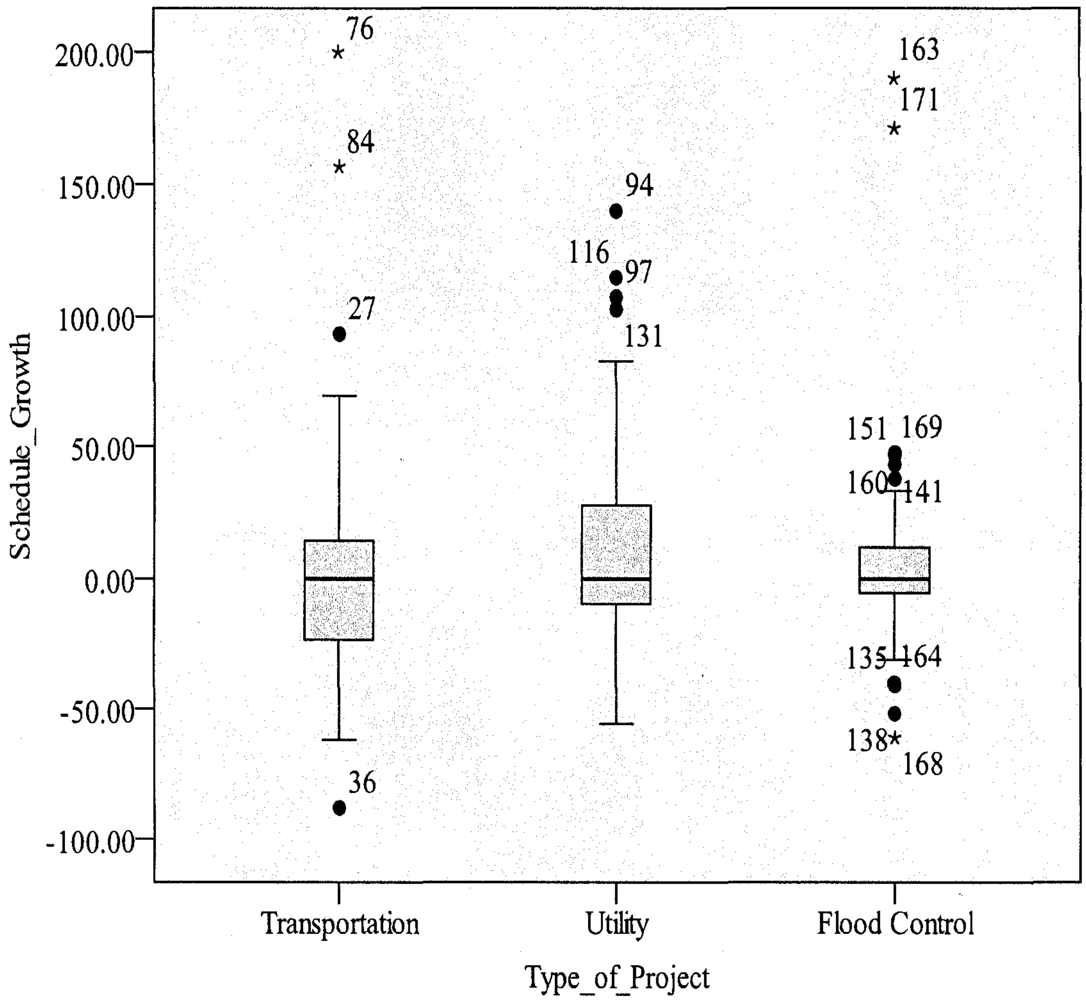

Figure 26. Schedule growth box plots.

CHAPTER 5

SUMMARY AND CONCLUSION

5.1 Discussion of the Results

The analysis of the data for the three types of projects indicated that there was a significant difference in cost growth between the transportation and utility projects and the utility and flood control projects. It did not, however, indicate a significant difference between the transportation and flood control projects.

The one-way ANOVA test results presented in Table 7 indicated that there was significant differences between the cost means of the three groups, as shown by the p value <0.001 which is less than the level of significance $\alpha = 0.05$ and the F value of 15.264 is greater than F critical value of 3.0467. The data was then tested to find where the differences in the sets of data were present.

The Post Hoc analysis of the cost growth data indicated that there is a statistically significant difference between the means of the transportation and utility cost data and the utility and flood control as shown by the p value < 0.001. The mean difference values between these two sets of data are both nine percentage points, but no significant difference between means of the transportation and flood control which produced a mean difference close to zero.

The schedule growth data was tested and provided the results shown in Table 9. This data did not indicate any statistical significant difference between any of the groups.

This was evident by the *F* value lower than *F* critical value of 3.0467 and *p* values greater than the level of significance $\alpha = 0.05$.

The Post Hoc analysis of the schedule growth data did not indicate any statistically significant difference between the means of the three groups of data since both the *p* values for the three types of projects were greater than the level of significance, $\alpha = 0.05$. The median difference values for each of the project types were also not close to zero.

5.2 Conclusion and Recommendations for Further Study

The hypotheses and null hypotheses being tested by this data are:

1. Research Hypothesis: The mean cost growth of utilities, transportation, and flood control projects are significantly different from each other

Null Hypotheses:

A. The mean utility cost growth is equal to the mean transpiration cost growth.

B. The mean utility cost growth is equal to the mean flood control cost growth.

C. The mean transportation cost growth is equal to the mean flood control cost growth.

2. Research Hypothesis: The mean schedule growth of utilities, transportation, and flood control projects are significantly different from each other.

Null hypotheses:

A. The mean utility schedule growth is equal to the mean transpiration schedule growth.

B. The mean utility schedule growth is equal to the mean flood control schedule growth.

C. The mean transportation schedule growth is equal to the mean flood control schedule growth.

For hypothesis number one, the *p* value of the ANOVA testing on cost growth was less than the level of significance $\alpha = .05$ indicating a significant difference within the group of three project types. Additional testing with Tukey Procedure indicated that the significant difference within the group was between the transportation cost growth and the utility cost growth and the utility cost growth and the flood control cost growth. Therefore, null hypotheses A and B for hypothesis number one are rejected and hypothesis number one is considered true. The mean cost growth of transportation, utilities, and flood control projects are significantly different from each other.

There are probably extensive lists of reasons why this might be true. Some of the reasons why the study utility costs were significantly different than the other two might include the expense to the contractor of having to wait for the local utility companies in the Las Vegas Valley to move conflicting facilities. In earlier years here in Las Vegas, the installation of utility lines was not watched for correct placement according to the codes like they are now. There was also a need to try to keep up with the ever expanding population and new commercial and residential building in what has been one of the fastest growing metropolitan areas of the country. Frequently, the conduit for electrical and communication lines are found much shallower than they are suppose to be by code and must be lowered.

Although water and waste water facilities are usually deep enough, many of the pipe lines are old and fragile meaning extra care is required when working around them. It is only within the last decade or so that the Las Vegas Valley Water District has started using GPS to locate their lines and valves and transfer the data collected to accurate drawings and master plans. Previously, the general location was shown on project drawings, but occasionally, the lines were shown several feet away from where they really were and lines were broken causing additional delays while repairs were made.

Flood control facilities have a different set of problems that slow contractors down and increase costs. Most of these projects are in active washes and have a steady stream of ground and nuisance water running through them. The need for dewatering is an extra expense and depending on the location can take several weeks to drain down the water table enough for the work to begin. Then, with just one rain storm somewhere in the water shed, all the work that has gone on to that point, can be washed away or damaged enough to require replacement. If a contractor is lucky, they can clean up after the runoff has subsided and continue.

Hypothesis number two testing did not produce any significant differences between the three types of projects for schedule growth. Therefore, the null hypotheses are not rejected and the hypothesis number two is considered false. Even though there were significant differences within the cost data for these same projects, it appears that the schedule impact to the different types of projects was equal.

To truly understand the causes of cost and schedule growth in the subject data, much more research within the individual project paperwork would be required. The possible causes stated here are typical of construction problems everywhere. It is recommended that further study be conducted to ascertain more specific reasons for both cost and schedule growth within the Public Works projects to try to isolate the causes enabling management to work toward the reduction and possible elimination of some reasons for the growth in costs and schedules found during this study. This study looked at only three of five or six types of construction undertaken by Public Works organizations and incorporating the data from the other types of projects not studied here should be included.

APPENDIX

TESTING DATA TABLES

Cost Growth Data Test Results

One-way ANOVA Test Results

Descriptive Data

Cost Growth

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
1	90	2.9281	10.07612	1.06212	.8177	5.0385	-36.22	34.33
2	44	-6.5193	8.96197	1.35107	-9.2440	-3.7946	-30.55	23.88
3	47	2.8955	10.21672	1.49026	-.1042	5.8953	-25.50	47.51
Total	181	.6230	10.60835	.78851	-.9329	2.1790	-36.22	47.51

Test of Homogeneity of Variances

Cost Growth

Levene Statistic	df1	df2	Sig.
.268	2	178	.765

ANOVA

Cost Growth

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2965.504	2	1482.752	15.264	.000
Within Groups	17291.173	178	97.141		
Total	20256.677	180			

Box Plots of Cost Data by Type of Project

Case Processing Summary

	Project Type	Cases					
		Valid		Missing		Total	
		N	Percent	N	Percent	N	Percent
Cost Growth	1	90	100.0%	0	.0%	90	100.0%
	2	44	100.0%	0	.0%	44	100.0%
	3	47	100.0%	0	.0%	47	100.0%

Post Hoc Test Results on Cost Growth Data

Multiple Comparisons

Dependent Variable: Cost Growth

	(I) Type_of_Project	(J) Type_of_Project	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Tukey HSD	1	2	9.44743*	1.81304	.000	5.1623	13.7325
		3	.03258	1.77375	1.000	-4.1597	4.2248
	2	1	-9.44743*	1.81304	.000	-13.7325	-5.1623
		3	-9.41485*	2.06751	.000	-14.3014	-4.5283
	3	1	-.03258	1.77375	1.000	-4.2248	4.1597
		2	9.41485*	2.06751	.000	4.5283	14.3014
Bonferroni	1	2	9.44743*	1.81304	.000	5.0656	13.8292
		3	.03258	1.77375	1.000	-4.2542	4.3194
	2	1	-9.44743*	1.81304	.000	-13.8292	-5.0656
		3	-9.41485*	2.06751	.000	-14.4116	-4.4181
	3	1	-.03258	1.77375	1.000	-4.3194	4.2542
		2	9.41485*	2.06751	.000	4.4181	14.4116

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

Cost Growth

	Type_of_Project	N	Subset for alpha = 0.05	
			1	2
Tukey HSD[a]	2	44	-6.5193	
	3	47		2.8955
	1	90		2.9281
	Sig.		1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 54.432.

Schedule Growth Test Data

One-way ANOVA tests on schedule data

Descriptive Data

Schedule Growth

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
1	90	-1.1920	40.94579	4.31607	-9.7679	7.3839	-88.00	200.00
2	44	15.2466	43.93576	6.62356	1.8889	28.6043	-55.56	140.00
3	47	7.9498	44.16732	6.44247	-5.0182	20.9178	-61.11	190.00
Total	181	5.1780	42.84513	3.18465	-1.1061	11.4620	-88.00	200.00

Test of Homogeneity of Variances

Schedule Growth

Levene Statistic	df1	df2	Sig.
.635	2	178	.531

ANOVA

Schedule Growth

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8473.580	2	4236.790	2.342	.099
Within Groups	321953.335	178	1808.727		
Total	330426.914	180			

Box Plots of Schedule Data

Case Processing Summary

		Cases					
		Valid		Missing		Total	
	Type_of_Project	N	Percent	N	Percent	N	Percent
Schedule Growth	1	90	100.0%	0	.0%	90	100.0%
	2	44	100.0%	0	.0%	44	100.0%
	3	47	100.0%	0	.0%	47	100.0%

Post Hoc Test Results on Schedule Growth Data

Multiple Comparisons

Dependent Variable: Schedule Growth

	(I) Type_of _Project	(J) Type_of _Project	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	1	2	-16.43859	7.82332	.092	-34.9289	2.0517
		3	-9.14179	7.65379	.458	-27.2314	8.9478
	2	1	16.43859	7.82332	.092	-2.0517	34.9289
		3	7.29680	8.92138	.692	-13.7887	28.3823
	3	1	9.14179	7.65379	.458	-8.9478	27.2314
		2	-7.29680	8.92138	.692	-28.3823	13.7887
Bonferroni	1	2	-16.43859	7.82332	.111	-35.3461	2.4690
		3	-9.14179	7.65379	.702	-27.6396	9.3560
	2	1	16.43859	7.82332	.111	-2.4690	35.3461
		3	7.29680	8.92138	1.000	-14.2645	28.8581
	3	1	9.14179	7.65379	.702	-9.3560	27.6396
		2	-7.29680	8.92138	1.000	-28.8581	14.2645

Homogeneous Subsets

Schedule Growth

	Type_of_Project	N	Subset for alpha = 0.05
			1
Tukey HSD[a]	1	90	-1.1920
	3	47	7.9498
	2	44	15.2466
	Sig.		.111

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 54.432.

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