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Ao Chen

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Ao Chen
Candidate

Civil Engineering
Department

This thesis is approved, and it is acceptable in quality and form for publication:

Approved by the Thesis Committee:

Susan Bogus Halter — Dr. Susan Bogus Halter, Chairperson

Giovanni Migliaccio — Dr. Giovanni C. Migliaccio

Michele Guindani — Dr. Michele Guindani

THE RELATIONSHIP BETWEEN PROCUREMENT DURATION AND DESIGN-BUILD SUCCESS IN TRANSPORTATION PROJECTS

BY

AO CHEN

B.S. CHANGSHA UNIVERSITY OF SCIENCE
AND TECHNOLOGY
CHANGSHA, CHINA-2007

THESIS

Submitted in Partial Fulfillment of the
Requirements for the Degree of

Master of Science
Civil Engineering

The University of New Mexico
Albuquerque, New Mexico

August 2009

DEDICATION

这篇论文献给我的家人,尤其是我的爸爸,妈妈.没有他们的支持和鼓励，这篇论文就永远不可能完成. 同时也感谢办公室里的其他的同事和系里不同专业的其他朋友们，没有你们的帮助，我也没法完成这篇论文.

This thesis dedicated to my family, especially my mother and my father. My thesis will never be completed without their support and encouragement. Also, this thesis dedicated to my other colleagues in construction graduate students office and other friends in Civil Engineering department. Without your help, I wouldn’t be able to complete my thesis.

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I really appreciate Dr. Susan B. Halter, my advisor and defense chair, for giving me her trust by providing me the chance to pursue my M.S. degree in the United States and work with her as her research assistant. I am deeply grateful to her, for her kindness, time and patience in helping me to adjust to this new world during my study period. Also, I am truly appreciating her that pats attention to reading my thesis and giving comments to me to make my thesis looking great.

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ABSTRACT OF THESIS

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ABSTRACT

State Departments of Transportation (DOTs) are increasingly interested in developing new strategies for the design and construction of transportation projects. As a result, they are adopting more integrated process. Projects that previously used separate steps and parties may now be included in a single Design-Build system. When making a decision between a traditional Design-Bid-Build delivery system or a more integrated project delivery system like Design-Build, the DOTs consider potential more cost savings, time savings, and quality improvement.

In order to maximum success in Design-Build project delivery, state DOTs need to pay attention to the initial steps, like procurement. DOTs should prepare the procurement phase carefully based on project size, complexity, risks, timing, external factors, environmental issues, selection methods, etc. To assist in improving the success of Design-Build projects, this paper analyzes the relationship between procurement duration and Design-Build project success.

Schedule growth, cost growth and total project time growth are used to measure project success in this paper. Linear regression analysis is used to analyze the relationship between procurement duration and each of the three project success factors.

The results of the linear regression analyses show that there is a strong linear correlation between procurement duration and schedule growth. The longer the procurement duration, the less the schedule growth as a percent of the total project schedule. However, the research results do not indicate any linear or non linear correlation between procurement duration and cost growth. There is no evidence to indicate that a longer procurement duration will reduce cost growth.

The research also shows that the effects of procurement duration on project success are variable based on different selection methods and project complexities. This research strongly suggests that DOTs focus on procurement duration as a way to improve project success.

Table of Contents

List of Figures

List of Tables

CHAPTER 1. INTRODUCTION

1.1. Overview

Design-Build is a construction project delivery system where, in contrast to the more traditional Design-Bid-Build, the design and construction aspects are contracted for with a single entity known as the design-builder or design-build contractor. Figure 1.1 compares the interrelationship between owner, architect and contractor in both the Design-Build system and Design-Bid-Build system.

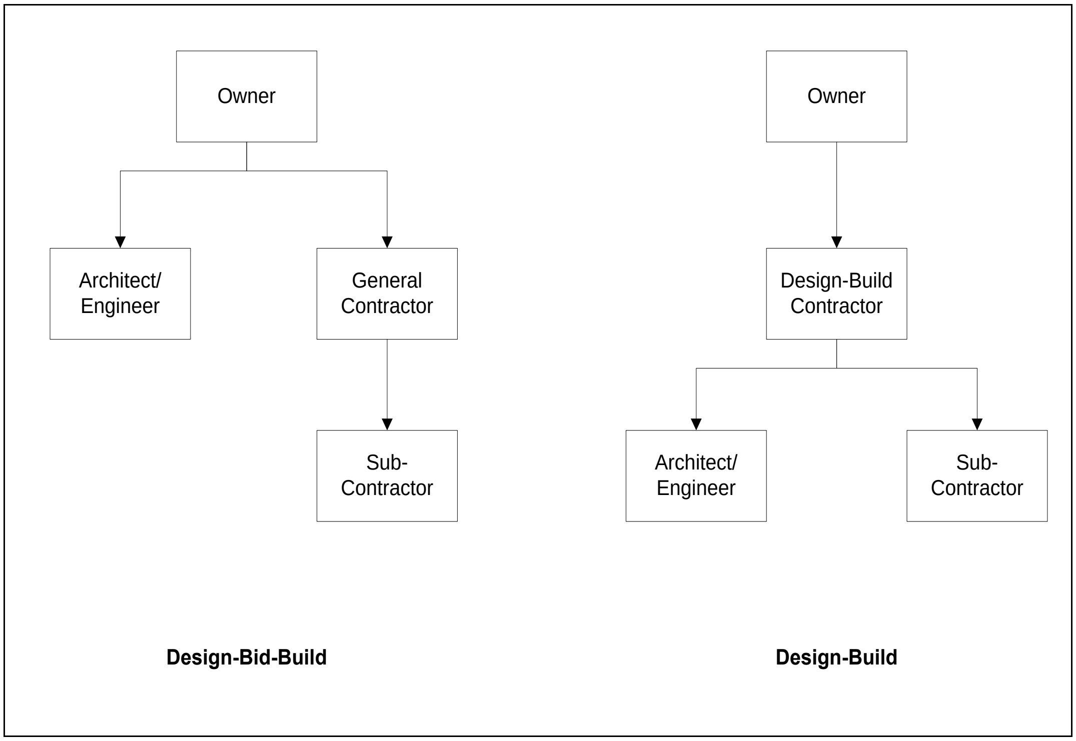


Fig.1.1 Comparison of Design-Bid-Build and Design-Build (LAO 2005)

The design-builder is usually the general contractor, but in other cases it may be the design professional (architect or engineer) or a joint venture between the construction and/or design entity

The hallmark of a Design-Build project is that one organization is responsible for both design and construction of the project. If this organization is a contractor, the process is known as "Contractor-led Design-Build". If the organization is a design firm, the process is known as "Design-led Design-Build".

The Design-Build system is used to minimize the project risk for an owner and to reduce the delivery schedule by overlapping the design phase and construction phase of a project (Molenaar et al. 1999).Even though Design-Build is considered to have more advantages over Design-Bid-Build, It is not widely accepted by all owners and contractors. However, Design-Build is growing in popularity due to its convenience and advantages. Figure 1.2 indicates the increasing trends of the Design-Build delivery system in the U.S. during the last 13 years.

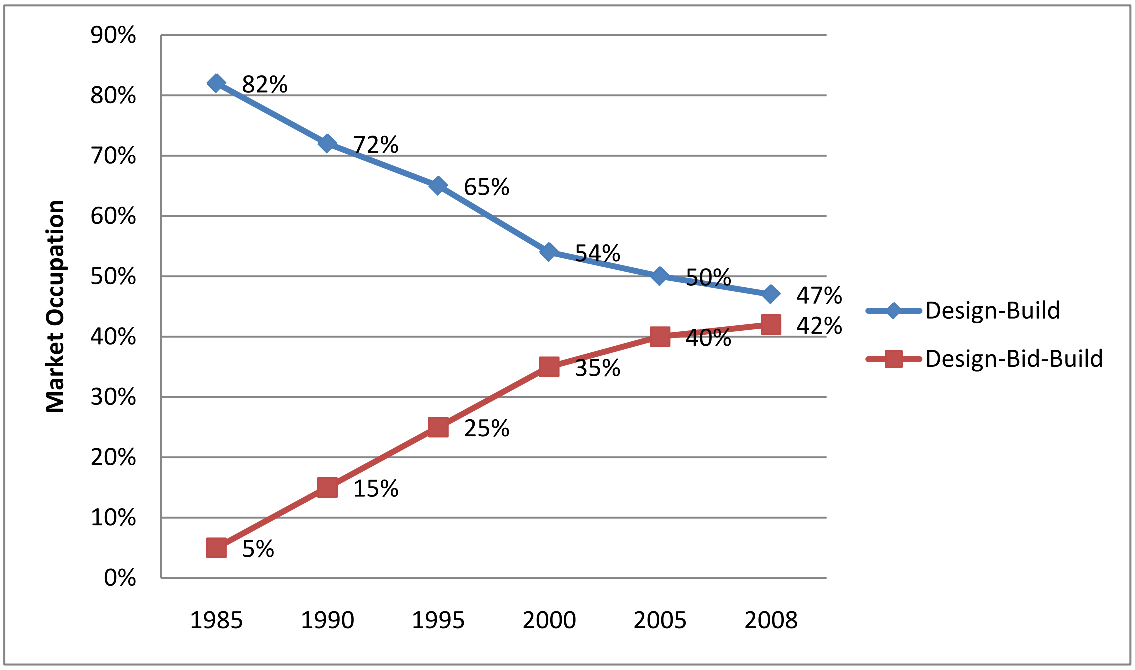


Fig.1.2 Non-Residential Design and Construction in the United States (DBIA 2009)

Previous research has identified several advantages of Design-Build over Design-Bid-Build, including: undivided responsibility, early knowledge of costs, time saving, cost saving and enhanced communication (DBIA 2009; Allen 2001; Turener et al 1994).

Undivided Responsibility: Design-Build provides both architecture/engineering and construction resources under a single contract. The owner looks to a single entity responsible for cost control, quality assurance, schedule adherence, and performance of the finished project. This results in clearly fixed responsibility, maximum cost control, and immediate responsiveness. The owner can exercise his desired degree of control over design, with the added advantage of continuously knowing the cost implications of each decision. The owner's control of the entire process is strengthened by contracting with a single firm unconditionally committed to the success of his project. It provides a comprehensive view of the project, as opposed to the one-piece-at-a-time method of multiple providers.

Early Knowledge of Costs: The Design-Build team, working closely with the owner, accurately conceptualizes the completed project at an early stage. Continuous and concurrent estimating during the development of design results in knowledge of firm, overall cost far sooner than is possible with other approaches. This process also permits making early decisions which have the greatest impact upon cost – in an informed, cost-based environment.

Time Savings: This is the biggest benefit of the Design-Build system and the main reason that owners choose the Design-Build system. Design and construction are overlapped, bidding periods and redesign time are eliminated, and long-delivery components are identified and ordered early in the design process. Therefore, total design-construction time is significantly reduced, which translates into earlier utilization of the completed facility.

Cost Savings: Design and construction personnel, working and communicating as a team, evaluate alternative materials and methods efficiently and accurately. From the outset of the project, both design and construction expertise is brought to bear upon all components of a project, from site work through mechanical and electrical systems. Because cost evaluation is progressively “fed back” into the design process – not after design is complete – decisions affecting cost and design are continuously optimized. Everything must work. Any other outcome leaves the DB solely responsible for owner’s complaints. Because the contractor is responsible for both design and construction, cost overruns resulting from design error or faulty coordination are the responsibility of the contractor, not the owner. The owner pays only for scope changes that he initiates.

Enhanced communication: Because the design parameters are being developed and weighted simultaneously with the budgetary goals, construction methodologies and budget conditions, a project is more likely to be realized than with a pure design approach. The owner has greater access to the "team" working on project development as the project is being developed. This efficiency is not a negative "short cut" as a rule, but rather the keystone to the success of the Design-Build system.

Given the numerous advantages (AIA/AGC 1994) of the Design-Build system, it is not surprising that Design-Build use is increasing. However, the relative newness of Design-Build compared to Design-Bid-Build means that there are still many areas where additional research is needed to identify how to best apply the Design-Build system. One of those areas, Design-Build procurement is the focus of this research.

1.2 Study Objective

Design-Build focuses on combining the design, permit, and construction schedules in order to streamline the traditional Design-Bid-Build environment. Though Design-Build does not necessarily shorten the time it takes to complete the individual tasks of creating construction documents (working drawings and specifications), acquiring building and other permits, or actually constructing the building, the Design-Build firm will strive to bring together design and construction professionals in a collaborative environment to complete these tasks at the same time. A lot of people believe that the Design-Build method can be executed successfully and give better results than other traditional delivery methods, but, most people focus on the performance of the design and construction component and ignore the procurement process. Since Design-Build is a very different delivery method, its procurement process also differs from traditional delivery methods (Figure 1.3).

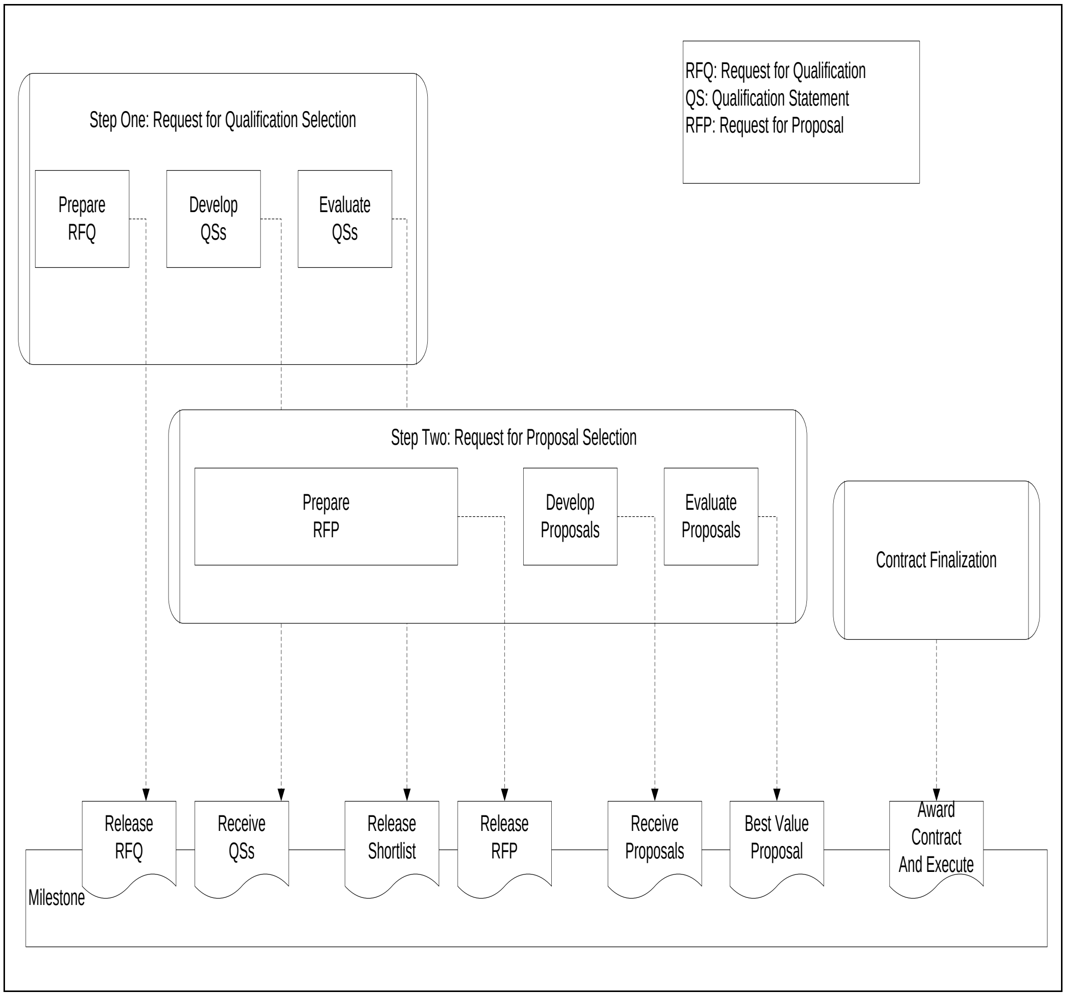


Fig. 1.3 Two-step Selection Procurement Process (Migliacco et al. 2009)

The procurement method for Design-Build projects is more complex than other methods, because Design-Build depends on contracting with a single entity to deliver the project. The procurement that is used to select the entity should be as comprehensive and cautious as possible to encourage project success. Figure 1.3 illustrates a typical process in Design-Build procurement.

Design-Build projects typically follow a best-value based two-step procurement, in the public sector. Under a two-step procurement, the owning agency will first issue a Request for Qualifications (RFQ) to all initial interested bidders. All interested bidders will have to submit their qualification statements (QS) to the agency before the required deadline, otherwise they will not be considered in the bidding. After receiving all qualified QSs, the evaluation committee will carefully review all QSs and score them. Then the committee will decide the bidders' ranking based on technical score. The committee will make a "shortlist" and only a few top qualified bidders will move to step two.

Usually, only 3-5 bidders will get into the second step. The agency will notify all shortlisted candidates and issue the Request for Proposal (RFP) to them. The bidders must prepare both technical proposals and price proposals. Both proposals must be handed in by the deadline, typically with separately sealed covers. Even though there are different evaluation and transformation methods, the basic process is the same. Price will be considered in this phase along with technical proposals. The committee carefully evaluates each bidder's proposals and awards the contract to the most appropriate bidder based on a best value selection method.

Based on the process, the question arises as to whether the time spent on procurement relates to eventual project success. Therefore, main question of this research is to discover whether there is a relationship between procurement duration and project performance.

The basic hypothesis is that increased time spent during procurement will lead to more successful projects. For the purpose of this research, project success is defined in terms of limiting cost growth and schedule growth. The objective of the research is trying to find whether there are some relationships between Design-Build procurement duration and project success. If some relationships indeed exist, this research will go on to identify controllable factors and criteria.

1.3 Research Methodology

As previously mentioned, this research aims to answer the question as to whether Design-Build procurement duration is related to project success such as cost growth and schedule growth. More specifically, the research focuses on transportation projects in the public sector that were completed using Design-Build. In this research, data are collected from published documents, state departments of transportation (DOTs) and other sources to calculate procurement duration, cost growth, and schedule growth for individual transportation projects.

The procurement duration starts at the date the final RFP is issued to the public and contractors. The procurement end date is the day that all the technical and price proposals are due. Cost growth will relate contracted price and actual price. The definition of contract price here is the final price in the final contract. The actual price is the total cost of the completed project. Schedule growth will relate contracted schedule and actual schedule. The contracted schedule is the project duration in the final contract. The actual schedule will start from the first day that the final contract is executed to the last day that the contract is finished.

Once data collection is complete, the basic project information will be calculated and summarized. Then a comparison will be made between procurement duration and schedule growth, procurement duration and total project time growth, and, procurement duration and cost growth. In each calculation, two research criteria/parameters (complexity and selection method) will be considered. Three different selection methods were used for the projects in the study: adjusted bid, best value, and low bid. The project complexity level is simply classified by contract price. In order to give enough data points for study, three complexity levels are used in this research, low complexity (below $ 10 million), medium complexity (between $10.01 million -$50.00 million), and high complexity (above $50.01 million). All the analysis is based on regression analysis. The linear regression analysis first will be used to test the relationship between procurement duration and schedule growth/total project time growth/cost growth. If the analysis results do not show a liner correlation, then non linear correlation will be conducted for those two factors and the conclusion will be summarized based on two different regression analyses.

1.4 Readers Guide to Thesis

This thesis discusses the relationships between procurement duration and project performance in highway Design-Build projects. Chapter 1 is the introduction section. The overview of the Design-Build system, study objectives and conceptual methodology are explained in Chapter 1. Chapter 2 is the literature review section. This section discusses previous research in Design-Build and this particular research topic. The overall performance and advantages of Design-Build will be discussed in this chapter. Also, the public Design-Build project procurement models will be compared and summarized. The different Design-Build procurement methods are explained and compared as well. The last section in this chapter summarizes successful performance factors and successful performance criteria in Design-Build projects. Some key factors and metrics are defined and analyzed. Chapter 3 is introducing data collection. The basic definition of data are defined and explained. Besides, research objective is illustrated in this chapter too and some data collection sample is given here in order to give readers better understanding. The research methodology composes Chapter 4. Concretely speaking, RFP procurement duration, cost growth and schedule growth will be researched and compared in order to discover the relationships between each other. Then Chapter 5, correlation analysis, will present the draft relationships and discuss its reliability under regression analysis. Chapter 6 concludes this research study and illustrates the unsolved problems that need to be studied in the future.

CHAPTER 2. BACKGROUND LITERATURE

2.1 Overview

Design-Build is a project delivery system that has existed for more than 30 year. In most papers, researchers illustrate that Design-Build comes from the “Master Builder” model which is used to build most pre-modern projects. Under the Master Builder model, the architect has responsibility for the total project. From the inception to completion, the master builder is the key party for success and he is also strictly liable to the owner for defects, delays, statutes and losses.

For nearly the entire 20th century, the conception of Design-Build was identified as a non-traditional construction method in the United States. In the United States, most public sectors are still using Design-Bid-Build for their projects, thus Design-Build is not only a construction delivery system, but a new innovation.

People choose Design-Build because it has many advantages. Design-Build can save cost. Comparing with Design-Bid-Build, owners need not hire a separate design team and construction firms, owner can also save money in holding a multi-party communication meeting or problem-solving meeting. Because Design-Build focuses on combining the design, permit, and construction schedules in order to get a successful completion, the critical point of Design-Build is that one organization is responsible for both design and construction of the project. If this organization is a contractor, the process is called

“Contractor-led Design-Build”. On the other hand, if the organization is a design firm, then the process is called “Design-led Design-Build”.

Another benefit of Design-Build is enhanced communication (AIA/AGC 1994). Because the design parameters of a project are being developed along with the budgetary goal, construction methodologies and budget conditions being weighed, a project is more likely to be realized than with a pure design approach. The owner has greater access to the "team" working on project development as the project is being developed. This efficiency is not a negative "short cut" as a rule, but rather the keystone to the success of the Design-Build model.

Also, instead of having several contractors and consultants, Design-Build can make an owner have just one entity to deal with. This mechanism can reduce clashes among the architect, contractor and owner and improve the communication efficiency a lot (Freeman and Beale 1992). Some processes and activities like design revisions, project feedback, budgeting, permitting, construction issues, change orders, and billing can all be routed through the Design-Build firm. This single point of contact allows a certain degree of flexibility for the owner (Ashle et al 1987). Most design-builders will leverage that flexibility for the owner's benefit by continually refining the construction program to maximize the owner's value at the completion of the project.

Fourthly, rather than a parcel level of responsibility of the classic Design-Bid-Build, Design-Build provides an integrated solution for the owner or client. This moves projects away from the "finger-pointing" that is often commonplace in contemporary construction projects, and allows the owner to look to one entity with any questions or concerns (Tan 1996). In Design-Build, the administrative burden and the time spent by the client on project performance are minimized. Critically, Design-Build enables superior risk management for the client. Implication in the Design-Build process is a client's shelter from liability. Owner can transfer his risk of design and arrangement faults to architect and contractor. Architects and constructors take sole-responsibility for any design errors or omissions, and thereby prevent typical litigation problems inherent in Design-Bid-Build.

Most projects encounter problems that need real-time solutions to prevent compromise on scheduling, costing or quality. With Design-Build, it is able to address crisis much more effectively due to the overall control over all delivery components and possess flexibility to provide in time solutions (Chan et al. 2002). The communication, scope and contractual problems that plague Design-Bid-Build seriously can be solved easily in the Design-Build. Since design and construction are finished by one entity in Design-Build system and the organization is not complex like Design-Bid-Build (Allen 2001). Figure 2.1 and Figure 2.2 show the basic organization framework of Design-Bid-Build and Design-Build. Design-Build can reduce the interaction of a problem between architect and contractor greatly. Owners can identify and classify each party's responsibility in a problem much more quickly than in Design-Bid-Build (AIA/AGC 2004). At the same time, owners can decrease mediation duration and get solution agreement faster than with Design-Bid-Build. Most importantly, clients usually do not have the expertise to manage the traditional triad of client-designer-builder and crisis situations accentuate the problem. Thus, another role of Design-Build is to insulate the client from all that does not require scope related decisions.

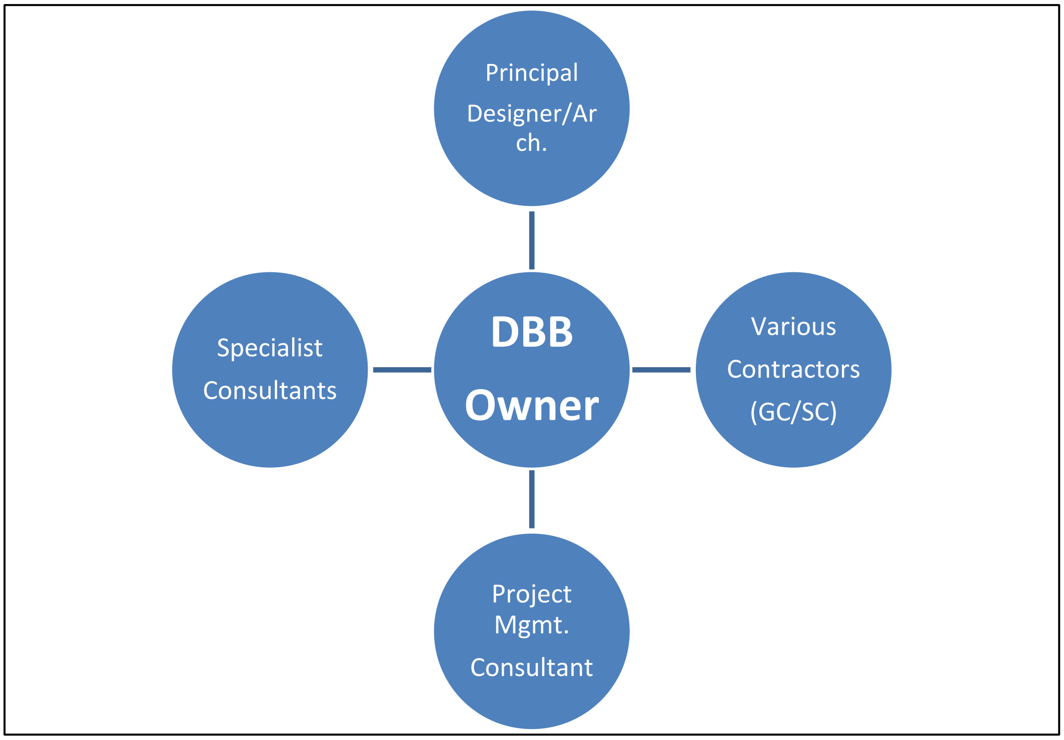


Fig.2.1 Design-Bid-Build Parties Organization (AIA/AGC 1994)

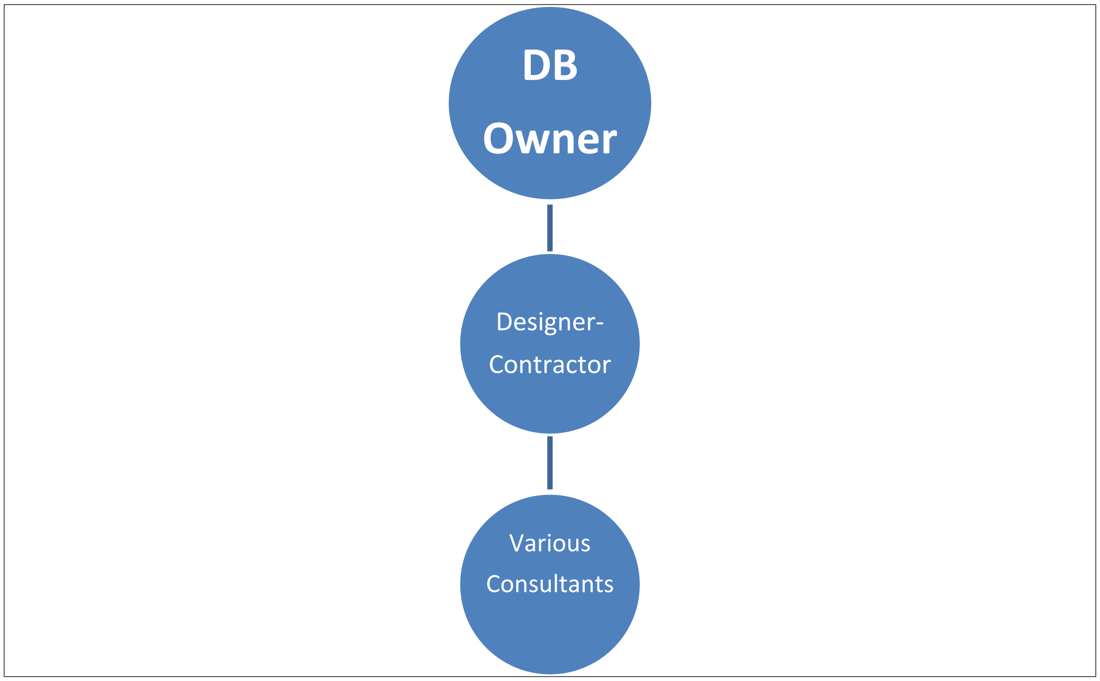


Fig. 2.2 Design-Build Parties Organization (AIA/AGC 1994)

The biggest benefit of Design-Build is time saving and it is the main reason that public sectors or private owners choose Design-Build (Songer and Molenaar 1996). Design-Build doesn't shorten the time which takes to complete the individual tasks of creating construction documents like working drawing and specification documents, acquiring building and other permits, or actually constructing the building. But, it doesn't mean that Design-Build saves little time for project (DBIA 2009). Design-Build strives to bring together design and construction professionals in a collaborative environment to complete these tasks in an overlapping like fashion. The following Figure 2.3 and Figure 2.4 indicate rough flow charts of Design-Bid-Build and Design-Build showing the overlapping for Design-Build.

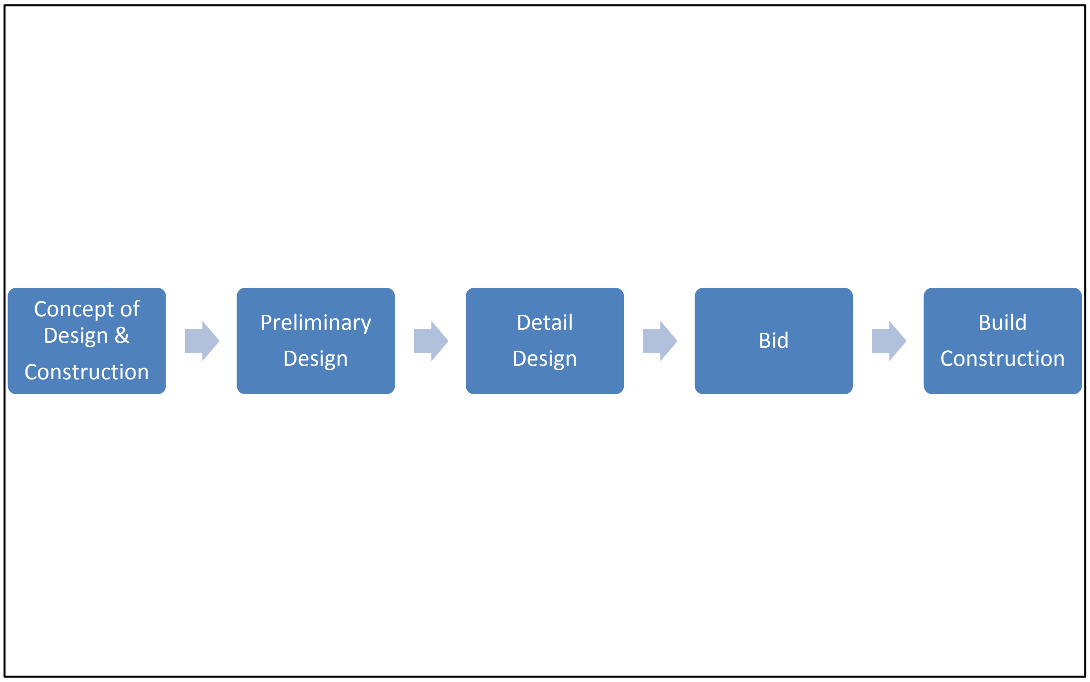


Fig.2.3 Flow of Design-Bid-Build (DBIA 2009)

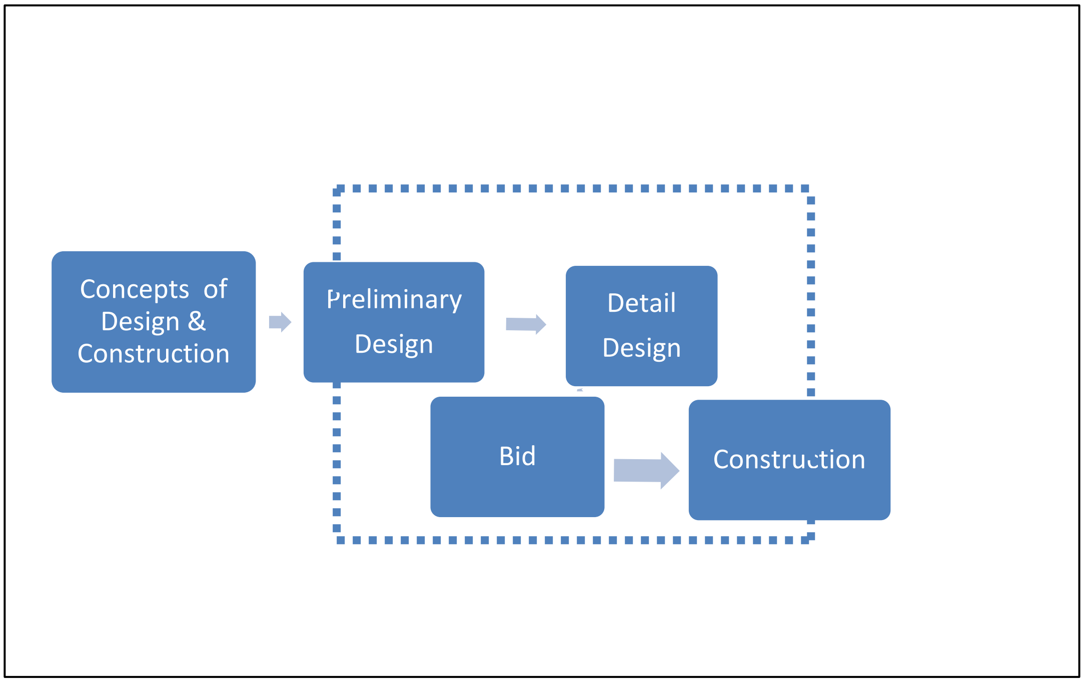


Fig. 2.4 Flow of Design-Build (DBIA 2009)

From Figure 2.3 and Figure 2.4, it is easy to see that the Design-Bid-Build method is time consuming and requires the completion of all design work before construction, which includes the solicitation of bids and bid selection. Design-Build greatly accelerates this process. Cost can be identified sooner and construction can begin on the first phases of the project while design of later phases continues (Konchar and Sanvido 1998). In addition, scheduling delays are prevented and errors can be detected earlier. In fact, an AIA report (1994) showed that facilities built using Design-Build construction were occupied in 33% less time than those using historical construction methods.

The initial time saving with Design-Build is in elimination of the bid phase between design and construction. Besides, it is able to save further by overlapping design and construction activities, like Figure 2.4 shows. Materials, equipment procurement and construction on site can be initiated well before preparation of all specific detail documents. The integrated process approach encourages time saving value engineering and parallel construction activities that do not get into each other's way. Most importantly, due to the better control that we exert over the various component agencies working on the project, any delays or non-performance can be addressed quickly and effectively without getting into contractual issues and time wasting procedures, making Design-Build the system of choice for 'Fast-Track' deliveries.

Based on the website documents of Design-Build Institute of America (DBIA

2009), Design-Build has more additional benefits beside main advantages. Design-Build can also enhance flexibility, timely feedback, and innovation.

It manages to align the interests of clients, designers, constructors and suppliers through a transparent process of constructibility assessment, design development, cost analysis and realistic scheduling. It is an integrated process that enables formation of a cohesive team of players who benefit from positive partnering and open communication. It nurtures far more innovation, creativity and project control than any other modes of delivery. In a conclusion, Design-Build has a lot of advantages and this new delivery system is recommended to most public sectors for their facilities and new constructions.

2.2 Procurement under Design-Build

From the overall literature, it is evident that Design-Build can offer a project numerous advantages. But, an important issue associated with the Design-Build delivery system is the procurement model and methods used to select the Design-Build team. It is a critical decision that involves several key project team members, including the owner, designer, and contractor firms, and requires the owner to carefully choose the Design-Build procurement model and method that will be used to select the team that will deliver the project.

A Procurement model is defined as a framework of procurement, such as a flowchart of the process in selecting a qualified Design-Build firm. The procurement method is defined as the metrics that affect evaluation emphasis and some factors or parameters which affect selection results and contract negotiation directly.

2.2.1 Procurement Model under Design-Build

In the United States, the delivery system in public sectors like the Department of Transportation (DOT), has traditionally been divided into two parts: (1) procurement of engineering services, and (2) procurement of construction services. If the owner doesn't perform engineering based on their own reliable staff, then procurement of engineering services purely focuses on qualification other than a price in traditional delivery system.

Under the Design-Build delivery system, procurement combines the procurement of engineering and construction under one contract. This new combination also requires a new procurement model. In order to reduce schedule and enhance constructability in Design-Build process, the design-builder selection must start before the contract documents are 100% complete (Molenaar et al. 1999). The private owner can negotiate with a single participant in all situations, whereas, the public sector requires a competitive selection process. Thus the former traditional "100% design complete" based sealed fixed-price procurement is not suitable. Based on Molenaar and Gransberg's research (2001), there are three common procurement models in Design Build: Fixed-Price Sealed Bidding, One-Step Selection, Two-Step Selection.

Fixed-Price Sealed Bidding model is the standard selection procedure used in the traditional Design-Bid-Build delivery system when design documents are 100% complete. But there are still some public sectors using it in their Design-Build procurement. Figure 2.5 shows the flowchart under a fixed-price bidding model.

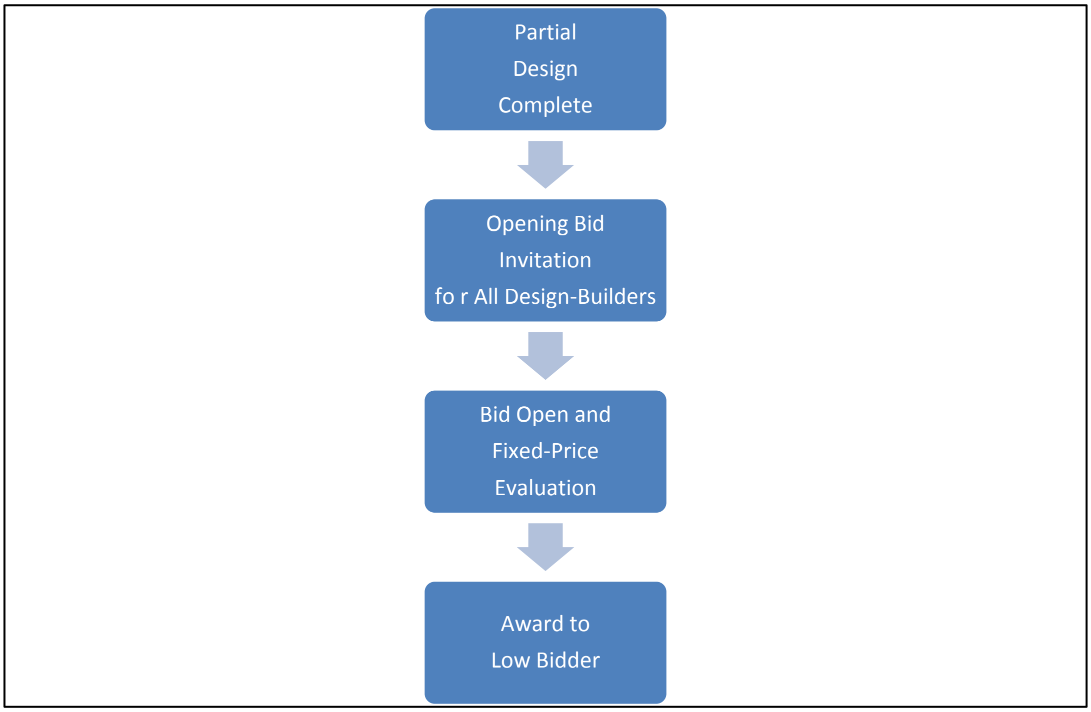


Fig. 2.5 Fixed-Price Sealed Procurement (Molenaar and Gransberg 2001)

In the fixed-price based model for Design-Build, the procurement process will start in the early design phase. Usually, the bid invitation will be sent to bidders when 15%-50% design work is finished. Then bid envelopes will be open and evaluated together. Since fixed-price based models use a qualified and reliable design firstly and starts to bid when partial design are finished, the evaluation metric only focuses the on price side. Usually, only the lowest price bidder will be awarded this contract and construction will start quickly after contract is signed.

The biggest advantage of this procurement model is that owners can still control the scope of the design but transfer the risk of errors and omissions in detailing to the design-builder (DBIA 2009). Also, since it is a low bid method of selection an owner can save cost through a competitive bid. Price is the only selection consideration, after general prequalification criteria are met.

But, comparing with the other two models, the fixed-price based model may have some potential problems. Firstly, it may cause some different interpretations of incomplete plans. Secondly and the biggest problem, it may lead to the loss of innovation when a significant amount of design is already finished (Molenaar and Gransberg 2001). Thirdly, fixed price based models may attract a lot of bidders and owners will spend more in preparing and evaluating bids.

Due to those potential problems, especial loss of design innovation, more and more public sectors adopt one-step or two-step procurement models.

The one-step procurement model includes the evaluation of a technical proposal in addition to price. Award method can be variable which means selection can be based on low bid or best value. Figure 2.6 shows the flowchart of the one-step procurement model.

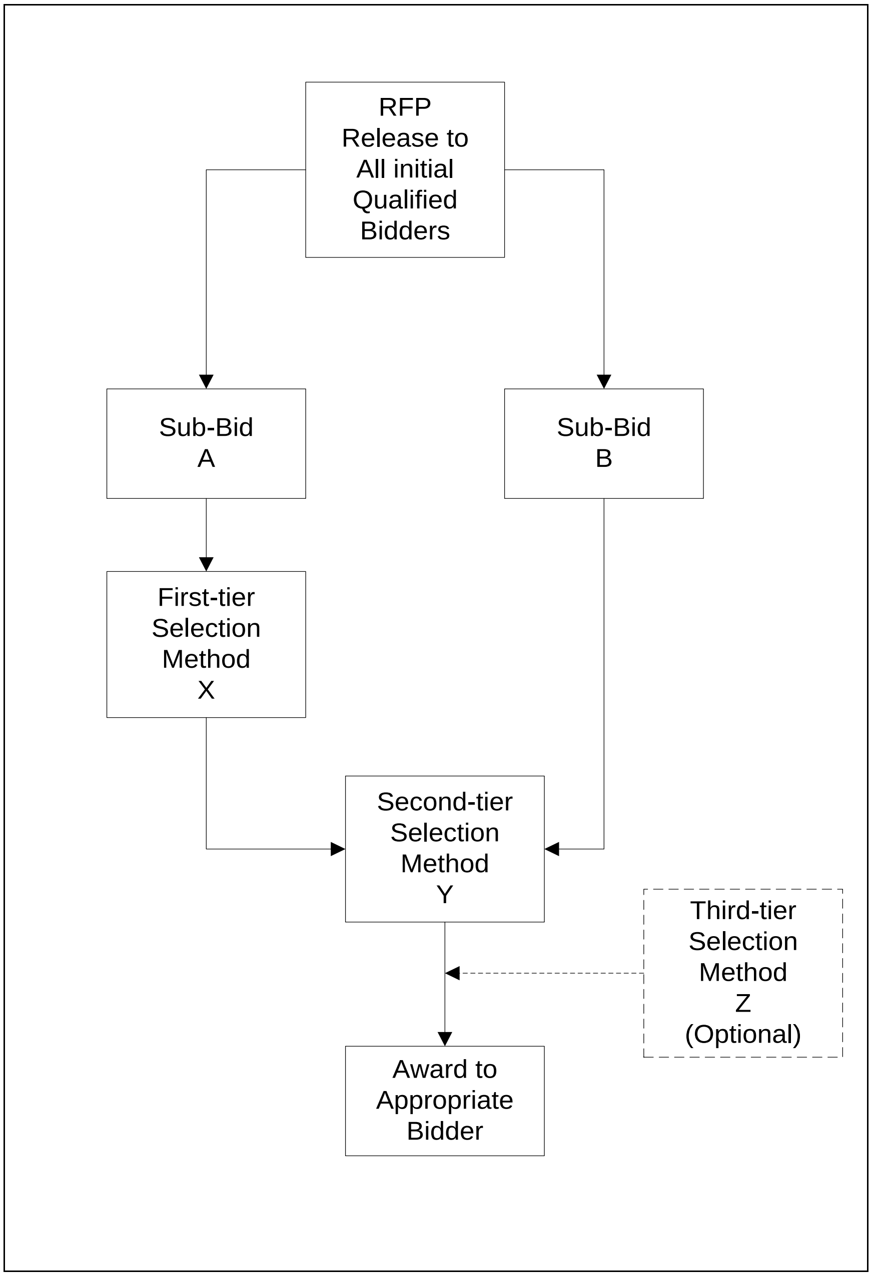


Fig.2.6 Flowchart of One-Step Procurement Model

In Figure 2.6, Sub-Bid A is technical bid and sub-bid B is price bid. Under this situation, different selection methods will affect the process and procurement durations a lot.

If a low bid method is chosen by the owner, then owner will issue the required documents to all qualified bidders, and bidders have to submit both technical and price bids by the deadline. But, technical proposals will be opened firstly and scored by an evaluation committee. The Evaluation committee will decided a minimum technical score baseline and make a bidder list based on this minimum score and move to the second-tier selection. In the second-tier selection, price bids will be opened and the contract will be awarded to the lowest price bidder in the qualified list, no matter their technical score they got.

If a best value method is chosen by the owner, then bidders have to submit their technical and price proposals with sealed covers separately before the required deadline. The technical proposal will be opened firstly and reviewed by an evaluation committee. Based on evaluation metrics like construction quality, design innovation, future maintenance, the evaluation committee will score all technical proposals and decide a minimum score line. Only bidders whose scores are over the minimum can move to second-tier evaluation process (code Y). In the second-tier evaluation round, qualified price bids will be opened and price will be also considered in this round associated with technical score. In Molenaar's research (2001), one evaluation equation is suggested:

$$\text{Composite score} = \frac{\text{Price proposal}}{\text{Technical Score}}$$

And, according to composite scores, the contract will be awarded to the lowest composite score bidder.

Under an alternative approach, Sub-bid A is price bid and sub-bid B is technical proposal. Under this situation, bidders are also required to submit their technical and price proposals together but with two individual sealed covers. Because time is typically a primary factor to choosing Design-Build (Herbsman 1995), the time factor will be considered.

The Evaluation committee will open the price bid and score it. However, this is not simply price-based consideration. Time will be also put into first-tier selection. The evaluation will use time value which means they transfer time into dollars. The committee will put the time value and price proposal together and the contract is temporarily awarded to the bidder who has the lowest adjusted price amount. In the second-tier and third-tier evaluation, committee members will review this bidder’s technical proposal, if they think this technical proposal is qualified, the contract will be officially awarded to this bidder. In case of a disqualified technical proposal, the second lowest adjusted price bidder will become the candidate and committee members will review the technical proposal for his firm. The evaluation committee will repeat this process until they find one meeting both price, time and technical requirements.

The two-step procurement model has become more and more popular in Design-Build projects. A two-step model contains the prequalification of firms via a request for qualifications (RFQ) and then evaluation of price and/or technical proposals.

In the two-step procurement model, the most common selection methods are best-value based selection and low bid based selection. The most typical characteristic of two-step models is that it requires two different proposals: Request for Qualification (RFQ) and Request for Proposals (RFP). Figure 2.7 shows the process of two-step procurement models.

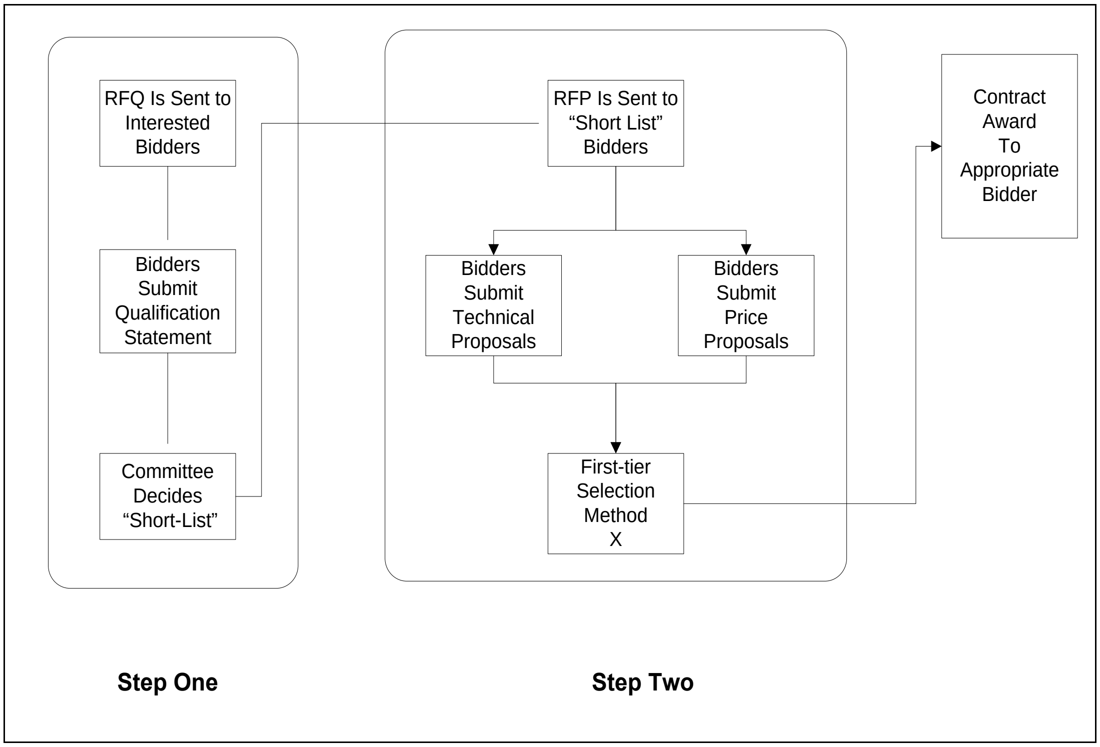


Fig.2.7 Flowchart of Two-step Procurement Model

From Figure 2.7, it is easy to see that the step one procedures are common no matter what kind of selection method the owner uses. In step one, owner will send their bidding invitations to all interested bidders or owners will post an advertisement to attract all potential bidders. Then, owners will issue an RFQ to all bidders and ask them to submit their Qualification Statement (QS) by the published deadline. After receiving all QSs, the evaluation committee will carefully review all QSs. In this phase, qualification is the only metric in evaluating and committees will make a “short list” which includes the most qualified bidders. Usually, the “short list” involves 3-10 bidders and the contract will be awarded to one of them.

The different selection methods will mostly affect step two. A best value based method is the most common selection method in the two-step procurement model. The selection methods are similar to those described for the one-step model.

Based on the illustration, it is obvious that the level of complexity can be low and similar to that of the traditional bid process, or complex including multiple iterations of a best value selection.

The literature review shows that there is a huge variation in Design Build procurement selection and different procurement models and selections method will affect the success of Design Build project a lot. The procurement can be affected by state procurement statutes, level of design at RFP stage, project complexity, agency familiarity with Design Build, and agency culture (Molenaar et al. 2001). But the trend is that more and more states are transitioning from fixed-price based and one-step based low bid model to two-step best value based model. The agency finds that one-step based models may create scope definition difficulties and two-step based model is much better on the more complex projects. In Design Build, minimal design, or design of less than 30%, can increase project complexity and can’t reasonably be bid (Molenaar and Gransberg 2001). A higher level of design creates a less complex selection process that resembles the sealed bid method, but decreases innovation and can lead to increased change orders.

In conclusion, when minimal design is used in the RFP, more innovation can be available, but procurement selection is more complex. It is best to use a two-step model when design is less than 30% in order to get the most innovation. The two-step model requires more administration than the one-step model and both cost and schedule performance is found to improve with the two-step procurement model. Based on Molenaar’s research (1999), the two-step model produced projects closer to the original budget and schedule than the one-step process on average and a “short list” can improve performance too.

2.2.2 Procurement Method under Design-Build

In a Design-Build procurement system, because of different state cultures and state statutes, there are many procurement methods. The most common procurement methods are: sole source, qualification-based, best value and low bid. Different selection methods will affect procurement result. Different procurement methods plus different procurement models, is can even decide how successful a project approaches are under Design-Build.

The sole source selection method only includes a direct selection of the Design-Build team based on selection factors like past performance for similar projects (Beard et al. 2001). As a fact, sole source selection is rarely used in public sector procurement, because it can greatly limit competition. This type of selection is primary used in extenuating circumstances, such as extremely short schedule constraints like emergency reconstruction or a limited set of qualified offers. If agency regulations allow and the process is properly managed, a sole-source selection has the potential to lower the agency’s administrative burden while delivering similar quality (Molenaar and Songer 1998).

The qualification-based selection method allows public sector owners to choose an appropriate bidder based on qualification and technical consideration. Owners can select a design-build team through RFQ evaluation and are allowed to negotiate a contract directly with the most qualified design-build team to an acceptable price. The evaluation criteria are purely technical. In this selection method, owners usually choose to award the project to a specific design-build team with whom they have a long-term relationship with minimal scope design completed at the time of procurement. Or, this selection method can be adopted by the public sector who wants to build a special high quality and long life project. In fact, in some states, public sectors do not use qualification-based selection methods in their Design-Build procurement, because they think that there is a conflict between the qualification-based selection procedures for engineers and the sealed-bid selection for constructors under a Design-Build system.

The best value based selection method has become more popular in

Design-Build procurement and a lot of researchers suggest that owners use this advanced procurement method in a two-step procurement model. In a best value selection, the prospective bidders have to submit their proposals that are primarily evaluated based on the technical aspects together with the associated cost of the project. Negotiations may take place after the proposal submittal phase. The owner will set up evaluation criteria and selects the proposal that offers the overall best value based on their evaluation metrics. A weighting criteria evaluation method is usually used to select the design-build team and the weights assigned to each of the factors are specific for the owner’s organization, in addition to the type and size of the project. Prequalification of the design-build team based on technical criteria before the final selection phase can also be part of the best value procurement method.

The low bid selection method is also used in the Design-Build procurement process. This method is widely used in fixed-price models and one-stop procurement models. The owner primarily selects the design-build team based on the project value and related cost items. To facilitate data categorization, if cost criteria represented more than 90% of the design-build team procurement selection process, the procurement method was considered low bid. This selection method is characterized by a high level of design completion at time of procurement to facilitate the competitive selection process. Usually, if the 50% design is completed, the Design-Build system will lose most innovation benefit and the evaluation committee will transfer their consideration to mostly price. Low bid type selection methods will award the contract to the lowest price bidder or lowest adjusted price amount.

Base on research of Wardani et al. (2006), some conclusions are shown in Table 2.1.

Table 2.1 Multi-Procurement Selection Methods Performance Comparison

Criteria	Sole Source	Qualify-Based	Best Value	Low Bid
Cost Growth		Best		Worst
Intensity	Worst			
Const. Speed	Worst	Best		
Sch. Growth	Worst		Best	
Quality	Similar	Similar	Similar	Similar

From this summarized table, it seems that the low bid method has the highest cost growth, and, the qualifications-based selection method should be considered whenever completion on budget is critical since it resulted in the lowest cost growth.

Based on the different procurement models and procurement methods, there are many types of Design-Build procurement. But the trends show that project complexity has a bearing on design-build selection methods. Less complex projects typically have a lower opportunity for innovation and their selection methods can more closely resemble the fixed-price, sealed-bid selection. Also, use of a sealed-bid, fixed-price method on simple projects with a high level of design completion can yield a faster, less burdensome selection process than the two-step model. The two-step procurement model has more advantages in Design-Build and more and more public owners choose best value based selection methods for their new projects. Thus, it is reliable fact that there are more best valued based two-step procurement models in the market and performance of Design-Build projects will be affected by this procurement model.

2.3 Performance under Design-Build

It is typical of construction that a project may be regarded as successful if the building is completed as scheduled and within budget and quality standards, and achieves a high level of client satisfaction. Increasingly, the fulfillment of these criteria has been associated with the selection of the procurement method for the construction. In short, the selection of the appropriate method can shape the success of the project.

In some cases, project success is measured by using one survey question asked of one project participant (Griffith et al. 1999). However, project success is a very complex concept that actually changes over time and may be drastically different for different project team members. Despite the complexities involved, project management researchers and practitioners need a method of measuring project success based on factual project data that enables the results from different projects to be compared.

Based on literature review, Design-Build project success is usually divided into two conceptual areas: success factors and success criteria.

Success factors are those factors, procedures, preconditions, and determinants that effect project outcomes.

Success criteria are the standards on which a judgment or decision regarding project success are based (Gibson and Hamilton 1994).

2.3.1 Success Factors of Design-Build Projects

There are many researchers and articles identifying Design-Build project success factors by using various methods, such as structured research or survey investigation. Pinto and Slevin (1992) identified 10 critical success factors that were uncovered as the result of a series of in-depth studies and interviews with practicing project managers. These ten factors are:

(1) Project mission,

(2) Top management support,

(3) Project schedule/plan,

(4) Client consultation,

(5) Personnel,

(6) Technical tasks,

(7) Client acceptance,

(8) Monitoring and feedback,

(9) Communication,

(10) Trouble-shooting.

Ashley et al. (1987) identified the following six factors as significant in determining construction project success:

(1) Planning effort,

(2) Project team motivation,

(3) Project manager goal commitment,

(4) Scope and work definition,

(5) Control systems,

(6) Project manager technical capabilities.

The reviewed articles attempt to narrow the list of possible factors to a critical few that can then be used by project team members in managing their projects and improving the chances of having a successful outcome.

2.3.2 Success Criteria of Design-Build Projects

Fewer articles identified in the literature review address the concept of success criteria. Freeman and Beale (1992) developed a method of measuring project success based on financial factors. Engineering economic principles such as net present value, return on investment, and return on sales are used to calculate a discounted cash flow comparison of different projects. These comparisons are used to determine the level of success for each project. Ashley et al. (1987) measured success for construction projects using six criteria:

(1) Budget performance,

(2) Schedule performance,

(3) Client satisfaction,

(4) Functionality,

(5) Contractor satisfaction,

(6) Project management team satisfaction.

Tan (1996) identified three criteria of success for technology transfer projects:

(1) Overall performance,

(2) Recipient satisfaction,

(3) Satisfaction with the transfer process.

Another study based on the review of 14 published papers covering the topic of measuring project success identified seven common criteria of success:

(1) Technical performance,

(2) Efficiency of project execution,

(3) Managerial and organizational expectations,

(4) Personal growth,

(5) Project termination,

(6) Technical innovativeness,

(7) Manufacturability and business performance (Freeman and Beale 1992).

Even though there has been a lot of research into success criteria, some common successful criteria can be concluded from reviewed articles: budget, time, cost, quality, satisfaction, expectation, functionality, schedule and administration. Table 2.2 indicates the definition of each common criteria.

Table 2.2 Common Criteria in Previous Research

Metrics	Definitions
Budget	The project is completed at or under the contracted cost
Cost	The completed project's unit cost, cost growth and intensity
Time	The project's construction speed, delivery speed and schedule growth
Quality	The completed project meets or exceeds the accepted standards of workmanship in all areas
Satisfaction	The completed project meets or exceeds the user's envisioned goals in all areas
Functionality	The completed project meets or exceeds all technical performance specifications provided by the owners
Schedule	The project is completed on or before the contracted finish time
Safety	The project meets or exceeds the standards of safety or warranties in all areas
Administration burden	The construction process does not unduly burden the owner's project management staff
Expectation	Relative comparison of owner expectations from project concept as compared to the completed project.

(WDBC Project 2007)

Beside common successful criteria, some researchers focus on the Design-Build delivery method in different areas. Naoum (1994) has researched Design-Build project performance through cost and time study and he has concluded ten measurements which are preconstruction time, construction time, total time, speed of construction, unit cost of building, time overrun, cost overrun, client satisfaction, time, cost, and quality. Songer and Molenaar (1997) have researched public-sector Design-Build projects and found the most important criteria that impact the performance are: on budget, conforming to user's expectations, on schedule, meeting specifications, high quality of workmanship and minimizing construction aggravation. Bogus et al. (2004) focused on public water/wastewater projects and they concluded not only typical performance criteria, but maintainability, startup and warranties can also be the important metrics that lead to project success.

There are also other scholars who determine that cost (unit cost, cost growth, intensity), time (construction speed, delivery speed, schedule growth), quality (turnover quality, system quality, equipment quality), owner's satisfaction and owner's administrative burden are the key criteria of successful projects (Ling et al. 2004). Dwayne and Whirt (2007) studied military Design-Build construction projects, and considered three typical metrics: cost, time and quality.

Performance criteria can be broken down into three types: relative, static and dynamic. Relative metrics include cost growth, schedule growth and award growth; static metrics contain design unit cost, construction unit cost and design build unit cost; dynamic metrics comprise design placement, construction placement, design build placement and construction intensity. Wardani et al.

(2006) studied 76 design-build projects which cover a very wide range of different kinds of projects nationwide. The research team determined unit cost, cost growth, intensity, construction speed, delivery speed and schedule are the most important factors in cost and time performances. But in quality performance, they divided it into seven areas, which are: starting up; calling back; operations and maintenance cost; envelopment, roof, structure, foundations; interior space and layout; environment and process equipment and layout. Chan et al. (2002) tried to help contractors and owners to make some standard metrics in Design-Build projects. In their research, they not only conclude the success criteria for Design-Build projects, but also criteria for measuring performance of Design-Build projects. They determined that time, cost and quality are the typical criteria, and there are other criteria which should be considered such as: safety; meeting specification/employer’s requirement; conformance to expectation of project team members; satisfaction of project team members; functionality; aesthetics; reduction in dispute; health; profitability; technical performance; functionality; productivity; satisfaction and environment sustainability. Table 2.3 summarizes the performance areas in previous research.

Table 2.3 Previous Successful Criteria Research Summary

Metrics **Resource**	**Budget**	**Cost**	**Time**	**Quality**	**Satisfaction**	**Functionality**	**Schedule**	**Safety**	**Administration burden**	**Expectation**
Anthony D.Songer and Keith R. Molenaar (1997)	√			√	√	√	√		√	√
Keith R.Molenaar, Susan M. Bogus and Jenny M. Priestley(2004)	√			√	√		√	√	√	√
Keith R. Molenaar, Anthony D. Songer and Mouji Barash(1999)	√				√		√		√	√
Florence Yean Yng Ling, Swee Lean Chan,etc.(2004)		√	√	√	√				√	
Mark Konchar and Victor Sanvido (1998)		√	√	√						
Darren Dwayne McWhirt (2007)		√	√	√	√		√	√	√	
Douglas D. Gransberg, Gayla M. Badillo-Kwiatkowski and Keith R. Molenaar (2003)		√	√	√		√				
Marwa A El Wardani ,John I. Messner and Michael J. Horman (2006)		√	√	√						
Albert P. C. Chan, David Scott and Edmond W.M. Lam (2002)		√	√	√	√	√	√	√		
Issaka Ndekugri and Adrian Turner (1994)		√	√	√					√	
Mark Konchar, and Victor Sanvido (1998)		√	√	√	√					√
Shamil G. Naoum (1994)		√	√	√	√		√		√	

(WDBC project 2007)

Besides the most typical common criteria that widely appeared in previous research, there are also a lot of additional criteria which are mentioned by researchers. Molenaar et al. (2004) mentioned that maintainability, start up and warranties should be added into the common criteria for successful projects. Wardani et al. (2006) performed a nationwide study of Design-Build projects of different types of construction and used different classifications to measure the quality performance. In their paper, start up; call back; operations and maintenance cost; envelop, roof, structure, foundations; interior space and layout; environment; process equipment and layout are the new criteria that lead to the better quality performance. The researchers, Chan et al. (2002), analyzed 95 Design-Build projects and made specific classifications of successful criteria. They think health, completion, absence of conflicts, profitability and environmental sustainability should be noted besides the common performance criteria. Dwayne and Whirt (2007) use different ways to measure the factors which lead to success besides common criteria.

2.3.3 Performance of Design-Build Projects

The following literature reviews will focus on researching three basic elements in Design-Build project performance.

Cost Performance: In Konchar and Sanvido’s research (1998), Design-Build projects have the lowest unit cost and cost growth, 5.2% less than

Design-Bid-Build, in public projects, and the intensity is better when using Design-Build. More than 50% of Design-Bid-Build projects have more than 14% additional cost in the project.

Ling and Chan (2004) led their group to compare the different delivery methods. They have found that for design-bid-build projects, the data show that privately owned building is likely to be more expensive. For Design-Build projects, 42% of variability in unit cost can be explained by the extent of design completion when bids are invited. If the owner provides more design, the unit cost is likely to be higher. Cost growth for Design-Build and Design-Bid-Build projects will be higher if contractors with lower paid-up capital are engaged. In the unit cost, Design-Build gets 6% less than Design-Bid-Build.

Gransberg et al. (2003) compared Design-Build with Design-Bid-Build methods. In comparing Design-Build with Design-Bid-Build for cost and time growth, Design-Build projects performed better in the relative metrics comparison. And, considering design costs and construction costs separately, the dynamic metrics have revealed that Design-Build has less cost than Design-Bid-Build in the design placement and construction placement. The study shows that Design-Build can get 4.5% to 16.4% less than Design-Bid-Build in cost growth and 21.5% less in unit cost. Though some items show that Design-Bid-Build unit costs are less than Design-Build, when averaged overall, Design-Build still outperforms Design-Bid-Build.

All the data and conclusion show that Design-Build is the better delivery method than any other methods in the cost performance.

Time performance: The most common goal of Design-Build delivery is reducing the delivery time. Mark Konchar's research shows that more than 50% of Design-Bid-Build projects delay the time of completion more than 4% than Design-Build projects (1998).The research results indicate that there is little difference between Design-Build and Design-Bid-Build in schedule growth. But, in the areas of construction speed and delivery speed, Design-Build performs best in these items and Design-Bid-Build performs worst.

Some scholars show that Design-Build can minimize the schedule growth in both large and small projects. The analysis proves the Design-Build delivery method can get 12% faster in construction speed and 33% faster delivery speed. And schedule growth can be 11.4% less when adopting Design-Build at the same time.

Ling (2004) pointed out that Design-Build can efficiently decrease the project delivery time and get the best time performance compared with other delivery methods. Design-Build gets the lowest error in construction speed and delivery speed, and gets the best performance in total areas of schedule and time.

Gransberg et al. have analyzed public projects and find Design-Build can get 19% less than Design-Bid-Build in time growth, not the same as the previous research that Design-Build only gets 4.5% less than the Design-Bid-Build. In their conclusion, projects delivered using Design-Build have been performed better in most metric categories than the Design-Bid-Build projects. The study indicates a more efficient execution of the project plan through the use of Design-Build project delivery.

Overall, it seems that Design-Build has high potential to actually accrue time savings over projects delivered using the traditional method. At a programmatic level, it would seem that Design-Build should be the choice for all projects.

Quality Performance: In comparing Design-Build with Design-Bid-Build, some experts (Ling et al. 2004) find Design-Build outperforms Design-Bid-Build in the interior space and layout quality category. None of them experience superior environmental system performance. Design-Build achieves equally if not better quality results than other projects studied. In particular, Design-Build offers the better quality results than Design-Bid-Build in all categories except interior space and layout. Their data shows design-build is similar to Design-Bid-Build in small projects, but better in the complex and large projects in turnover quality. In the system quality and equipment quality, Design-Build performs much better than Design-Bid-Build.

In Chan's research (2004), a contractor's ability to complete past projects to acceptable quality significantly affects a Design-Bid-Build project's equipment quality, and Design-Build project's turnover quality. The conclusion indicates that Design-Build performs well in turn quality, but worse than Design-Bid-Build in the system quality.

There is no absolute conclusion about the relationship between Design-Build and quality performance. Some scholars think Design-Build can get better performance in quality. Some researchers think there is little difference between Design-Build and Design-Bid-Build in the quality performance. Even some people think Design-Build can lead to worse results in some areas of quality performance.

Other performance: 68% of Design-Build project owners' satisfaction can be explained by the contractors' technical expertise and ability in health and safety management. For owners to have low administrative burden, the results show that they should engage contractors who have good quality performance in past projects (Design-Build projects) and high staffing level (Design-Bid-Build projects). Studies prove Design-Build in the private sector performs significantly better than Design-Bid-Build in 6 of 9 owners' satisfaction performance categories. Again in no instance does Design-Bid-Build delivery outperform either Design-Build in public or private sectors.

Design-Build projects to be at least 5.2% less in the area of cost growth than Design-Bid-Build projects and effects of delivery system indicate Design-Build projects to be 11.37% less than Design-Bid-Build projects in schedule growth. Otherwise, Design-Build project can perform 21.7% better than Design-Bid-Build project in construction placement. Thus, based on the above data, Design-Build on average outperforms Design-Bid-Build by the same amount and situation. Table 2.4 provides a summary comparison of Design-Build vs. Design-Bid-Build based on previous research studies.

Table 2.4 Delivery Methods Comparison Conclusion

Performance Previous Research	Cost	Time	Quality	Others
Mark K onchar, Victor Sanvido (1998)	DB better than DBB	DB better than DBB	DB better than DBB	
Florence Yean Yng Ling, Swee Lean Chan,etc.(2004)	DB better than DBB	DB better than DBB	Some items DB better	DB better than DBB
Keirth R. Molenaar Anthony D. Soner Mouji Barash(1999)	DB better than DBB	DB better than DBB	DB better than DBB	
Douglas D. Gransberg Gayla M. Badillo-Kwiatkowski Keith R. Molenaar (2003)	DB better than DBB	DB better than DBB		DB better than DBB
Marwa A El Wardani John I. Messner Michael J. Horman(2006)	DB better than DBB	DB better than DBB	DB better than DBB	

DB= Design-Build
DBB= Design-Bid-Build
Blank means not mentioned
(WDBC project 2007)

In conclusion, most researchers think Design-Build is a very competitive and strong delivery method when compared with other traditional delivery methods, and their studies prove Design-Build can get better results in most performance criteria. As a fact, the Design-Build delivery system is increasingly used by both public and private owners due to the potential time and cost savings it can offer. The selection of the most appropriate procurement method can often be crucial to the successful performance of a Design-Build project. In particular, the procurement duration may significantly impact project performance. The following chapters present a study that evaluates project performance and procurement duration specifically for Design-Build projects.

CHAPTER 3. RESEARCH DEFINITION AND METHODOLOGY

3.1 Objectives of Study

The aim of the writer's study is to research the relationship between Design-Build project success and procurement duration. The research will be narrowed to only include public highway and bridge projects. The research consists of data from a number of Design-Build projects in the United States with regard to type, cost and schedule of the project.

For the purpose of this research four research questions are presented:

(1) Is there a significant relationship between Design-Build project success and procurement duration?

(2) What is the relationship if there is one?

(3) Does the relationship vary with procurement selection methods?

(4) Does the relationship vary with project complexity?

3.2 Research Hypotheses

The research hypotheses, summarized as follows, are proposed to test by a correlation analysis:

- The longer procurement duration, the lower the awarded bidder's cost growth performance in construction.
- The longer procurement duration, the lower the awarded bidder's schedule growth performance in construction.

- Different selection methods will affect the relationship between procurement duration and project success.
- Project complexity will affect the relationship between procurement duration and project success.

3.3 Data Definition

Several types of data are required to perform the correlation analysis:

RFP Issue Date is defined as the date that RFP released to public or bidders.

RFP Due Date is defined as the official deadline that both technical proposals and price proposals must be submitted to agency

Contract Price is defined as the overall price that is listed in the final contract. And calculation dimension is million dollars ($M).

Actual Price is defined as the final overall payment for completed projects. The calculation dimension is million dollars ($M).

Contracted Construction Time is defined as the construction duration that is listed in the final contract. The dimension of this data is calendar days (CD).

Actual Construction Time is calculated as the number of calendar days (CD) from start to completion of the project.

Contracted Total Project Time is measured as the number of procurement calendar days and contracted or actual construction duration.

Schedule Growth is measured by the increase or decrease in the project delivery time (%).

Cost Growth is measured by the increase or decrease in the project overall price (%)

Procurement Duration is measured by the duration between RFP issue date and RFP due date in (CD).

3.4 Data Collection

The data will be collected through three ways: survey, published project information, and previous research. Thus, the data resources are variable. In this research, the data resources include published project RFPs and public project reports, research documents from previous studies, project records from contractors, and state DOT reports or databases. In this paper, most data come from state DOT reports and state DOT databases. The main data collection method is investigation survey via email. Survey table will be made and sent to project managers in each state DOT to ask them to fill out required items. A survey sample is listed in (Table 3.1).

Table 3.1 Investigation Survey Sample (North Carolina)

Project Name	RFP Issue Date	RFP Due Date	Contract Price (million)	Actual Price (million)	Contract Schedule	Actual Schedule
SR500	9/7/2000	12/13/2000	32.5	22.73	12/18/00-10/1/02	10/7/2002
IM229	1/7/2000	3/16/2000	40.0	32.40	4/18/2000-7/1/2004	7/15/2004
…	…	…	…	…	…	…

Information was collected on 146 qualified Design-Build projects. Each project includes all required information. The valid data are collected from 15 states but most data come from east coast states. All projects here use a two-step procurement model but different selection methods. All the data come from different four resources: Benchmarking study, D-B effectiveness study (Molenaar et al. 2006), state DOT documents and state DOT websites. Because of different state statues, the popularity of Design-Build in each state and other reasons, most projects are from Florida in this research. But there are still some qualified projects from other states being used in this research. The details of each project are listed as an appendix. Table 3.2 summarizes the projects information for this research.

Table 3.2 Design-Build Projects and Data Type Summary

State	# of all projects	# of best value	# of low bid	# of adjusted bid
Arizona	1	0	0	1
North Carolina	2	1	0	1
Alaska	1	0	0	1
Florida	124	70	32	22
South Dakota	1	0	0	1
Alabama	1	1	0	0
Maine	3	3	0	0
Massachusetts	1	1	0	0
New Mexico	1	1	0	0
Utah	1	1	0	0
Washington	3	3	0	0
Pennsylvania	1	0	1	0
Colorado	1	0	1	0
Virginia	1	0	1	0
Maryland	4	0	4	0
Total	**146**	**81**	**39**	**26**

3.5 Correlation Analysis

Correlation analysis will be used to test the research hypotheses. The correlation analysis will compare procurement duration with cost growth and schedule growth. The analysis will also consider selection method and project complexity.

As previously illustrated, cost growth is measured by the increase or decrease in the overall project price. The value is defined by the following equation.

$$\text{Cost Growth} = \frac{\text{Actual Price} - \text{Contracted Price}}{\text{Contraced Price}} \times 100\%$$

Schedule growth is measured by increase or decrease in the contracted project delivery time. The value is defined by the following equation.

$$\text{Schedule Growth} = \frac{\text{Actual Delivery Time} - \text{Contracted Delivery Time}}{\text{Contracted Delviery Time}} \times 100\%$$

Total project time growth is measured by increase or decrease in the sum of procurement duration and contracted construction duration. The value is defined by the following equation.

$$\begin{aligned}&\text{Total Project Time Growth}\\ &\qquad = \frac{\text{Actual Delivery Time} - \text{Contracted Delivery Time}}{\text{Contracted Total Project Time}} \times 100\%\end{aligned}$$

Contracted total project time is measured as the number of procurement calendar days and contracted delivery time.

$$\begin{aligned}&\text{Contracted Total Project Time}\\ &\qquad = \text{Procurment Duration} + \text{Contracted Delivery Time}\end{aligned}$$

The purpose of computing total project time growth is testing whether the longer procurement duration the shorter the whole project time (including construction time). In one sense, the best success situation for a project would be if both procurement duration and construction duration are all shortened.

Firstly, a linear correlation analysis will be conducted. If no linear relationship is found, then a normal distribution analysis will be conducted. If these two analyses do not show any relationship, the residual plot observation will be used.

CHAPTER 4. DESCRIPTIVE STATISTICS OF DATA SET

4.1 Data Group Summary

The preliminary research is based on two criteria: different selection methods and project complexity. The comparison research will be classified and conducted under these two principle research metrics. All construction performance which relates to project success will be analyzed through different viewpoints and preliminary comparison results and hypothesis will be given in the end of this chapter.

4.1.1 Different Selection Methods Comparison Research

According to different selection methods, all data are calculated and classified by one of the following methods: adjusted bid type, best value type, and low bid type. Firstly, all projects are compared together. Based on the overall performance observation (Table 4.1), the range of procurement duration is significant, the maximum duration is 4.62 months and the minimum duration is only 0.36 month. In all 146 projects, the average procurement time is nearly 3 months. But, when separated by selection method, (Table 4.2, 4.3, and 4.4), low bid based projects have the longest maximum procurement duration and best value based projects have the second longest maximum procurement duration. Whereas, adjusted bid type projects have the shortest procurement duration in all projects. Comparing with averages of all different types of projects, adjusted bid type projects have the shortest procurement duration (2.65 months), low bid type projects have the longest procurement duration (3.06 months). Best value type projects have the lowest deviation value in procurement duration.

Table 4.1 Overall Project Performance Summary

Overall Projects	Range of Durations (Months)	Range of Project Size ($ Million)	Cost Growth (%)	Schedule Growth (%)	Total Project Time Growth(%)
Max	4.62	1840.00	84.29%	118.33%	98.61%
Min	0.36	0.15	-56.33%	-57.82%	-55.31%
Average	2.92	53.72	0.43%	12.65%	10.96%
Media	3.02	6.98	0.58%	9.20%	7.91%
Standard Deviation	0.90	204.56	15.75%	28.58%	23.93%

The range of project amounts is very large. The biggest cost in all sample projects is $ 1.84 billion and the smallest amount is only $0.15 million. From the individual statistics, it seems that low bid type and best value type selection methods are widely used in most different projects. Low bid type is more widely applied in all different priced projects than best value type. But best value type has more reliable standard deviation and less error.

Comparing three performance indexes, the biggest changes happened in schedule growth. The overall performance shows that pure schedule growth can range from -57.82% to 118.33%. But, an interesting phenomenon is that the variability of total project time growth is not as large as schedule growth. The individual statistical summary shows that low bid type projects have the best schedule growth performance in average and adjusted bid type projects have the worst schedule growth performance. Adjusted bid type projects have the lowest satisfied standard deviation value. In total project time growth, the situation is similar as schedule growth performance. The statistical bar charts 4.1 and 4.2 show the overall schedule performance and overall total project time performance.

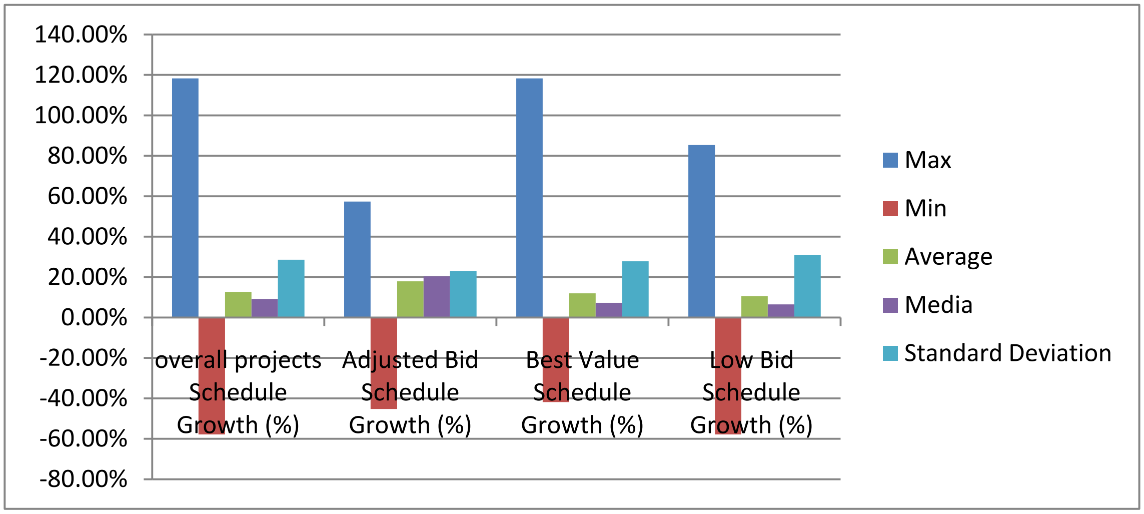


Fig. 4.1 Schedule Growth Performance

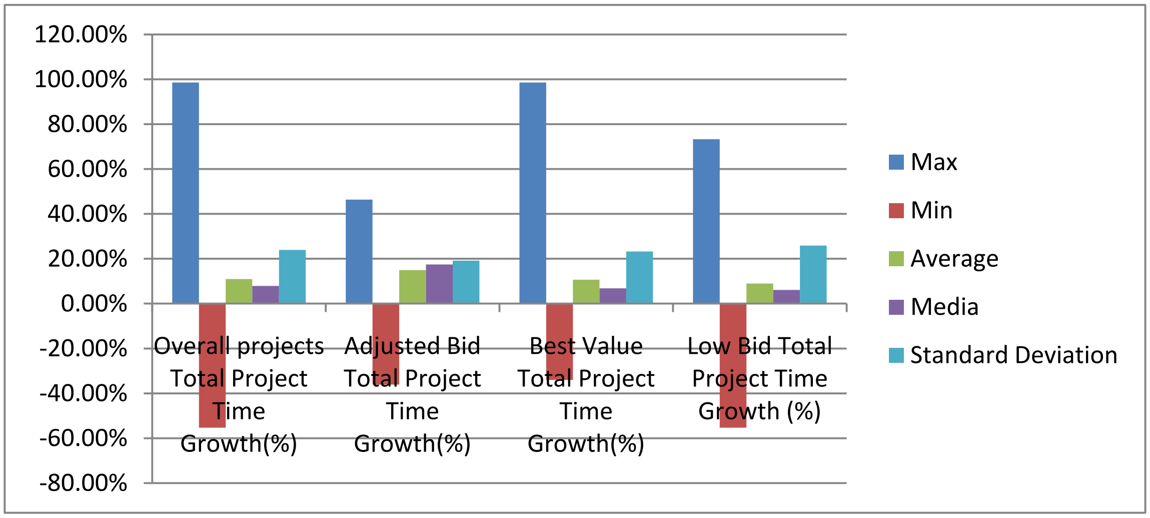


Fig.4.2 Total Project Time Performance

Table 4.2 Adjusted Bid Project Performance Summary

Adjusted Bid Projects	Range of Durations (Months)	Range of Project Size ($ Million)	Cost Growth (%)	Schedule Growth (%)	Total Project Time Growth(%)
Max	4.37	239.00	84.29%	57.33%	46.36%
Min	0.36	0.70	-27.84%	-45.25%	-36.13%
Average	2.65	28.22	2.40%	17.88%	14.94%
Media	2.70	8.00	0.48%	20.34%	17.47%
Standard Deviation	0.94	53.02	21.22%	22.99%	19.19%

Table 4.3 Best Value Project Performance Summary

Best Value Projects	Range of Durations (Months)	Range of Project Size ($ Million)	Cost Growth (%)	Schedule Growth (%)	Total Project Time Growth(%)
Max	4.52	1430.00	33.62%	118.33%	98.61%
Min	0.61	0.30	-56.33%	-41.82%	-34.01%
Average	2.94	56.72	-1.48%	12.00%	10.64%
Media	3.10	7.43	0.00%	7.29%	6.79%
Standard Deviation	0.86	183.11	15.79%	27.79%	23.25%

Table 4.4 Low Bid Project Performance Summary

Low Bid Projects	Range of Durations (Months)	Range of Project Size ($ Million)	Cost Growth (%)	Schedule Growth (%)	Total Project Time Growth(%)
Max	4.62	1840.00	66.23%	85.36%	73.31%
Min	0.84	0.15	-44.11%	-57.82%	-55.31%
Average	3.06	64.50	3.06%	10.50%	8.97%
Media	3.30	6.10	1.69%	6.53%	6.08%
Standard Deviation	0.95	294.36	15.52%	30.95%	25.89%

For the cost growth performance, the performance chart (Figure 4.3) shows the difference of overall performance between maximum value (84.29%) and minimum value (-56.3%) is large. Best value type has the lowest average cost growth value (-1.48%) among all three values. Also, best value type projects have a low standard deviation value. Low bid type projects have the highest cost growth on average. Adjusted bid type projects have the biggest difference between maximum cost growth value and minimum cost growth value. Also, adjust bid type projects have the highest standard deviation value.

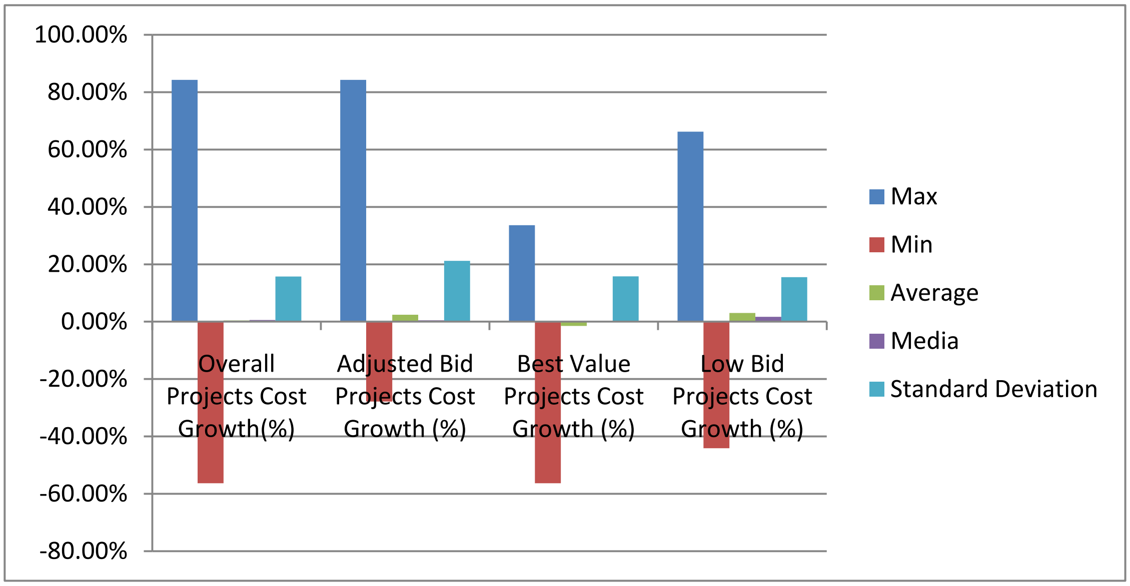


Fig.4.3 Cost Growth Performance

4.1.2 Different Complexity Levels Comparison Research

Project complexity has recently become an important element of Design-Build projects. Project complexity includes two main areas: structural complexity and technological uncertainty (Figure 4.4). These items were not measured in this study, but usually, in Design-Build projects, the higher the contract price, the higher the complexity. Different sizes of projects, project locations, more construction activities, and multi-construction parties all contribute to complexity and price.

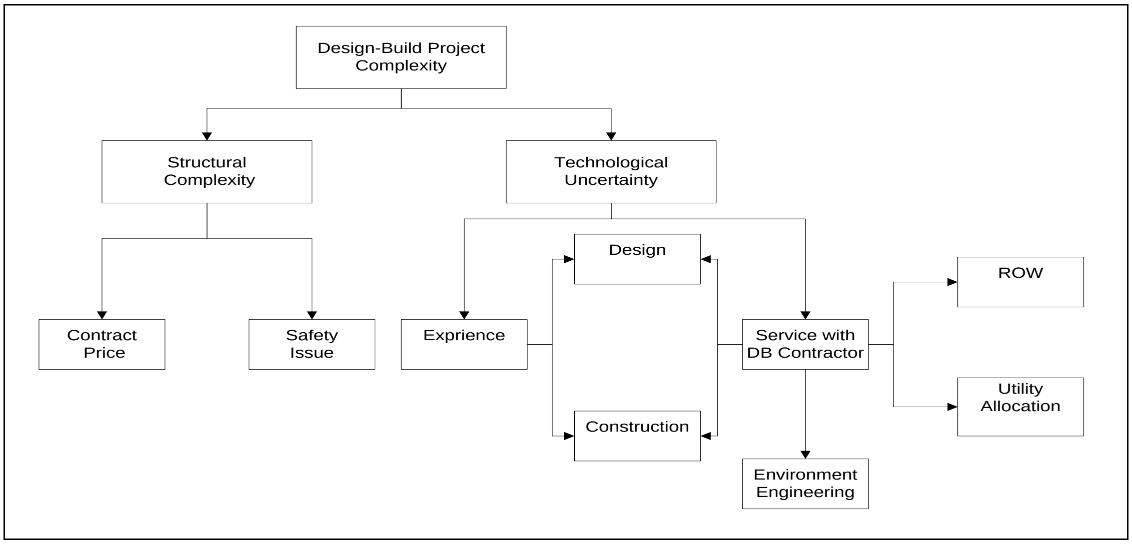


Fig.4.4 Design-Build Project Complexity Structure

Currently, there is no uniform and systemic guide book to classify and identify the construction complexity level. Different scholars use their own viewpoints in their research. There is no common metric or method to identify the complexity degree of any project. And there is no research to show the relationship between construction cost and project complexity. Based on the current lack of former research and the collected limited data, the construction complexity classification depends on the skilled and seasoned contractors. According to the opinion and feedback from several contractors, the low complexity project is defined that contract price is below $10.00 million. The medium complexity project is measured that contract price is between $10.01 million to $50.00 million. The high complexity project is measured that the contract price is over $50.01million. Table 4.5 shows the summary of basic projects information based on complexity classification.

Table 4.5 Projects Complexity Summary

Project Type /Complexity	**Adjusted Bid**	**Best Value**	**Low Bid**	**Total**
High (>$50.01 million)	4 (2.7%)	15(10.3%)	4(2.7%)	23(15.8%)
Medium ($10.01~$50.00 million)	8(5.5%)	19(13.0%)	11(7.5%)	38(26.0%)
Low (< $ 10.00 million)	14(9.6%)	47(32.2)	24(16.4%)	85(58.2%)
Total	26(17.8%)	81(55.5)	39(26.7%)	146

Table 4.6, 4.7 and 4.8 exhibit that different complexity level will have different performance results. Medium complexity level projects have the minimum procurement duration average. High complexity level projects and low complexity level projects have very close procurement duration values in average. The average value in high complexity projects is 2.95 months and the average value in low complexity projects is 2.93 months. It seems that procurement duration in Design-Build is not variable by different project size and complexity (contract price). The preliminary research also shows that high complexity level projects and medium complexity level projects have better cost growth performance than low complexity level projects in Design-Build system. In schedule growth and total project time growth, high complexity projects have the best results in both average value and standard deviation value.

Table 4.6 High Complexity Projects Performance

High Complexity Projects	Range of Durations (Months)	Range of Project Size ($ Million)	Cost Growth (%)	Schedule Growth (%)	Total Project Time Growth(%)
Max	4.39	1840.00	30.95%	40.18%	36.20%
Min	0.90	57.17	-56.33%	-30.59%	-29.73%
Average	2.95	291.21	-4.73%	4.36%	3.77%
Media	2.94	116.00	1.69%	4.00%	3.49%
Standard Deviation	0.86	453.06	17.86%	19.22%	17.60%

Table 4.7 Medium Complexity Projects Performance

Medium Complexity Projects	Range of Durations (Months)	Range of Project Size ($ Million)	Cost Growth (%)	Schedule Growth (%)	Total Project Time Growth(%)
Max	4.62	46.60	33.62%	62.20%	55.39%
Min	0.87	10.16	-44.11%	-57.82%	-55.31%
Average	2.88	21.44	-1.24%	13.20%	10.65%
Media	3.03	18.35	1.56%	5.65%	4.99%
Standard Deviation	0.94	9.45	13.51%	26.90%	22.96%

Table 4.8 Low Complexity Projects Performance

Low Complexity Projects	Range of Durations (Months)	Range of Project Size ($ Million)	Cost Growth (%)	Schedule Growth (%)	Total Project Time Growth(%)
Max	4.52	9.99	84.29%	118.3%	98.61%
Min	0.36	0.15	-37.28%	-45.25%	-36.13%
Average	2.93	3.89	2.56%	14.64%	13.04%
Media	3.03	3.59	0.00%	12.58%	10.89%
Standard Deviation	0.91	2.53	15.84%	31.18%	25.62%

For deeper research, the following study focuses on individual complexity level plus different procurement selection methods. Tables 4.9, 4.10 and 4.11 illustrate different procurement selection methods for high complexity projects. Low bid type has the shortest value in procurement duration section (2.70 months) and best value has lower standard deviation performance (0.79). Adjusted bid type and best value type perform better than low bid type in

Table 4.9 Adjusted Bid Based High Complexity Projects Performance

Adjusted Bid H-Complexity Projects	Range of Durations (Months)	Range of Project Size ($ Million)	Cost Growth (%)	Schedule Growth (%)	Total Project Time Growth(%)
Max	4.17	239.00	9.06%	40.18%	36.20%
Min	2.23	80.00	-27.84%	-8.57%	-7.92%
Average	2.89	134.23	-14.19%	9.85%	8.79%
Media	2.58	108.97	-18.99%	3.90%	3.44%
Standard Deviation	0.89	71.40	16.78%	21.06%	19.04%

Table 4.10 Best Value Based High Complexity Projects Performance

Best Value H-Complexity Projects	Range of Durations (Months)	Range of Project Size ($ Million)	Cost Growth (%)	Schedule Growth (%)	Total Project Time Growth(%)
Max	4.39	1430.00	30.95%	35.59%	32.39%
Min	1.10	57.17	-56.33%	-30.59%	-29.73%
Average	3.03	264.00	-3.34%	3.11%	2.58%
Media	3.10	126.00	2.06%	-1.37%	-1.26%
Standard Deviation	0.79	366.87	20.02%	20.08%	18.36%

Table 4.11 Low Bid Based High Complexity Projects Performance

Low Bid H-Complexity Projects	Range of Durations (Months)	Range of Project Size ($ Million)	Cost Growth (%)	Schedule Growth (%)	Total Project Time Growth(%)
Max	3.74	1840.00	2.88%	18.55%	16.63%
Min	0.90	57.70	-9.24%	-22.93%	-21.74%
Average	2.70	550.25	-0.51%	3.54%	3.18%
Media	3.07	151.65	2.16%	9.28%	8.91%
Standard Deviation	1.26	863.72	5.84%	18.32%	17.16%

cost growth. But low bid has lower standard deviation values. Schedule growth and total project time growth have similar trend, best value has the least schedule growth value and total project time growth value. Low bid type has the second best performance and adjusted bid type performs worst in schedule performance.

In medium complexity research, the situation has changed. Adjusted bid type has the shortest procurement duration (2.57 months) and low bid type has the longest procurement duration (3.41 months).

Table 4.12 Adjusted Bid Based Medium Complexity Projects Performance

Adjusted Bid M-Complexity Projects	Range of Durations (Months)	Range of Project Size ($ Million)	Cost Growth (%)	Schedule Growth (%)	Total Project Time Growth(%)
Max	3.87	40.00	8.88%	57.33%	46.36%
Min	1.27	13.17	-19.00%	-9.95%	-8.44%
Average	2.57	18.72	-3.94%	19.93%	15.49%
Media	2.49	15.24	1.38%	25.77%	18.26%
Standard Deviation	0.96	9.06	11.92%	23.26%	18.80%

Table 4.13 Best Value Based Medium Complexity Projects Performance

Best Value M-Complexity Projects	Range of Durations (Months)	Range of Project Size ($ Million)	Cost Growth (%)	Schedule Growth (%)	Total Project Time Growth(%)
Max	3.64	46.60	33.62%	62.20%	55.39%
Min	0.87	10.98	-30.06%	-10.68%	-9.92%
Average	2.71	23.12	0.67%	16.97%	14.77%
Media	3.10	19.28	1.93%	6.78%	5.96%
Standard Deviation	0.89	10.43	12.22%	25.37%	22.07%

Table 4.14 Low Bid Based Medium Complexity Projects Performance

Low Bid M-Complexity Projects	Range of Durations (Months)	Range of Project Size ($ Million)	Cost Growth (%)	Schedule Growth (%)	Total Project Time Growth(%)
Max	4.62	39.20	20.87%	58.95%	39.44%
Min	1.74	10.16	-44.11%	-57.82%	-55.31%
Average	3.41	20.52	-2.56%	1.80%	0.01%
Media	3.45	18.90	0.53%	0.16%	0.14%
Standard Deviation	0.87	8.09	17.08%	30.57%	25.50%

Adjusted Bid type gets better cost growth performance than the other two types. Best value type performs the worst in cost growth. In schedule growth and total project time growth, low bid has the best performance on average and adjusted bid performs the worst. Under medium complexity, best value projects perform normally in both cost growth and schedule growth.

In low complexity level projects, the statistical results differ from previous results. Tables 4.15, 4.16 and 4.17 show that adjusted bid type has the shortest average procurement duration (2.63 months). Best value type has the longest procurement duration (3.01 months) but lower standard deviation value. Best value performs best in cost growth performance. The average value is -1.75% which is the lowest amount among all three types and best value type has a reliable standard deviation value in cost growth.

Table 4.15 Adjusted Bid Based Low Complexity Projects Performance

Adjusted Bid L-Complexity Projects	Range of Durations (Months)	Range of Project Size ($ Million)	Cost Growth (%)	Schedule Growth (%)	Total Project Time Growth(%)
Max	4.37	9.99	84.29%	51.43%	40.58%
Min	0.36	0.70	-3.42%	-45.25%	-36.13%
Average	2.63	3.37	10.76%	19.00%	16.39%
Media	2.70	2.75	2.69%	20.34%	17.88%
Standard Deviation	1.00	2.41	23.23%	24.47%	20.50%

Table 4.16 Best Value Based Low Complexity Projects Performance

Best Value L-Complexity Projects	Range of Durations (Months)	Range of Project Size ($ Million)	Cost Growth (%)	Schedule Growth (%)	Total Project Time Growth(%)
Max	4.52	9.29	24.70%	118.33%	98.61%
Min	0.61	0.30	-37.28%	-41.82%	-34.01%
Average	3.01	4.15	-1.75%	12.83%	11.54%
Media	3.10	4.16	-0.67%	11.34%	10.80%
Standard Deviation	0.87	2.58	11.83%	32.65%	26.75%

Table 4.17 Low Bid Based Low Complexity Projects Performance

Low Bid L-Complexity Projects	Range of Durations (Months)	Range of Project Size ($ Million)	Cost Growth (%)	Schedule Growth (%)	Total Project Time Growth(%)
Max	4.27	9.40	66.23%	85.36%	73.31%
Min	0.84	0.15	-18.67%	-44.27%	-33.33%
Average	2.96	3.70	6.23%	15.65%	14.04%
Media	3.19	3.28	1.97%	11.29%	9.34%
Standard Deviation	0.93	2.56	15.45%	32.56%	26.75%

Best value shows the best performance in both schedule growth and total project time growth. Best value has the least schedule growth value (12.83%) and total project time growth (11.54%). Adjusted bid type performs the worst in schedule growth under low complexity. The performance of low bid type is between best value and adjusted bid.

4.2 Preliminary Results and Conclusions

In conclusion, each type has its own advantages and disadvantages under different complexity levels. Based on the high complexity statistical charts (Figures 4.5, 4.6 and 4.7), low bid type has the shortest procurement duration and best value type has the longest procurement duration. Adjusted bid type has the best performance in cost growth. Best value performs best in both schedule growth and total project time growth. The longest procurement duration gets the best performance in schedule growth and total project time growth. It shows that procurement duration indeed affects project schedule performance. Best value selection is recommended for high complexity Design-Build projects if the focus is on time and adjusted bid is recommended in case of more cost side consideration.

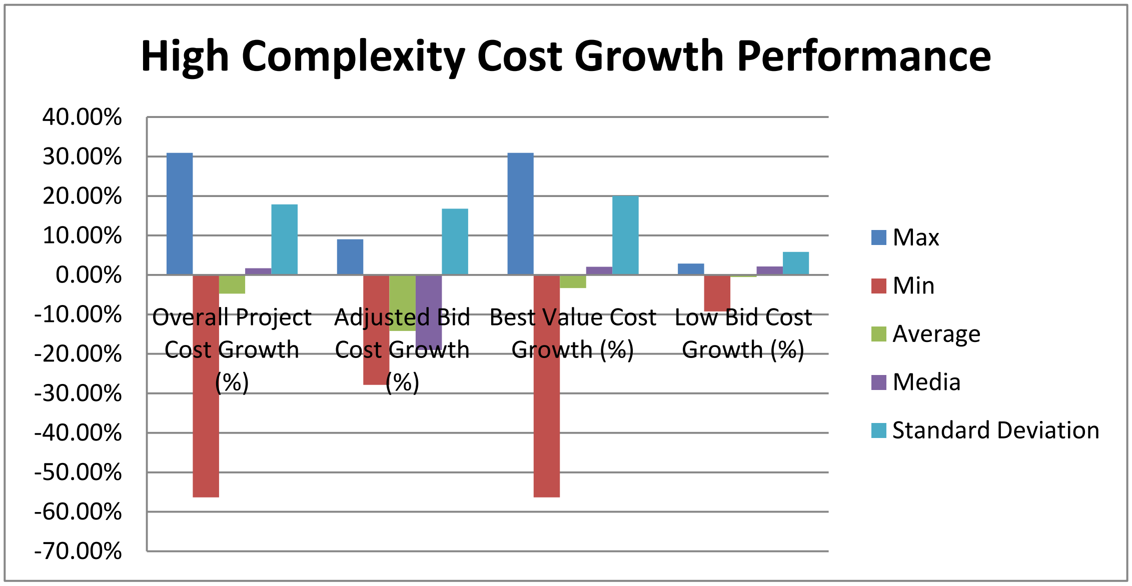


Fig. 4.5 Cost Growth Performance for High Complexity Projects

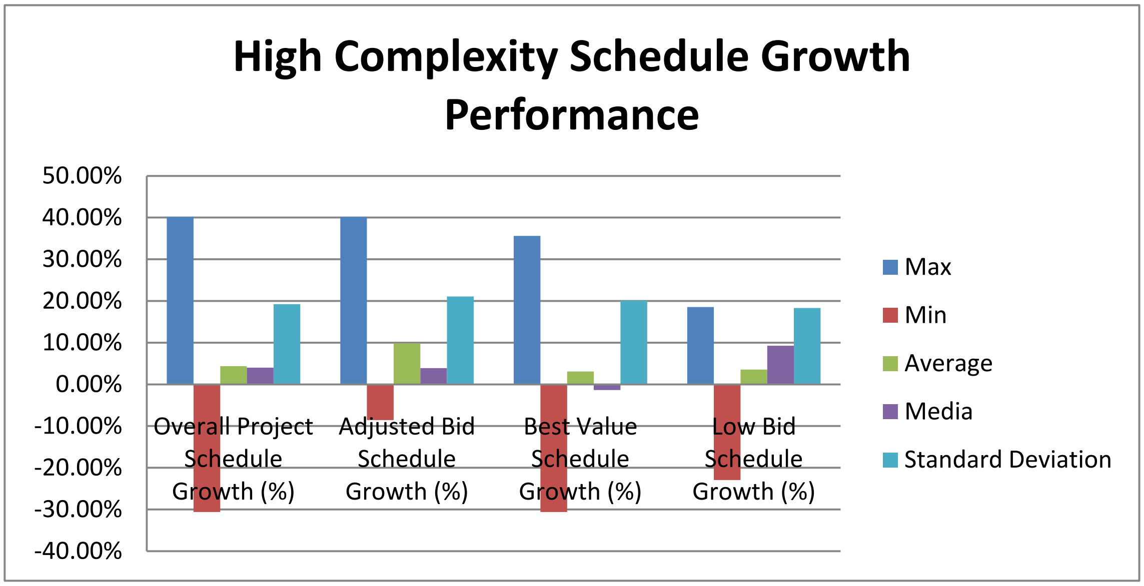


Fig. 4.6 Schedule Growth Performance for High Complexity Projects

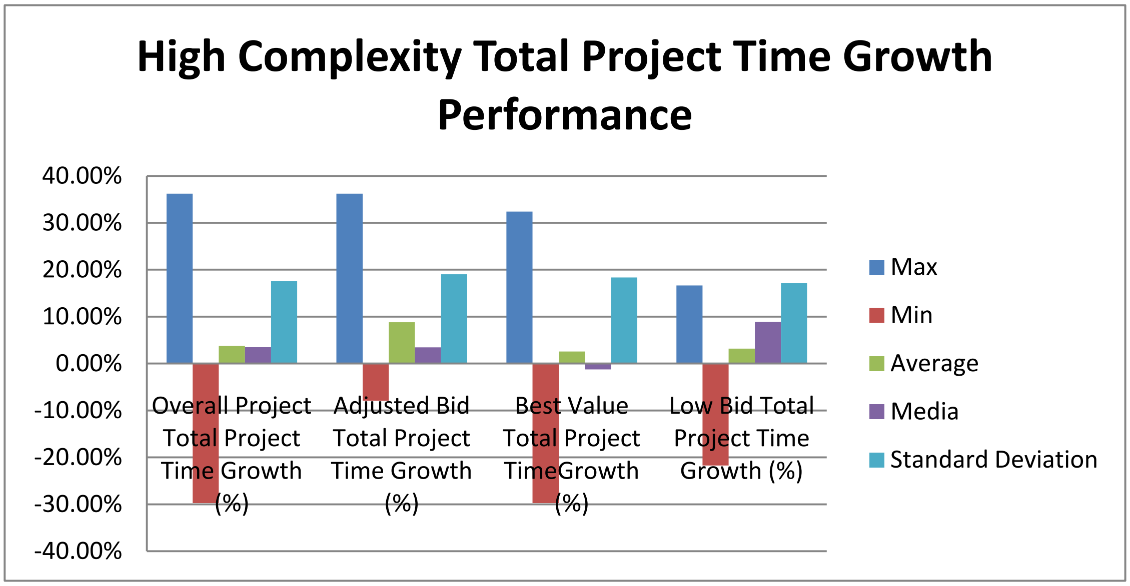


Fig. 4.7 Total Project Time Growth Performance for High Complexity Projects

For medium complexity, statistical results (Figures 4.8, 4.9 and 4.10) show that adjusted bid type has the shortest procurement duration and low bid type has the longest procurement duration. Adjusted bid gets the best performance in cost growth performance but performs worst in schedule growth and total project time

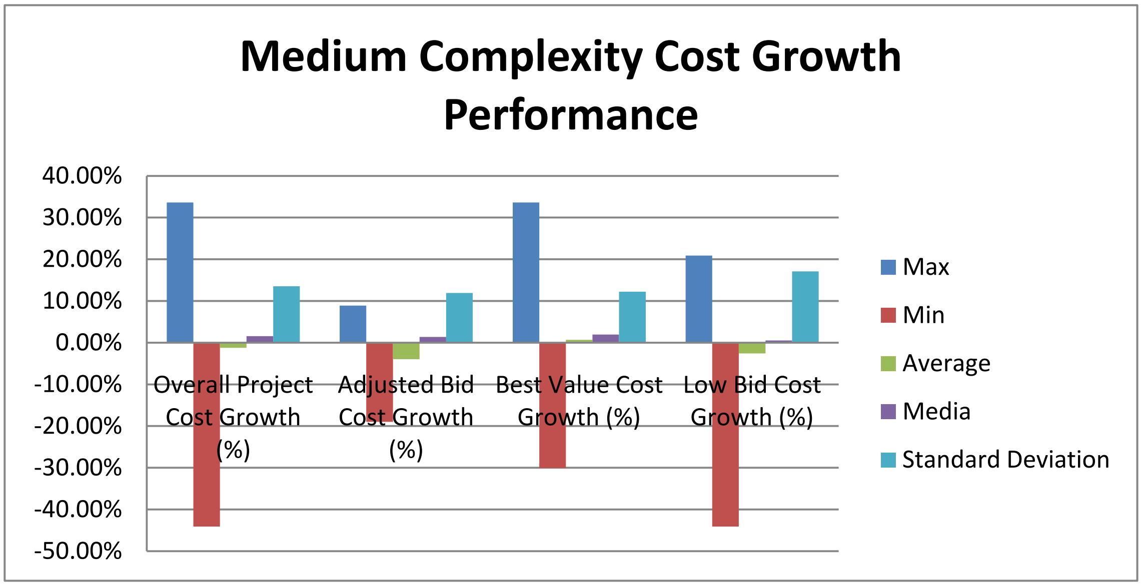


Fig. 4.8 Cost Growth Performance for Medium Complexity Projects

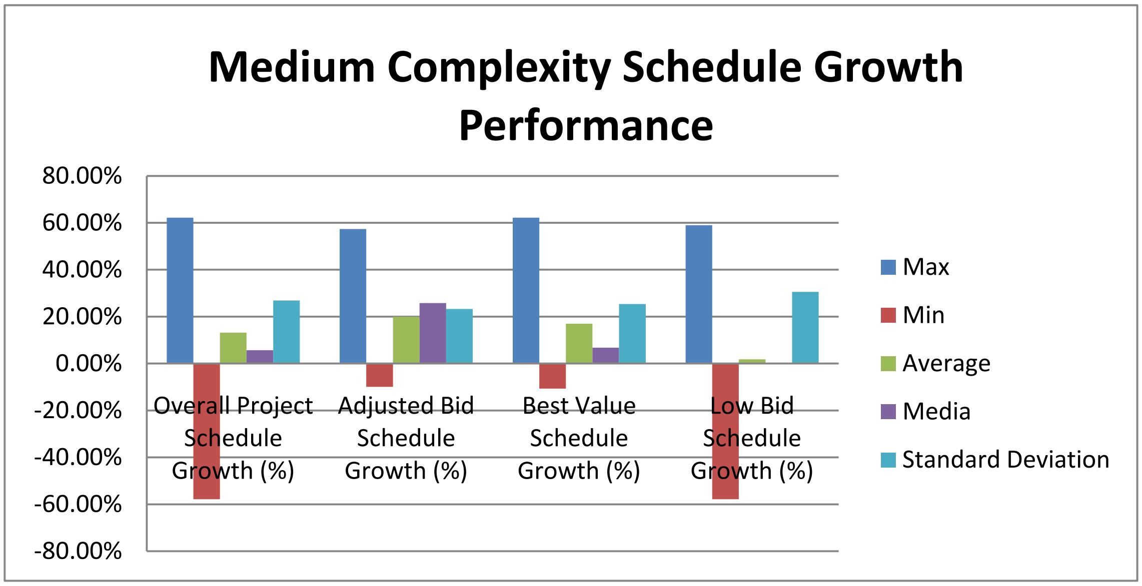


Fig. 4.9 Schedule Growth Performance for Medium Complexity Projects

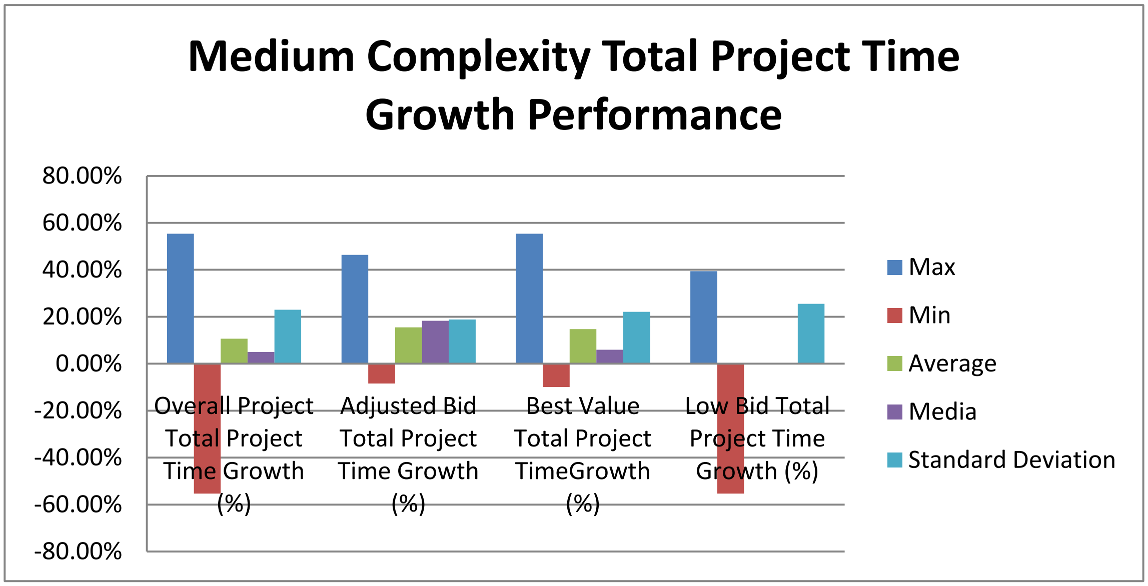


Fig. 4.10 Total Project Time Growth Performance for Medium Complexity Projects

growth. Low bid performs best in schedule growth and total project time growth. The results imply again that the longer procurement duration the better schedule side performance.

Under low complexity, best value type has the longest procurement duration value and adjusted bid type has the shortest procurement duration value. Also, the statistical charts (Figures 4.11, 4.12 and 4.13), show that best value type is the best choice for low complexity level Design-Build projects. Best value performs best in all cost growth, schedule growth, and total project time growth areas.

Thus, the preliminary research proves some hypothesis and assumptions:

(1) There are indeed some relationships between procurement duration and schedule growth performance. The rough trend shows that longer procurement duration, better schedule growth and total project time growth performance. The kind of relationship between them will be studied in the next chapter.

(2) There are no clear values to imply that there are relationships between procurement duration and cost growth. Deeper research will be conducted in the next chapter.

(3) Different selection methods have different effects under different complexity levels. It is suggested to use adjusted bid type in high complexity. It is also suggested to adopt low bid type in medium complexity projects if agencies want to limit delivery time and avoid unnecessary schedule growth.

(4) Best value is the perfect choice in low complexity projects. Best value has the longest procurement duration but the least cost growth value, the least schedule growth value, and the least total project time growth value.

Adjusted bid type is strongly not recommended in low complexity projects. Adjusted bid type has the shortest procurement duration value in low complexity level which means agency and design-builder can start to execute contract quicker than other selection types. But, adjusted bid type performs the worst in all project performance areas. Best value has better project performances than any other types. Best value also has the best schedule performance in high complexity projects. Due to the better overall performance of best value type, here it is strongly suggested to use best value in Design-Build projects, especially low complexity projects.

The preliminary results are prepared for follow-up, deeper research. The following research will include correlation analysis, data comparison and other statistical methods. The linear correlation analysis will be conducted first. If the procurement duration and project success do not have a linear relationship, the normal distribution analysis will be conducted in the second phase, if second phase still doesn't show any relationship, the residual plot observation and analysis will be used in the final phase.

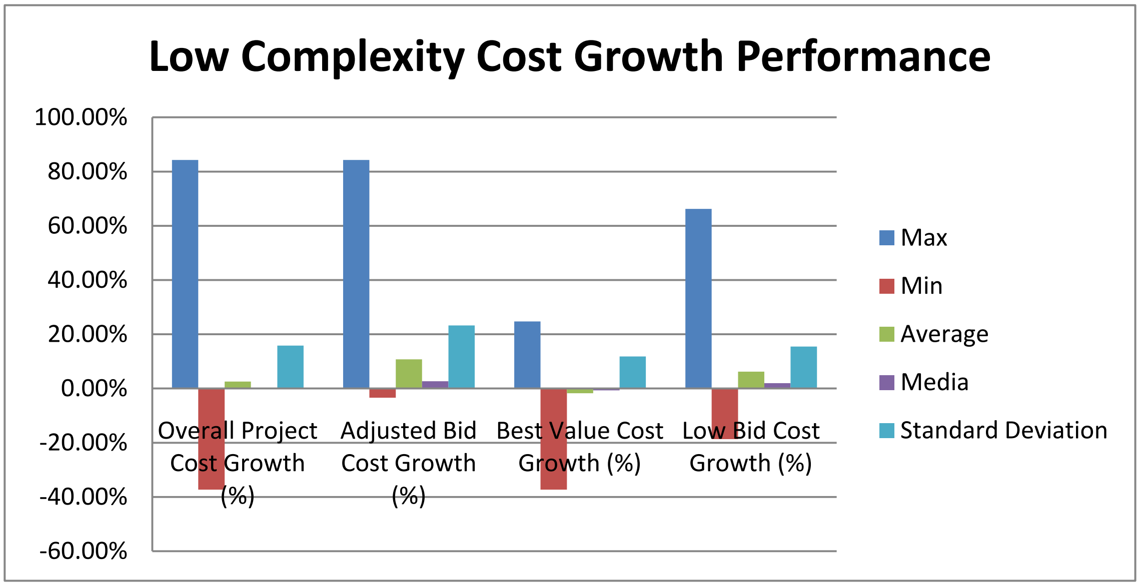


Fig. 4.11 Cost Growth Performance for Low Complexity Projects

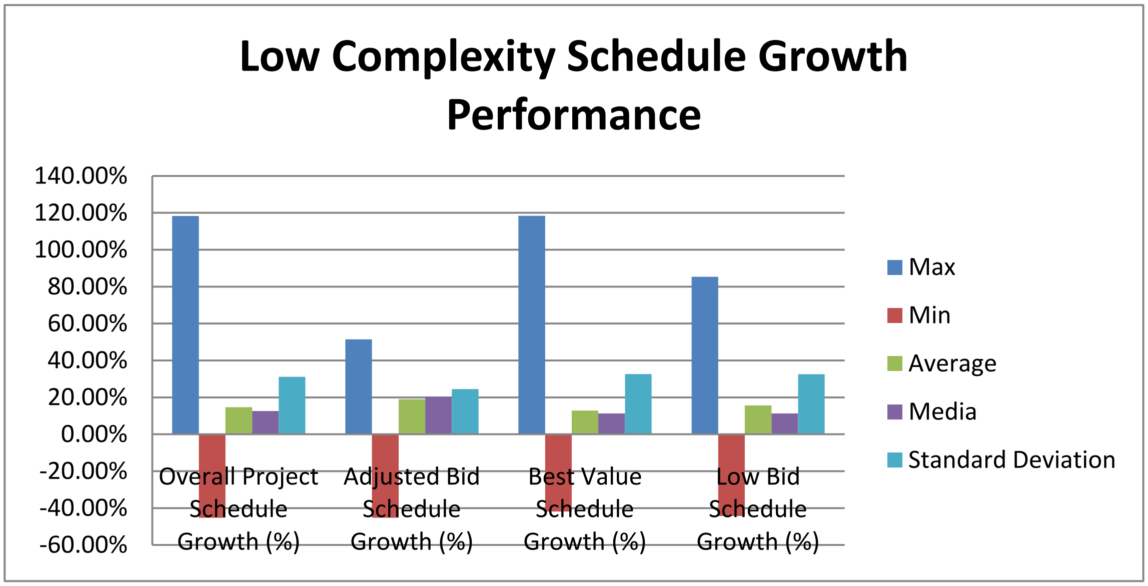


Fig.4.12 Schedule Growth Performance for Low Complexity Projects

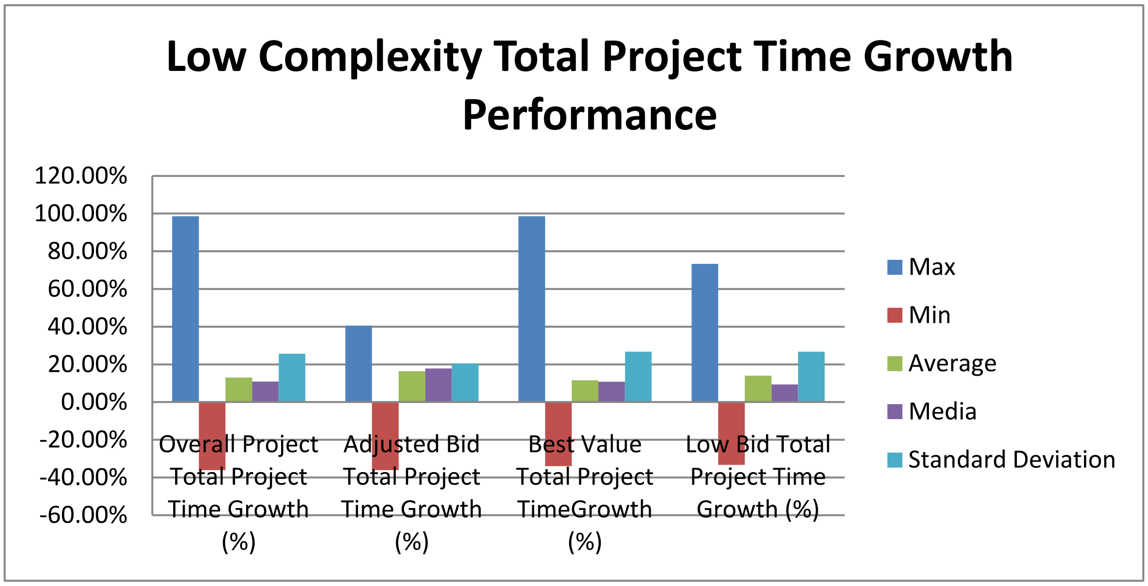


Fig.4.13 Total Project Time Growth Performance for Low Complexity Projects

CHAPTER 5. CORRELATION ANALYSIS

In this chapter, a linear correlation analysis will be conducted on all data to see if there is a relationship between procurement duration and project success. Procurement duration and project success haven't linear relationship. If the analysis does not show any relationship, other analyses will be used to see if any relationship exists

5.1 Procurement Duration and Schedule Growth

Firstly, a linear regression correlation analysis is used to examine the relationship between procurement duration and schedule growth. In this analysis, Pearson value is used to test the reliability level. A confidence level of 95% will be used for all analyses which is one of the most common confidence levels in research.

The Pearson value is a product moment correlation coefficient (David 2006). This value is a dimensionless index that ranges from -1.0 to 1.0 inclusive and reflects the extent of a linear relationship between two data sets. The closer the value is to ±1.0, the stronger the linear relationship between different two factors is.

The formula for the Pearson product moment correlation coefficient is:

$$r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2 \sum(y-\bar{y})^2}}$$

Here, x is the sample means of procurement duration, y is the sample mean of cost growth, schedule growth, or total project time growth.

From the data distribution chart (Figure 5.1), it shows that there is a linear correlation between procurement duration and schedule growth in all collected projects. The chart shows a trend that the schedule growth will decrease accompanying with the increasing of procurement duration.

The Pearson value is -0.8004 which is above the required confidence value and it proves that there is a strong linear relationship between procurement duration and project schedule growth. Also the Pearson value is negative and it agrees with the chart. The regression simulation table (Figure 5.2) shows that the two factors, procurement duration and schedule growth, have a very strong one-dimensional linear regression relationship. The regression relationship is:

$$y = -0.253x + 0.8658$$

The R square value of this equation is 0.6406, the adjusted R square value 0.6381. The standard error of this simulation is 0.1720. All the values indicate that this equation has a very high reliability and they have a very typical linear correlation.

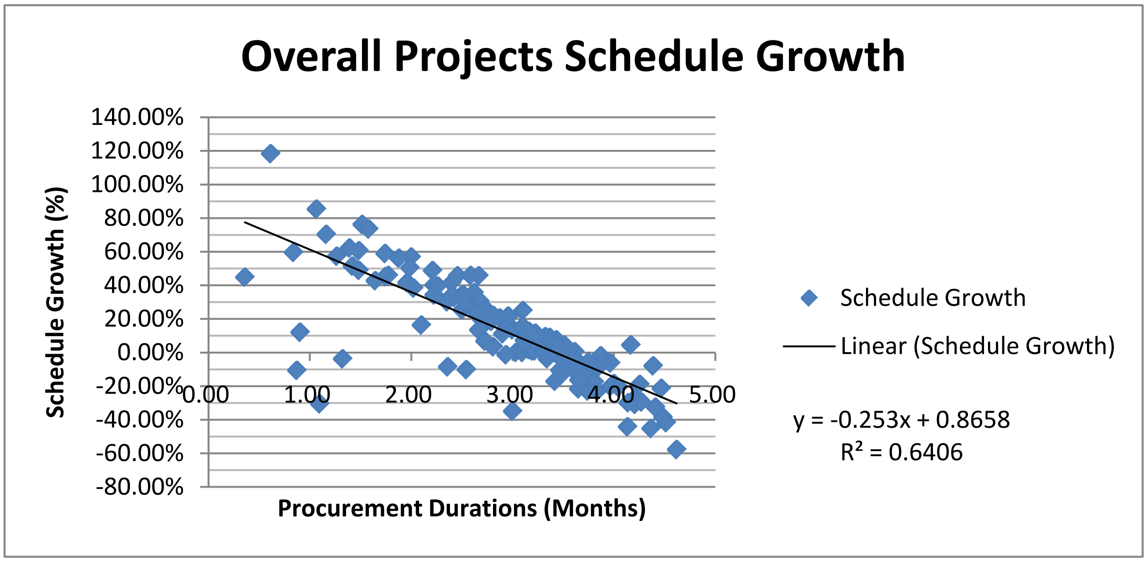
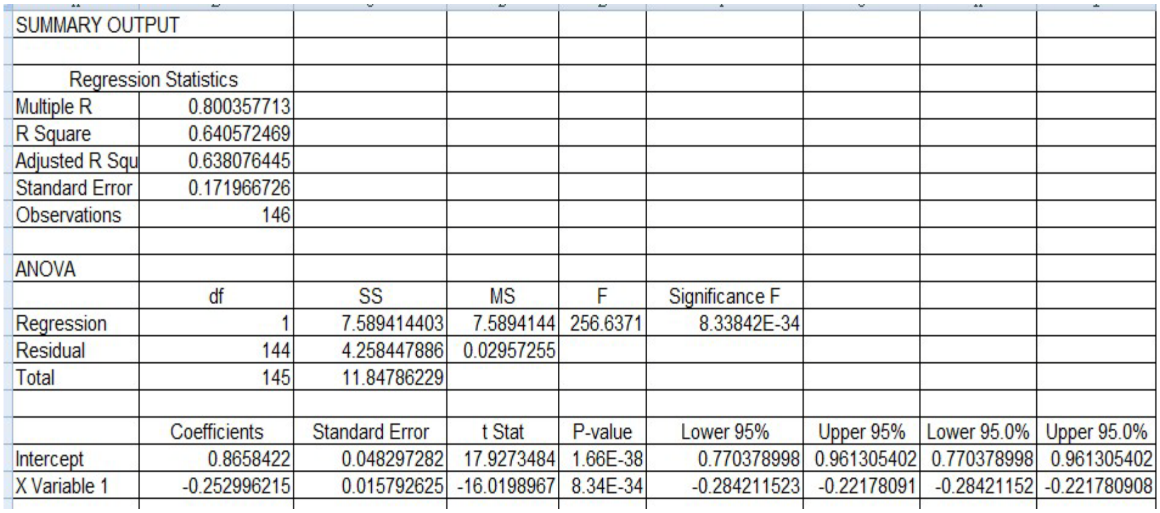


Fig. 5.1 Overall Projects Schedule Growth Data Distribution



SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.800357713							
R Square	0.640572469							
Adjusted R Squ	0.638076445							
Standard Error	0.171966726							
Observations	146							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	7.589414403	7.5894144	256.6371	8.33842E-34			
Residual	144	4.258447886	0.02957255					
Total	145	11.84786229						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.8658422	0.048297282	17.9273484	1.66E-38	0.770378998	0.961305402	0.770378998	0.961305402
X Variable 1	-0.252996215	0.015792625	-16.0198967	8.34E-34	-0.284211523	-0.22178091	-0.28421152	-0.221780908

Fig.5.2 Overall Projects Schedule Growth Simulation Table Summary

The analysis also shows that if procurement duration is around 3.4 months the schedule growth value is around 0%. It seems like a critical value. If the procurement duration is over 3.4 months, most projects schedule growth values will become negative, which means the project will be delivered earlier than the scheduled delivery time. If the procurement duration value is below 3.4 months, most projects schedule growth values are positive. That means those projects are not delivered on time.

The regression analysis was also conducted for overall project time growth (including procurement time). The results show a similar trend to schedule growth. The chart (Figure 5.3) tells that there is a very strong linear correlation between procurement duration and total project time growth. Just like the schedule growth analysis, most projects' total project time growth decreases when procurement duration increases. The critical procurement value is also around 3.4 months. Most projects are delivered earlier than scheduled if the procurement duration is above 3.4 months. If the procurement duration is below 3.4 months, most projects have to delay their delivery date. The Pearson value of total project time growth regression analysis is -0.7929 which is very close to the schedule growth Pearson value. The simulation summary (Figure 5.4) also shows that the R square value is 0.6287 and adjusted square value is 0.6261. And the standard error is only 0.14633. All the values prove that total project time growth has a similar regression trend with schedule growth. The simulation reliability value exceeds the required value and the linear relationship is acceptable and reliable with the following linear equation:

$$y = -0.2098x + 0.7227$$

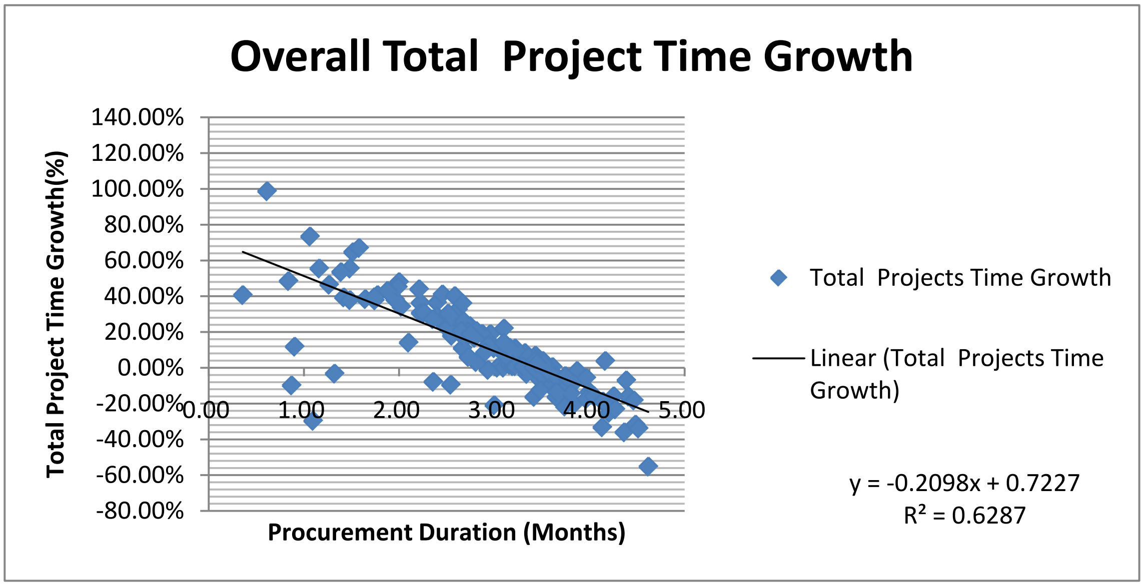
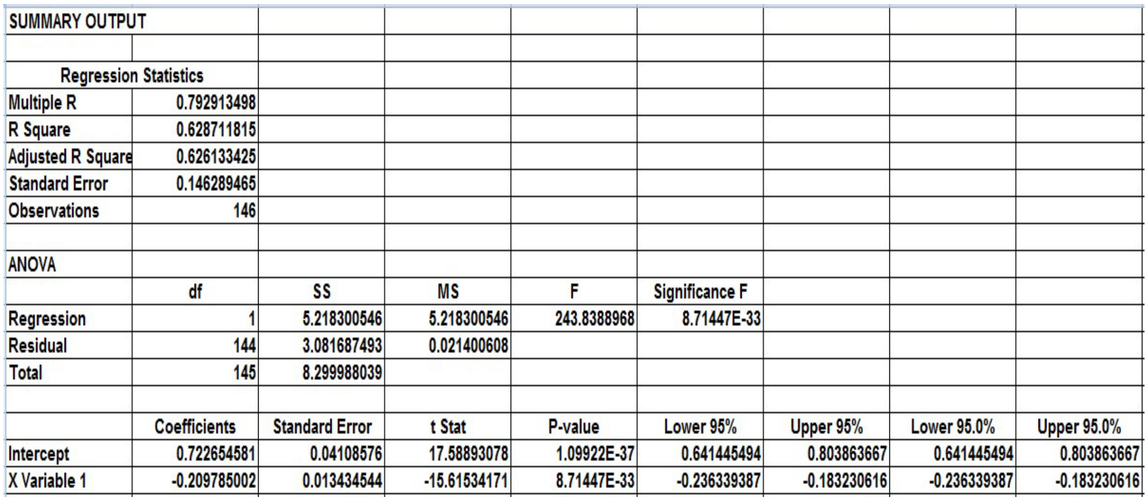


Fig. 5.3 Overall Total Project Time Growth Data Distribution



SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.792913498							
R Square	0.628711815							
Adjusted R Square	0.626133425							
Standard Error	0.146289465							
Observations	146							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	5.218300546	5.218300546	243.8388968	8.71447E-33			
Residual	144	3.081687493	0.021400608					
Total	145	8.299988039						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.722654581	0.04108576	17.58893078	1.09922E-37	0.641445494	0.803863667	0.641445494	0.803863667
X Variable 1	-0.209785002	0.013434544	-15.61534171	8.71447E-33	-0.236339387	-0.183230616	-0.236339387	-0.183230616

Fig.5.4 Overall Projects Total Project Time Growth Simulation Table Summary

The overall project sample shows a very strong relationship between procurement duration and schedule growth, and procurement duration and total project time growth. The following analysis is based on different selection methods and the same type of regression analysis is conducted in adjusted bid type projects, best value type projects, and low bid type projects.

5.1.1 Different Selection Methods Regression Analysis

The adjusted bid projects distribution (Figure 5.5) shows that there is a linear relationship existing. The trend is just like the overall projects schedule growth, the schedule growth value decreases with the increasing of procurement duration. For adjusted bid projects, the critical procurement duration value is around 3.7 months. The Pearson value of adjusted bid type schedule growth -0.7251, which exceed the minimum requirement. The simulation result (Figure 5.6) indicates that the R square value and adjusted R square vale are close, but standard error is 0.1616 which is a little bit higher.

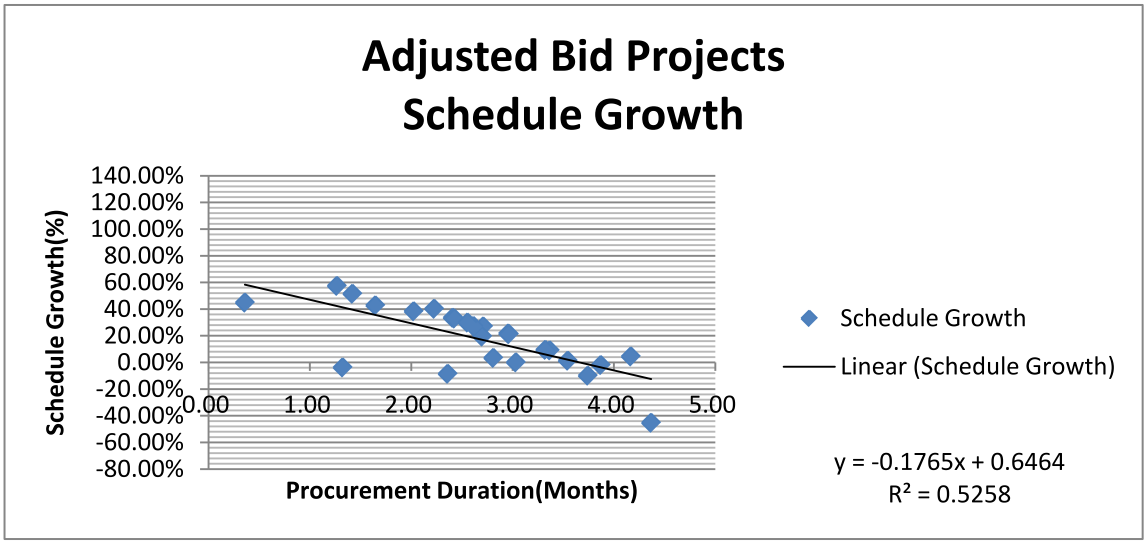
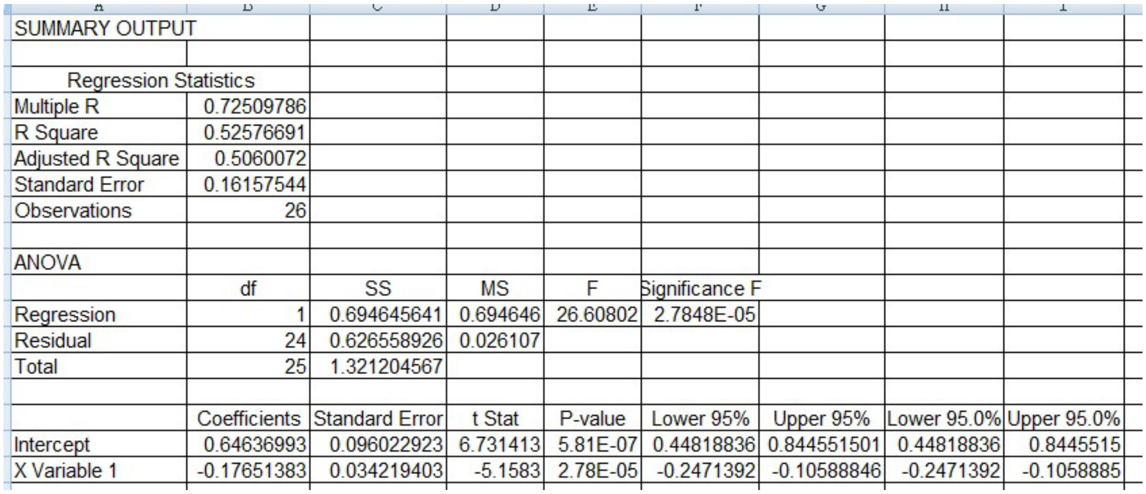


Fig.5.5 Adjusted Bid Projects Schedule Growth Data Distribution



SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.72509786							
R Square	0.52576691							
Adjusted R Square	0.5060072							
Standard Error	0.16157544							
Observations	26							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	0.694645641	0.694646	26.60802	2.7848E-05			
Residual	24	0.626558926	0.026107					
Total	25	1.321204567						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.64636993	0.096022923	6.731413	5.81E-07	0.44818836	0.844551501	0.44818836	0.8445515
X Variable 1	-0.17651383	0.034219403	-5.1583	2.78E-05	-0.2471392	-0.10588846	-0.2471392	-0.1058885

Fig. 5.6 Adjusted Bid Projects Schedule Growth Simulation Table Summary

The current analysis shows that adjusted bid based procurement durations and schedule growth values have a linear correlation, but the reliability level is not as strong as the overall projects result. The one dimension linear equation for adjusted bid projects can be listed as:

$$y = -0.1765x + 0.6464$$

The adjusted bid projects total project time growth analysis result is similar to the former results. But for this analysis, the Pearson value is higher than the last analysis. Also the analysis results (Figure 5.7 and 5.8) show that R square value, adjusted R square value and standard error value are all better than “pure” schedule growth and procurement duration regression analysis performance. It proves the hypothesis in last chapter, which attests that the procurement duration can affect the schedule performance of adjusted bid Design-Build projects. The longer procurement duration will decrease construction duration. There is a linear correlation between them however the reliability level of linear correlation equation is not so evident. The linear correlation equation for adjusted bid.

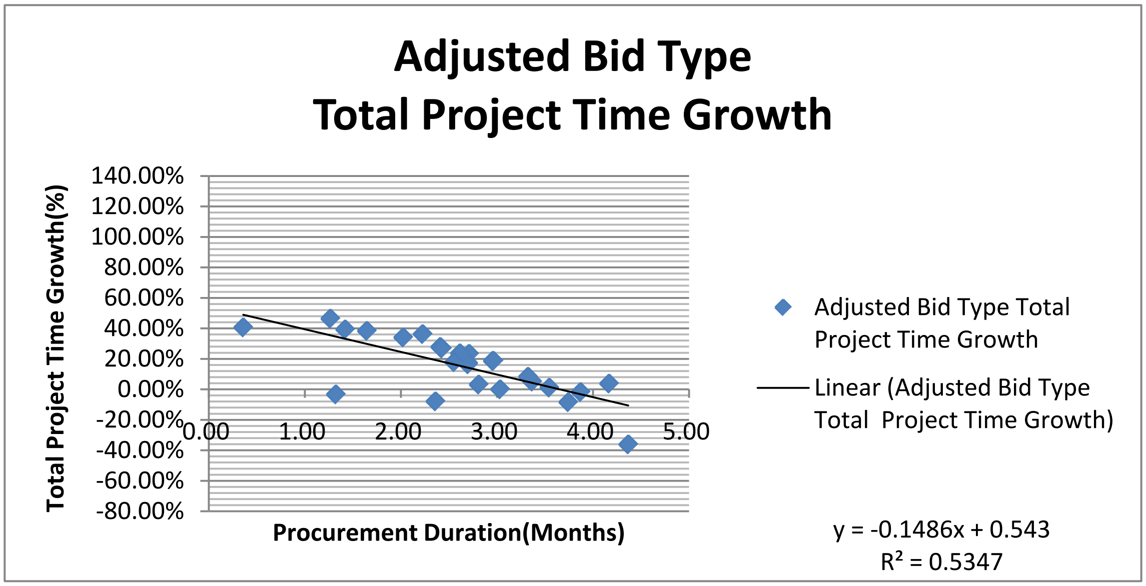
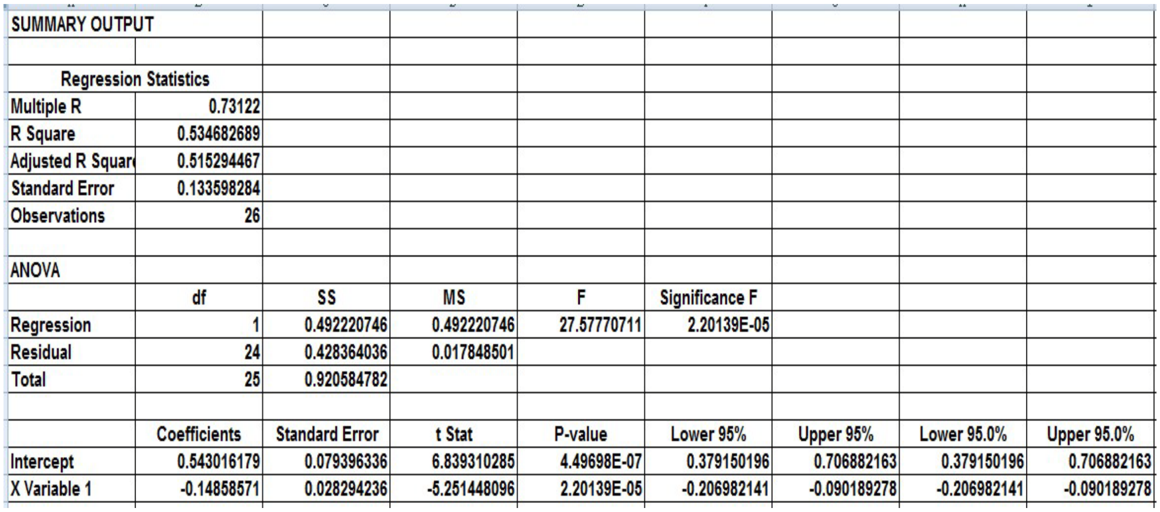


Fig. 5.7 Adjusted Bid Projects Total Project Time Growth Data Distribution



SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.73122							
R Square	0.534682689							
Adjusted R Square	0.515294467							
Standard Error	0.133598284							
Observations	26							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	0.492220746	0.492220746	27.57770711	2.20139E-05			
Residual	24	0.428364036	0.017848501					
Total	25	0.920584782						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.543016179	0.079396336	6.839310285	4.49698E-07	0.379150196	0.706882163	0.379150196	0.706882163
X Variable 1	-0.14858571	0.028294236	-5.251448096	2.20139E-05	-0.206982141	-0.090189278	-0.206982141	-0.090189278

Fig. 5.8 Adjusted Bid Projects Total Project Time Growth Simulation Table Summary

total project time growth and procurement duration can be conducted as:

$$y = -0.1486x + 0.5430$$

More detailed analysis will be conducted to test which type can reflect this linear trend best. For the best value projects, the project spots distribution (Figure 5.9) shows similar trends to overall projects and adjusted bid type. But, the critical procurement duration value for best value type projects differs from overall projects and adjusted type. The critical procurement duration value is 3.45 months. The simulation table (Figure 5.10) shows that the Pearson value is -0.7746, and, the R square value, the adjusted R square value and standard error are all better than adjusted bid type. And the linear correlation equation:

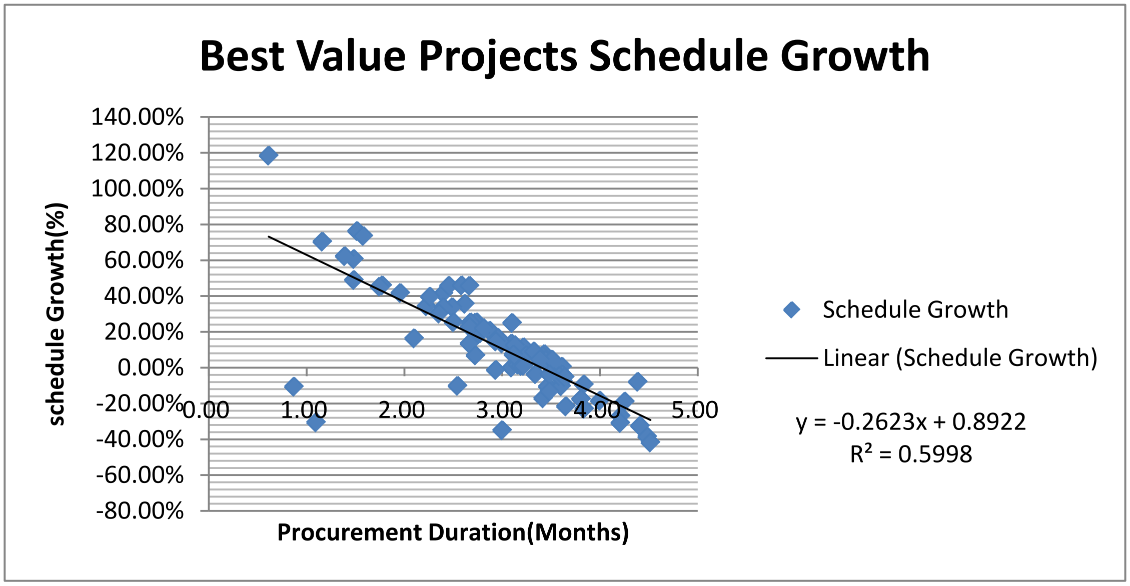
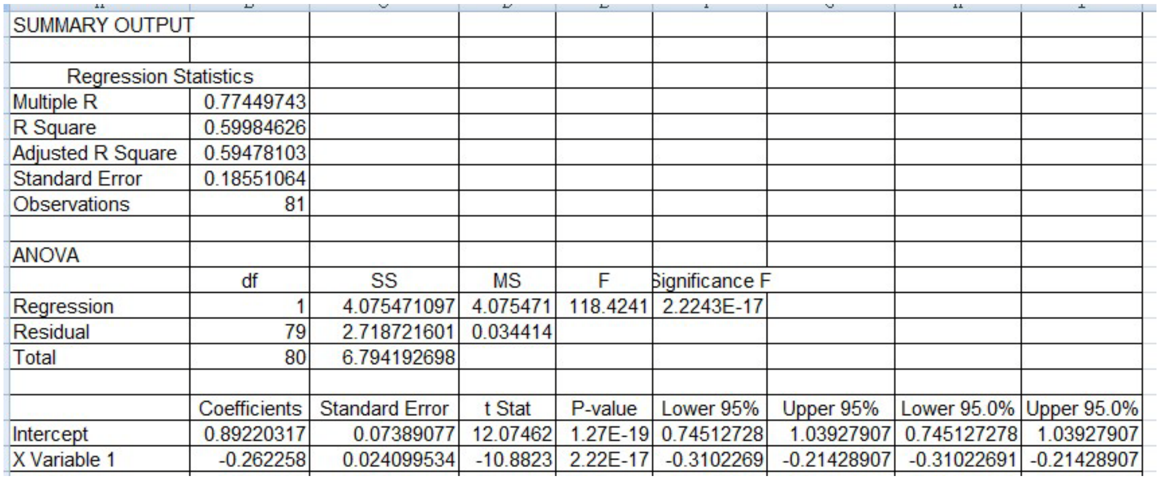


Fig.5.9 Best Value Projects Schedule Growth Data Distribution

$$y = -0.2623x + 0.8922$$



SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.77449743							
R Square	0.59984626							
Adjusted R Square	0.59478103							
Standard Error	0.18551064							
Observations	81							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	4.075471097	4.075471	118.4241	2.2243E-17			
Residual	79	2.718721601	0.034414					
Total	80	6.794192698						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.89220317	0.07389077	12.07462	1.27E-19	0.74512728	1.03927907	0.745127278	1.03927907
X Variable 1	-0.262258	0.024099534	-10.8823	2.22E-17	-0.3102269	-0.21428907	-0.31022691	-0.21428907

Fig. 5.10 Best Value Projects Schedule Growth Simulation Table Summary

Comparing with best value type total project time growth analysis, some results have changed. In this analysis, the critical procurement duration is a little bit longer than the schedule growth analysis (Figure 5.11), the value becomes 3.50 months. But the basic trend and linear correlation is almost the same. The Pearson value is a little lower than “pure” schedule growth based value but it still has a high reliability. The R square value, adjusted R square value and standard error are shown in Figure 5.12 can attest it. The linear correlation equation for this analysis is:

$$y = -0.2164x + 0.7435$$

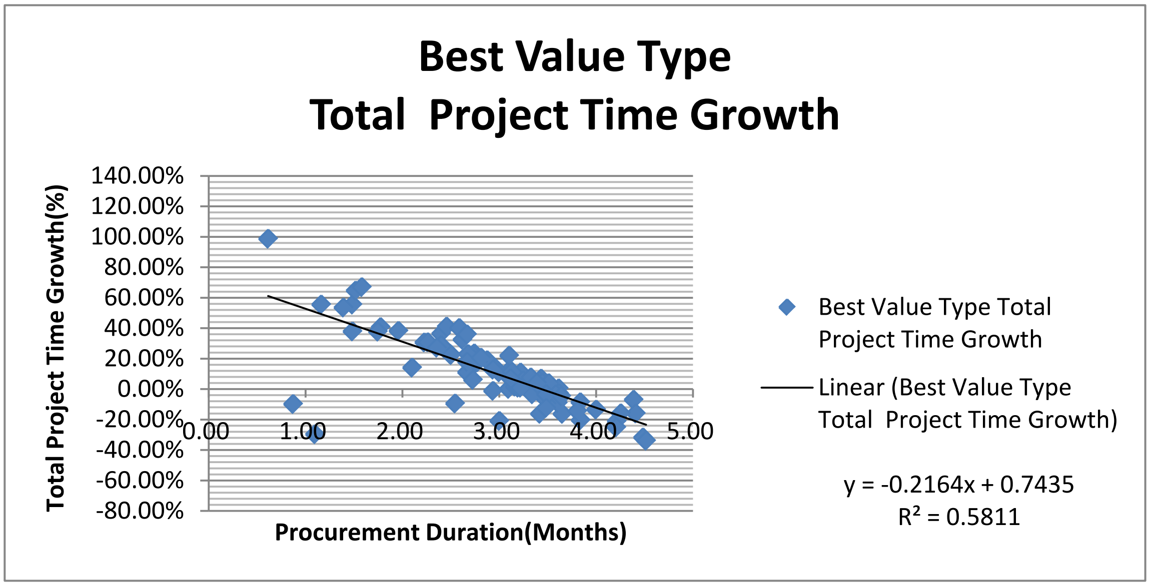
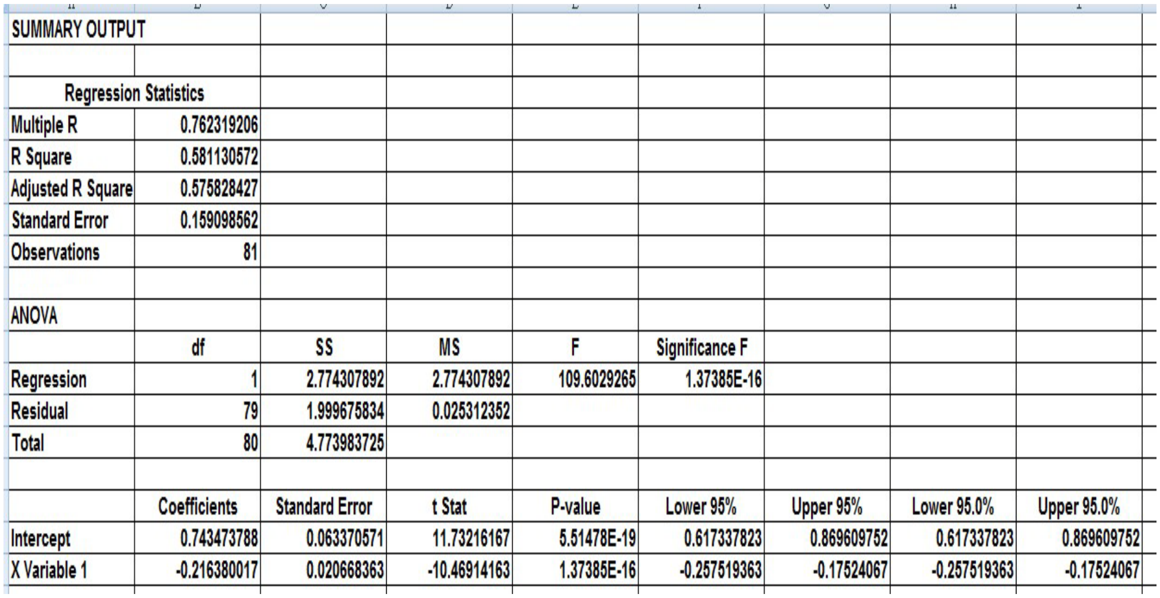


Fig.5.11 Best Value Projects Total Project Time Schedule Growth Data

Distribution



SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.762319206							
R Square	0.581130572							
Adjusted R Square	0.575828427							
Standard Error	0.159098562							
Observations	81							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	2.774307892	2.774307892	109.6029265	1.37385E-16			
Residual	79	1.999675834	0.025312352					
Total	80	4.773983725						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.743473788	0.063370571	11.73216167	5.51478E-19	0.617337823	0.869609752	0.617337823	0.869609752
X Variable 1	-0.216380017	0.020668363	-10.46914163	1.37385E-16	-0.257519363	-0.17524067	-0.257519363	-0.17524067

Fig. 5.12 Best Value Projects Total Project Time Growth Simulation Table

Summary

For the low bid projects analysis (Figures 5.13 and 5.14), the critical procurement duration is 3.45 months, the same as the best value critical procurement duration value. But, low bid has the best Pearson value among all three different selection methods. The Pearson value is -0.8971 which is the highest value in all analysis. The R square value, adjusted R square value and standard error value are also the best results among current analysis. It shows that low bid type has the highest reliability of linear correlation between procurement duration and schedule growth. The linear correlation equation is:

$$y = -0.2922x + 0.9989$$

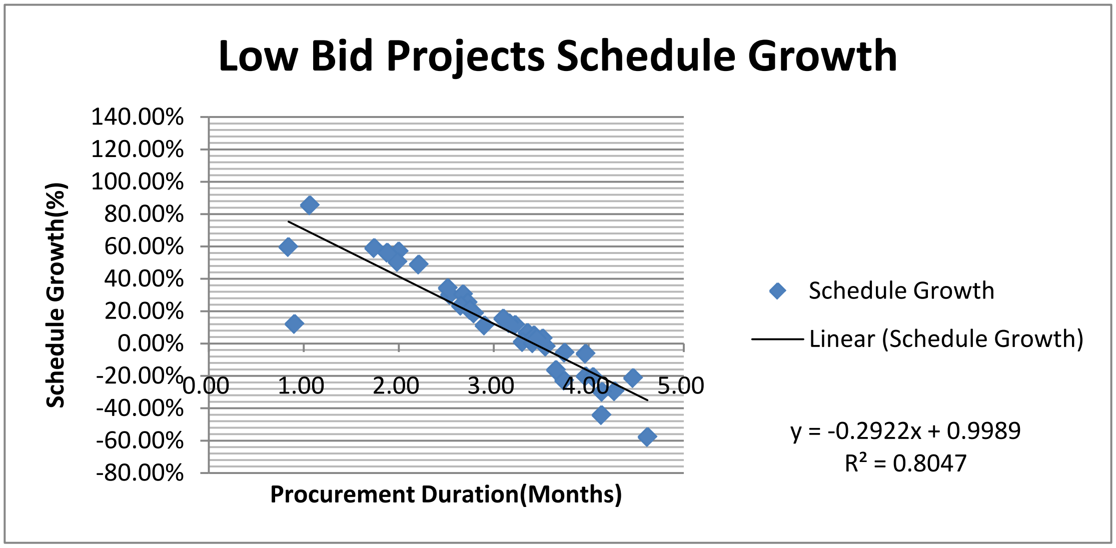
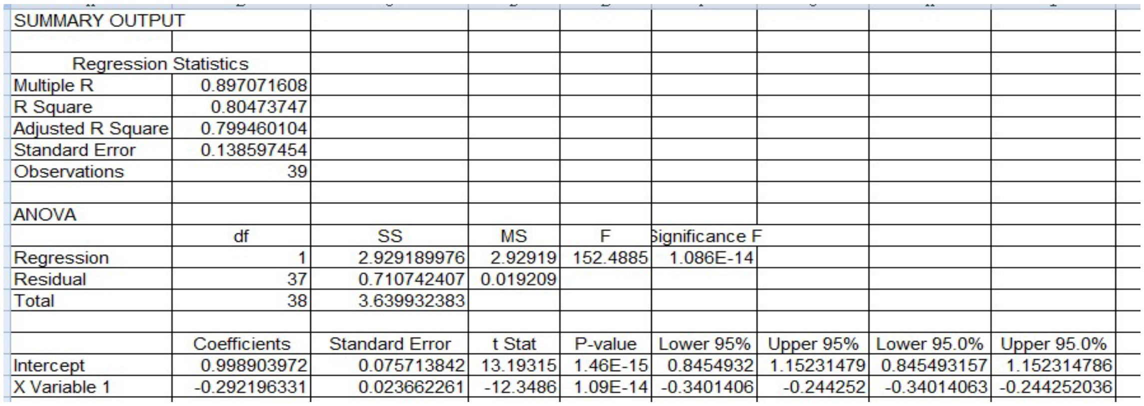


Fig.5.13 Low Bid Projects Schedule Growth Data Distribution



SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.897071608							
R Square	0.80473747							
Adjusted R Square	0.799460104							
Standard Error	0.138597454							
Observations	39							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	2.929189976	2.92919	152.4885	1.086E-14			
Residual	37	0.710742407	0.019209					
Total	38	3.639932383						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.998903972	0.075713842	13.19315	1.46E-15	0.8454932	1.15231479	0.845493157	1.152314786
X Variable 1	-0.292196331	0.023662261	-12.3486	1.09E-14	-0.3401406	-0.244252	-0.34014063	-0.244252036

Fig. 5.14 Low Bid Projects Schedule Growth Simulation Table Summary

In the low bid based total project time growth analysis (Figures 5.15 and 5.16), the results do not change much. The critical procurement is 3.45 months. Other parameters like Pearson value and standard error are very close to the “pure” schedule growth based regression analysis. The reliability of this analysis is also high and the linear correlation formula is:

$$y = -0.2432 + 0.8338$$

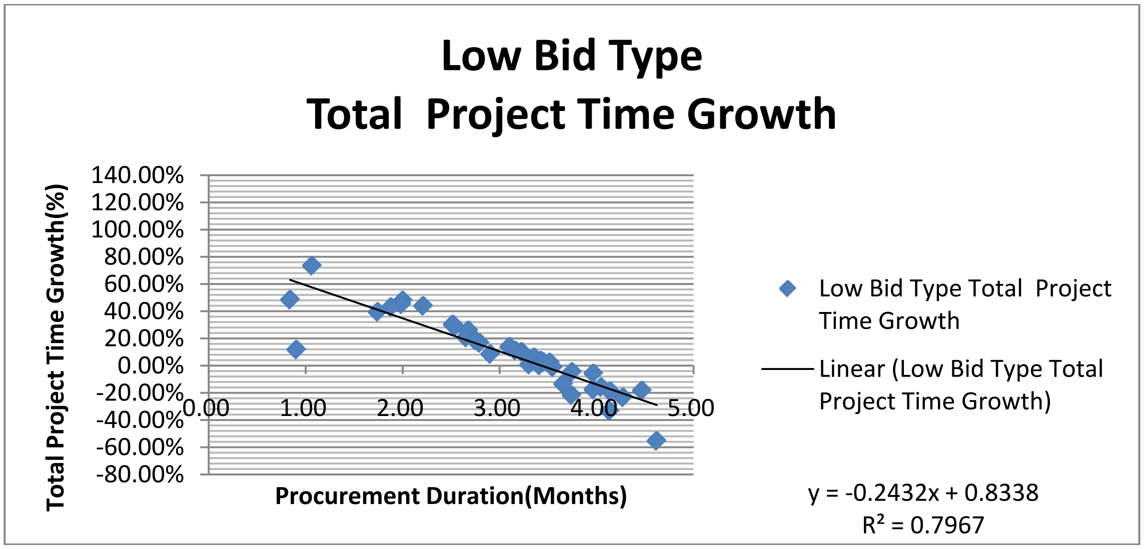
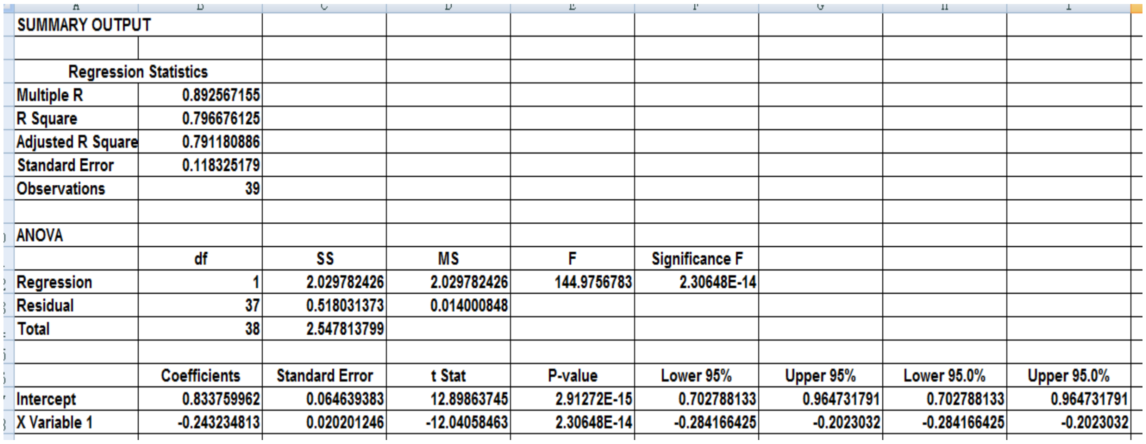


Fig.5.15 Low Bid Projects Total Project Time Schedule Growth Data Distribution



SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.892567155							
R Square	0.796676125							
Adjusted R Square	0.791180886							
Standard Error	0.118325179							
Observations	39							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	2.029782426	2.029782426	144.9756783	2.30648E-14			
Residual	37	0.518031373	0.014000848					
Total	38	2.547813799						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.833759962	0.064639383	12.89863745	2.91272E-15	0.702788133	0.964731791	0.702788133	0.964731791
X Variable 1	-0.243234813	0.020201246	-12.04058463	2.30648E-14	-0.284166425	-0.2023032	-0.284166425	-0.2023032

Fig. 5.16 Low Bid Projects Total Project Time Growth Simulation Table Summary

From the regression analysis, it is obvious that there is a strong linear correlation between procurement duration and schedule growth. The longer procurement duration it has, the less schedule growth there is, which means better schedule performance. There exists a critical procurement duration value. If procurement duration is below this value, most projects do not finish on time, whereas the closer the procurement duration is to the critical value, the less schedule or total project time growth they have. If the procurement is above this critical value, then most projects can be delivered on time or earlier than the scheduled delivery time.

The critical procurement duration value is not fixed. It depends on different procurement selection methods. For the over projects, the critical procurement duration value is 3.4 months. But the critical value under adjusted bid section method is 3.7 months. The critical value for best value and low bid based section methods based projects are both 3.45 months. Whereas, the adjusted bid method has the biggest critical procurement duration value, the Pearson value is the worst among all three selection methods. All the analysis results show that the linear correlation between procurement duration and schedule growth commonly exists in all Design-Build projects no matter what kind of selection method the agency adopts.

5.1.2 Different Complexity Levels Regression Analysis

This analysis focuses on different complexity levels. As illustrated in the last chapter, project complexity here is classified by contract price. If the contract price over $ 50.01 million then project will be considered as high complexity level. The project whose contract price is between $10.1 million to $50.00 million will be treated as having medium complexity level. The low complexity project is defined that contract price is below $10.00 million.

The regression analysis gives the different simulation results under different complexity levels. The data distribution and simulation analyses (Figures 5.17 and 5.18) show that there is no strong linear correlation between procurement duration and schedule growth under high complexity level. The Pearson value is only -0.2407. This value is very weak and even below the minimum required reliability value. Also, the simulation table (Figure 5.18) indicates that the R square value and adjusted R square value are only 0.058 and 0.013 which are very weak. The standard error value is as high as 0.1909 and they prove that the hypothesis about relationship between procurement duration and schedule growth is untenable for high complexity projects.

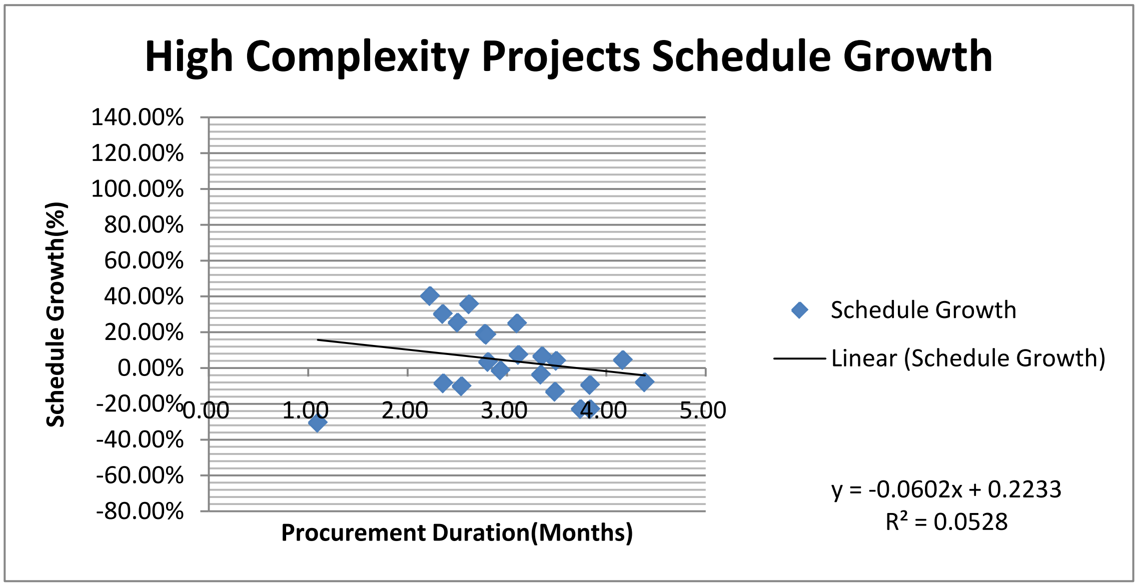
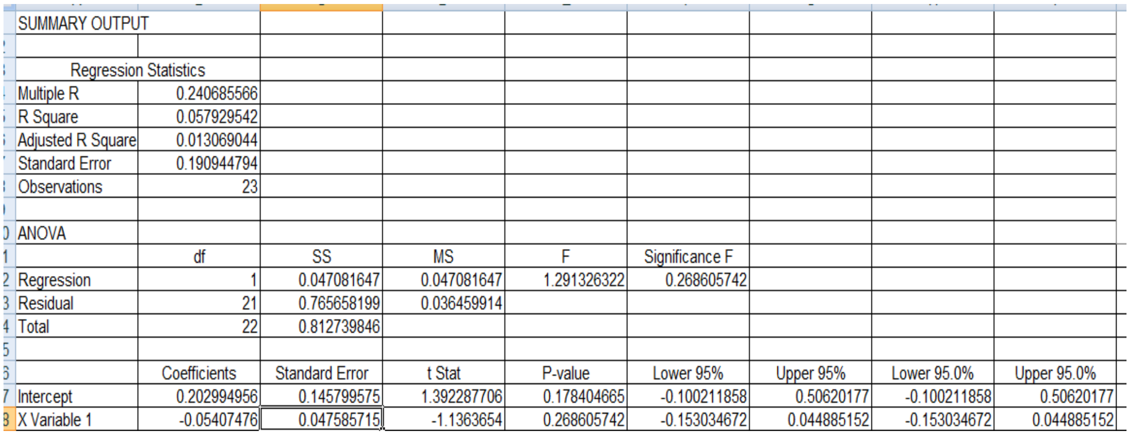


Fig.5.17 High Complexity Projects Schedule Growth Data Distribution



SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.240685566							
R Square	0.057929542							
Adjusted R Square	0.013069044							
Standard Error	0.190944794							
Observations	23							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	0.047081647	0.047081647	1.291326322	0.268605742			
Residual	21	0.765658199	0.036459914					
Total	22	0.812739846						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.202994956	0.145799575	1.392287706	0.178404665	-0.100211858	0.50620177	-0.100211858	0.50620177
X Variable 1	-0.05407476	0.047585715	-1.1363654	0.268605742	-0.153034672	0.044885152	-0.153034672	0.044885152

Fig.5.18 High Complexity Projects Schedule Growth Simulation Summary

The situation for total project time growth analysis (Figures 5.19 and 5.20) is a little better than schedule growth analysis. The Pearson value is -0.2331 but it still doesn’t meet the confidence coefficient requirement. The other parameters like standard error and adjusted R square value improve a little but still show a very weak linear correlation. In one sense, in high complexity level projects, the procurement duration can’t affect project schedule performance a lot. At least they do not have clearly a linear correlation.

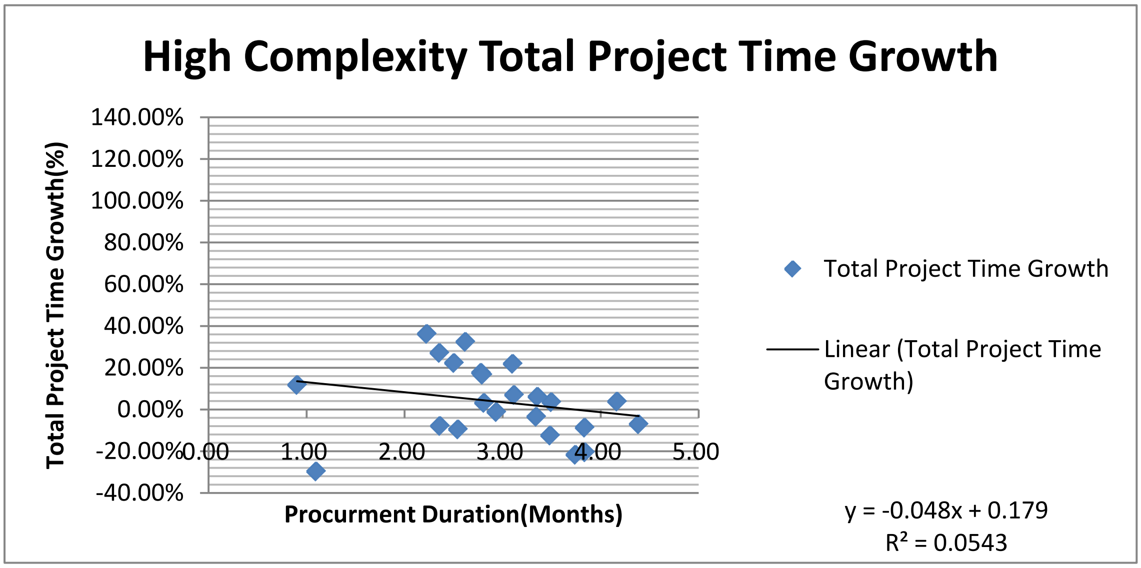
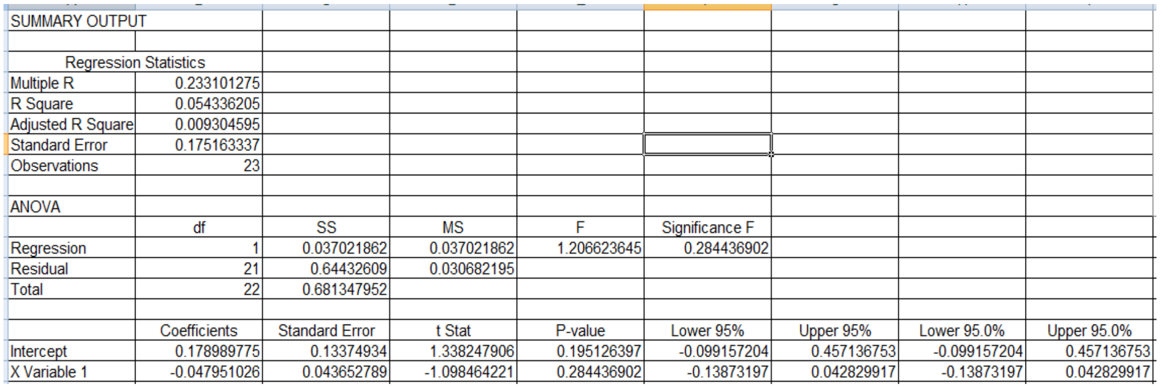


Fig.5.19 High Complexity Total Project Time Growth Data Distribution



SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.233101275							
R Square	0.054336205							
Adjusted R Square	0.009304595							
Standard Error	0.175163337							
Observations	23							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	0.037021862	0.037021862	1.206623645	0.284436902			
Residual	21	0.64432609	0.030682195					
Total	22	0.681347952						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.178989775	0.13374934	1.338247906	0.195126397	-0.099157204	0.457136753	-0.099157204	0.457136753
X Variable 1	-0.047951026	0.043652789	-1.098464221	0.284436902	-0.13873197	0.042829917	-0.13873197	0.042829917

Fig.5.20 High Complexity Total Project Time Growth Simulation Summary

Since there is no one-dimension linear correlation between procurement duration and schedule performance for high complexity projects, a non linear correlation analysis will be processed. The total project time growth will be chosen as an analysis sample because of better Pearson value and standard error value than schedule growth analysis results.

The non linear analysis residual plot (Figure 5.21) and probability table (Table 5.1) show that the residual values of procurement duration and total project time growth are distributed randomly. The probability table also shows that

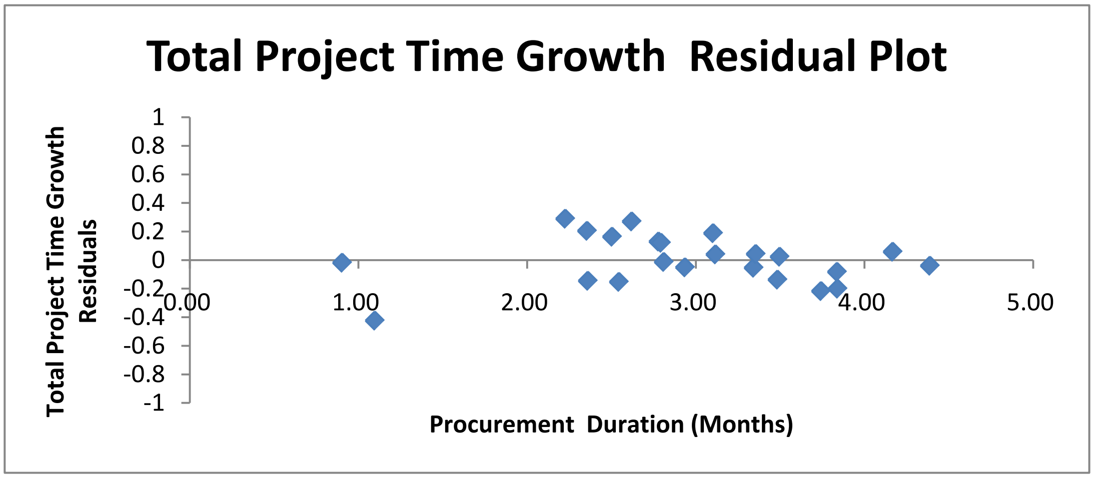


Fig.5.21 Total Project Time Growth Residual Plot

Table 5.1 Probability and Reliability Table

RESIDUAL OUTPUT			PROBABILITY OUTPUT	
Observation	**Predicted Y**	**Residuals**	**Percentile**	**Y**
1	0.044262859	-0.012961376	2.173913043	-0.297250859
2	0.065848186	-0.145023891	6.52173913	-0.217359323
3	-0.020806169	0.058381926	10.86956522	-0.20524836
4	0.072260071	0.2897234	15.2173913	-0.125

Table 5.1 (cont.)

5	0.058957528	0.163683982	19.56521739	-0.095594347
6	0.045758106	0.129974112	23.91304348	-0.087248322
7	-0.004977174	-0.082271148	28.26086957	-0.079175705
8	0.066072841	0.204802922	32.60869565	-0.070941337
9	0.03823031	-0.050797635	36.95652174	-0.035056447
10	0.011326912	0.023556809	41.30434783	-0.012567325
11	0.053378354	0.27055327	45.65217391	0.031301483
12	0.030238472	0.1884494	50	0.034883721
13	0.018712091	-0.053768538	54.34782609	0.037575758
14	-0.005131855	-0.200116505	58.69565217	0.060794045
15	0.126398326	-0.423649185	63.04347826	0.069472617
16	0.05701297	-0.152607318	67.39130435	0.117323556
17	0.029568189	0.039904427	71.73913043	0.166304348
18	-0.031376019	-0.039565318	76.08695652	0.175732218
19	0.011934586	-0.136934586	80.43478261	0.218687873
20	0.045036262	0.121268086	84.7826087	0.222641509
21	0.018121815	0.04267223	89.13043478	0.270875764
22	-0.000439873	-0.216919451	93.47826087	0.323931624
23	0.13567917	-0.018355614	97.82608696	0.361983471

the probability outputs of total project time growth are also at random and don't show any other non linear correlation like normal distribution or bi-distribution. Based on the table and residual plot, the normal probability plot (Figure 5.22) is listed. The plot shows that there is also no non-linear correlation between procurement duration and total project time growth.The normal distribution correlation is weak and the reliability level is also low and at least there is no normal distribution relationship between those two factors. The procurement duration and schedule performance shows little relationship under high complexity level in Design-Build projects.

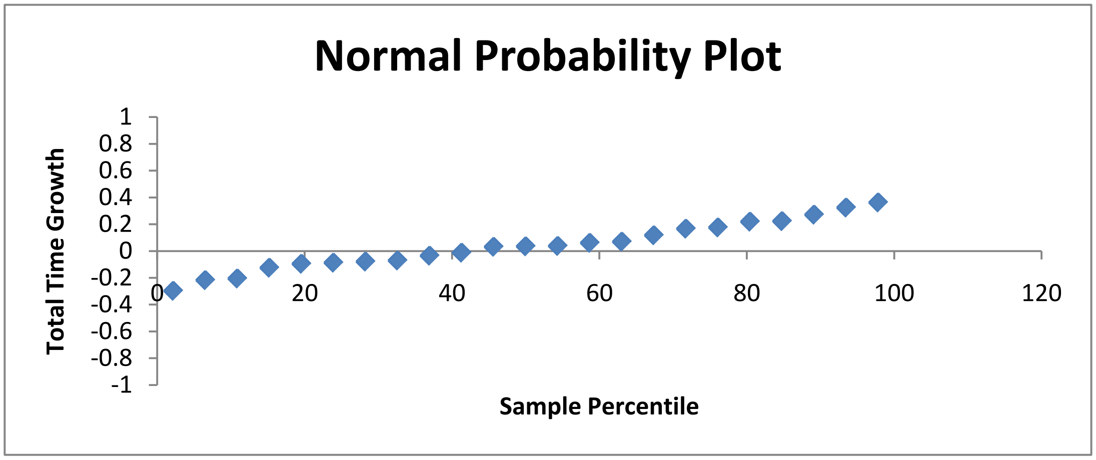


Fig. 5.22 Normal Probability Plot for Total Project Time Growth

The other two complexity level analyses show different trends and results. For medium complexity level projects (Figures 5.23 and 5.24), the Pearson value is -0.7543 and adjusted R square is 0.5571. Those values indicate the procurement duration and schedule growth having a linear correlation for medium complexity level. Also the critical procurement duration value is 3.5 months. The linear equation for medium complexity is:

$$y = -0.2157x + 0.7534$$

Comparing with schedule growth performance, total project time growth analysis has similar results (Figures 5.25 and 5.26). The critical procurement duration value is about 3.48 months which is close to 3.5 months. The Pearson value is -0.7440 which indicates enough reliability to attest the linear correlation between the two factors. The simulation shows that this analysis has a satisfactory R square value, adjusted R square value and standard errors. The data distribution shows a clear linear trend between procurement duration and total project time growth value for medium complexity projects. The linear correlation equation is:

$$y = -0.1815x + 0.6295$$

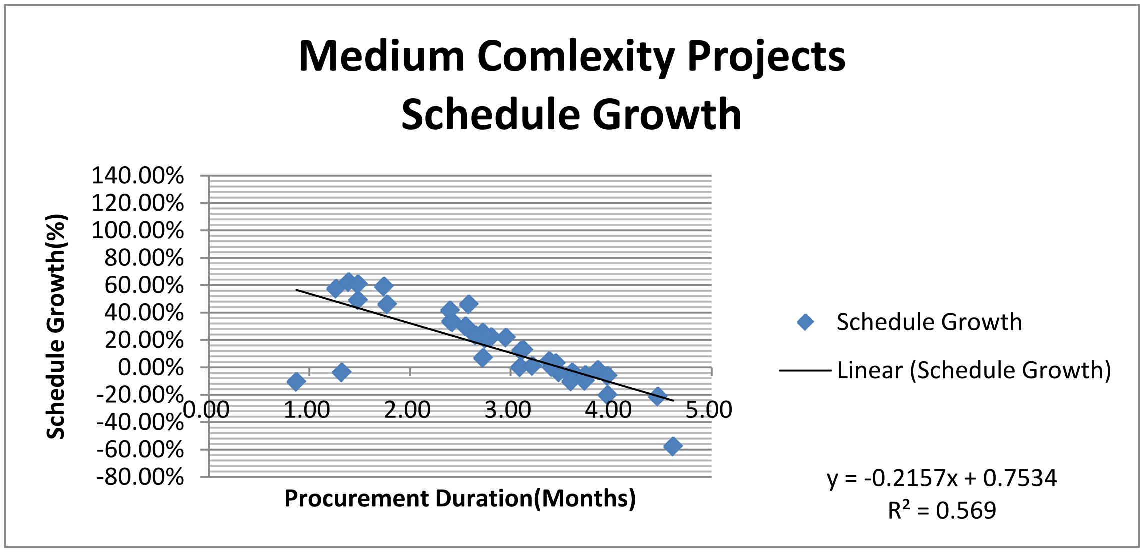
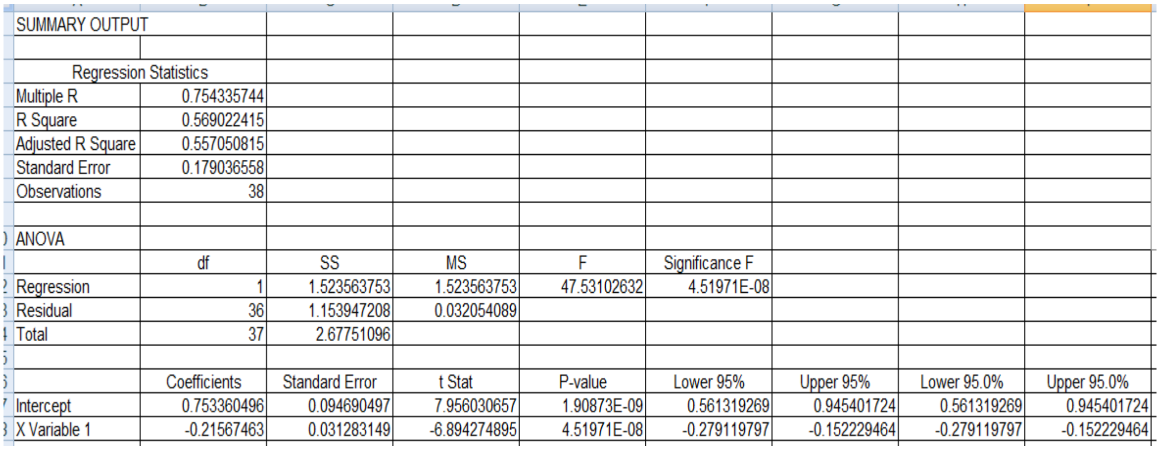


Fig.5.23 Medium Complexity Projects Schedule Growth Data Distribution



SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.754335744							
R Square	0.569022415							
Adjusted R Square	0.557050815							
Standard Error	0.179036558							
Observations	38							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	1.523563753	1.523563753	47.53102632	4.51971E-08			
Residual	36	1.153947208	0.032054089					
Total	37	2.67751096						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.753360496	0.094690497	7.956030657	1.90873E-09	0.561319269	0.945401724	0.561319269	0.945401724
X Variable 1	-0.21567463	0.031283149	-6.894274895	4.51971E-08	-0.279119797	-0.152229464	-0.279119797	-0.152229464

Fig.5.24 Medium Complexity Projects Schedule Growth Simulation Summary

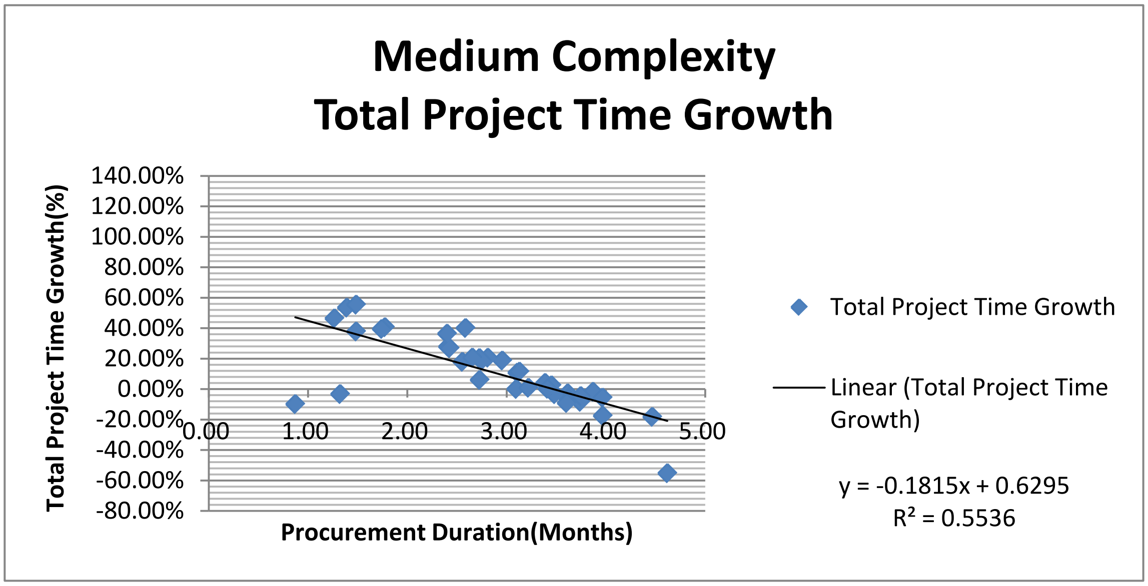
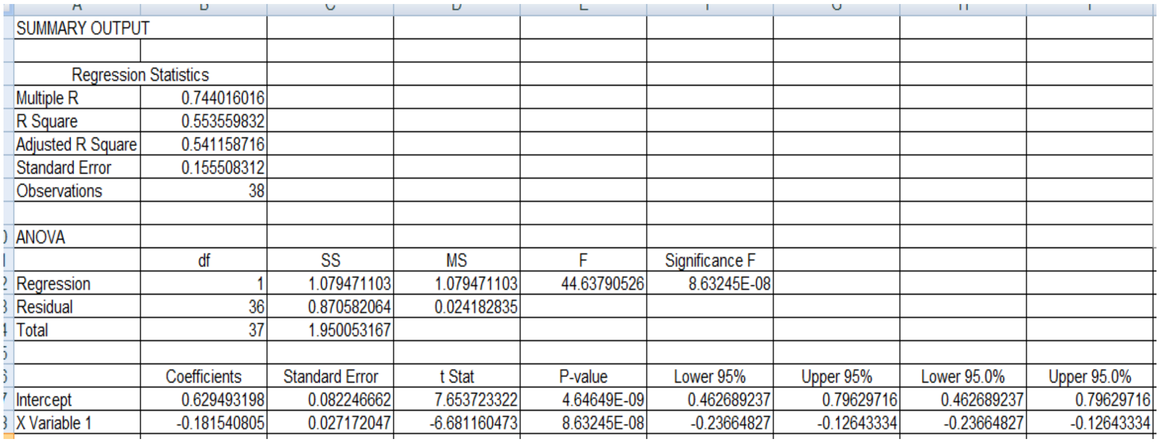


Fig.5.25 Medium Complexity Total Project Time Growth Data Distribution



SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.744016016							
R Square	0.553559832							
Adjusted R Square	0.541158716							
Standard Error	0.155508312							
Observations	38							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	1.079471103	1.079471103	44.63790526	8.63245E-08			
Residual	36	0.870582064	0.024182835					
Total	37	1.950053167						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.629493198	0.082246662	7.653723322	4.64649E-09	0.462689237	0.79629716	0.462689237	0.79629716
X Variable 1	-0.181540805	0.027172047	-6.681160473	8.63245E-08	-0.23664827	-0.12643334	-0.23664827	-0.12643334

Fig.5.26 Medium Complexity Total Project Time Growth Simulation Summary

For low complexity projects, the analysis results are strong. The critical procurement duration value is 3.4 months. The Pearson value under low complexity is -0.9239. It is the second highest value among all analyses and it shows that procurement duration and schedule growth have a very strong linear correlation. It is very obvious that the longer the procurement duration in low complexity projects, the lower schedule growth. The regression simulation also gives the good R square value (0.8535), adjusted R square value (0.8517), and standard error (0.1200). Thos results prove that there is very strong correlation between the two factors and the linear correlation formula has a very high reliability level:

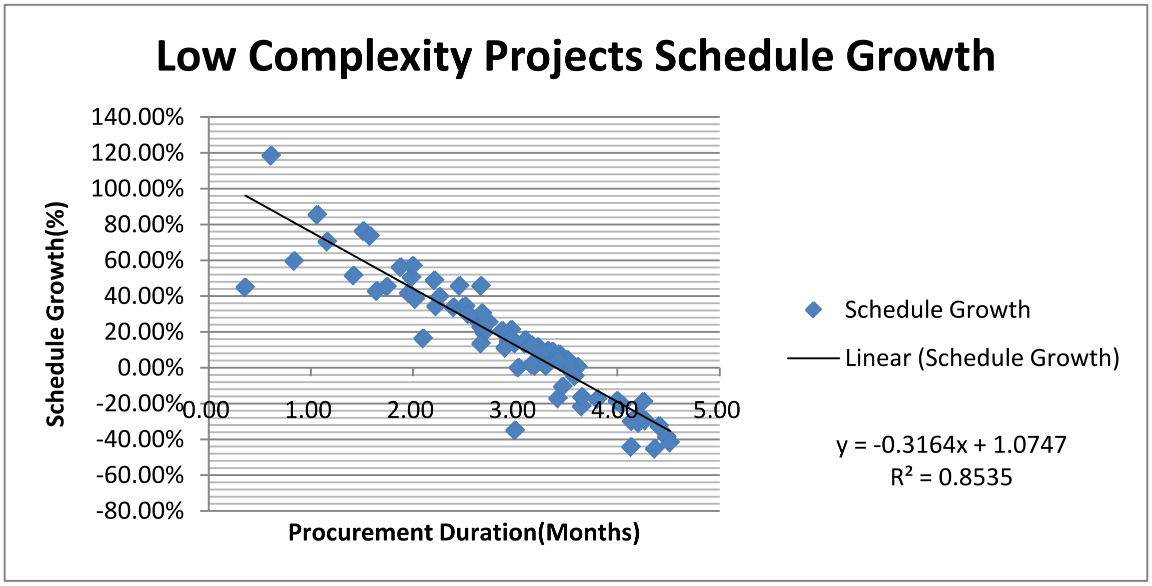
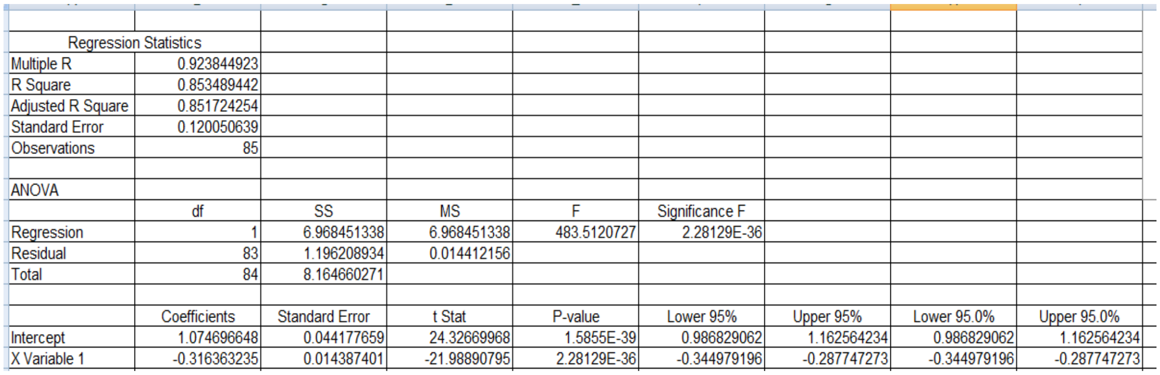


Fig.5.27 Low Complexity Projects Schedule Growth Data Distribution



Regression Statistics								
Multiple R	0.923844923							
R Square	0.853489442							
Adjusted R Square	0.851724254							
Standard Error	0.120050639							
Observations	85							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	6.968451338	6.968451338	483.5120727	2.28129E-36			
Residual	83	1.196208934	0.014412156					
Total	84	8.164660271						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	1.074696648	0.044177659	24.32669968	1.5855E-39	0.986829062	1.162564234	0.986829062	1.162564234
X Variable 1	-0.316363235	0.014387401	-21.98890795	2.28129E-36	-0.344979196	-0.287747273	-0.344979196	-0.287747273

Fig.5.28 Low Complexity Projects Schedule Growth Simulation Summary

$$y = -0.3164 + 1.0747$$

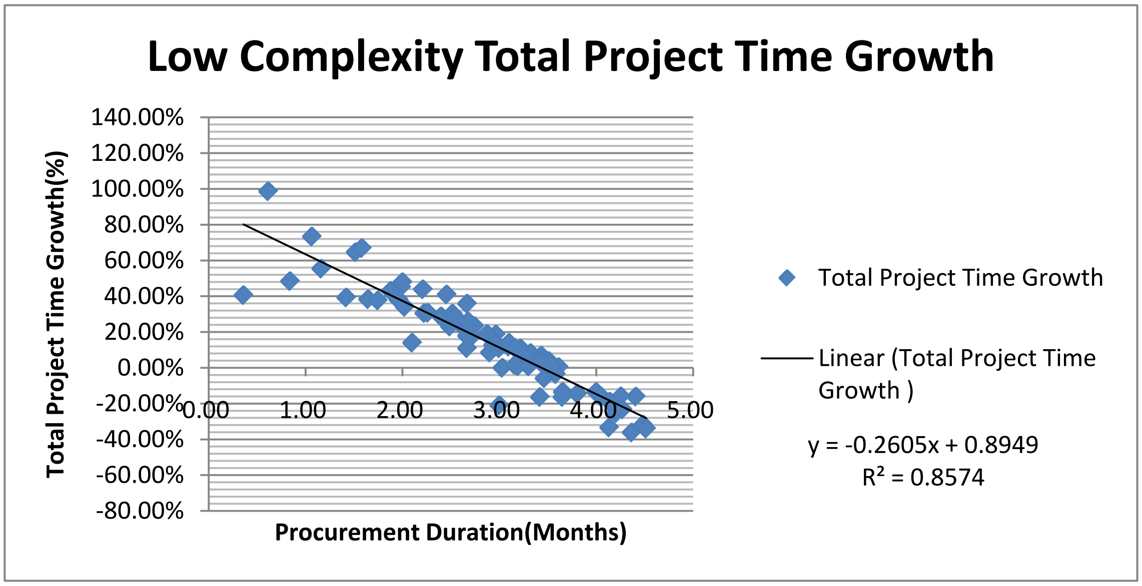
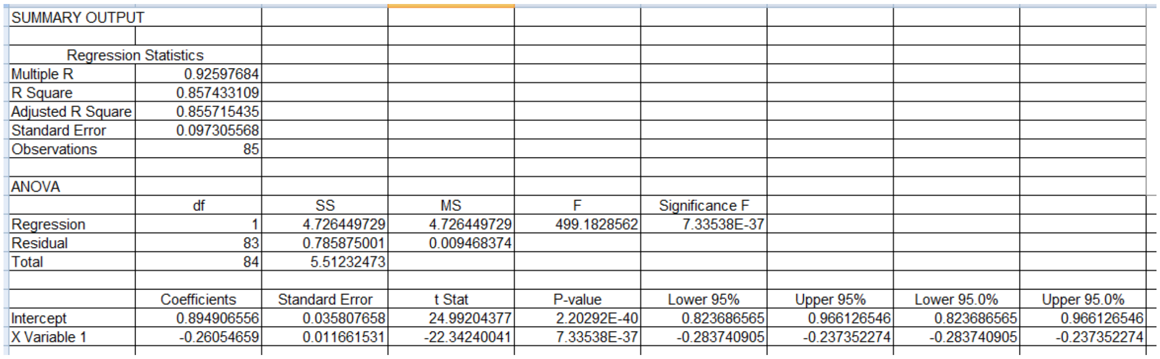


Fig.5.29 Low Complexity Total Project Time Growth Data Distribution



SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.92597684							
R Square	0.857433109							
Adjusted R Square	0.855715435							
Standard Error	0.097305568							
Observations	85							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	4.726449729	4.726449729	499.1828562	7.33538E-37			
Residual	83	0.785875001	0.009468374					
Total	84	5.51232473						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.894906556	0.035807658	24.99204377	2.20292E-40	0.823686565	0.966126546	0.823686565	0.966126546
X Variable 1	-0.26054659	0.011661531	-22.34240041	7.33538E-37	-0.283740905	-0.237352274	-0.283740905	-0.237352274

Fig.5.30 Low Complexity Total Project Time Growth Simulation Summary

The total project time growth regression analysis also shows a strong relationship. The critical procurement duration value of 3.47 months is a little larger than the schedule growth critical value. The bigger critical value brings the best Pearson value. The Pearson value for total project time growth regression analysis is -0.9260 which is the highest one in all of the analyses. This indicates that procurement duration and schedule performance have the strongest linear correlation in low complexity projects. The spots distribution chart (Figure 5.29) shows a very obvious trend that the total project time growth will decrease with the increasing of procurement duration. The simulation table (Figure 5.30) also provides very high R square value, adjusted R square value and the lowest standard error value (0.0973). The values prove that the linear correlation equation has the highest reliability with the following equation:

$$y = -0.2605x + 0.8949$$

In summary, it seems that there is little relationship between procurement duration and schedule performance for high complexity projects. But there is strong linear correlation between the two factors for medium complexity and low complexity projects. The low complexity level regression analysis has the best simulation results. This analysis results strongly suggests that owners pay more attention to their procurement phase duration in their medium and low complexity levels projects. The appropriate procurement duration can limit schedule growth and improve project performance.

Since regression analysis of high complexity projects shows that there is no relationship between procurement duration and schedule performance. The following analysis does not include high complexity projects. The lack of enough sample projects is the other reason to abandon the high complexity regression analysis by selection method.

The regression analyses show the procurement duration and schedule performance has a strong linear correlation for medium complexity and low complexity projects. This analysis now expanded to determine whether different selection methods affect the relationship.

In medium complexity projects, there are three different selection methods: Adjusted Bid, Best Value, and Low Bid. In this section, the analysis of adjusted bid is not considered because of lack of enough samples. There are only 8 adjusted bid type projects in medium complexity projects. The sample amount is not enough to run a reliable regression analysis. The adjusted bid projects data distribution chart (Figure 5.31) shows all 8 projects distribution. Even though there is a weak linear correlation, this analysis is not reliable because of the size of the data group. There is a bias and it can’t reflect the real situation based on only 8 projects.

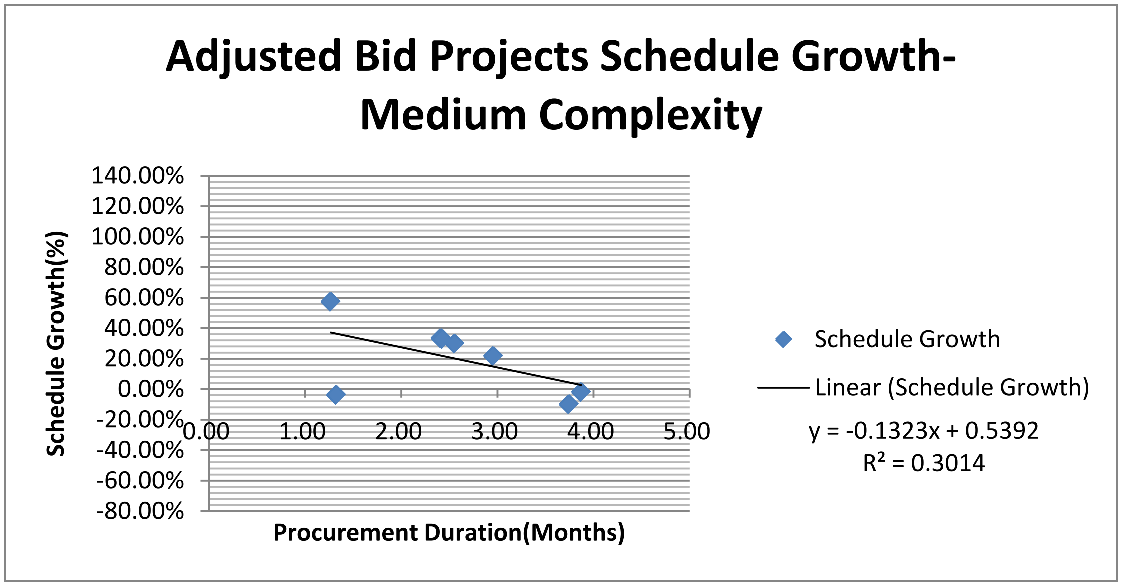


Fig.5.31 Adjusted Bid Projects Schedule Growth Data Distribution

for Medium Complexity Projects

For medium complexity projects, best value projects do not have as strong a correlation as low bid. From the data distribution and simulation table (Figures 5.32 and 5.33), the Pearson value is calculated as -0.6614 and the standard error is close to 0.2. The reliability of this regression analysis is not strong like the overall projects analysis under the same complexity level. The linear correlation formula can be calculated as:

$$y = -0.1886x + 0.6803$$

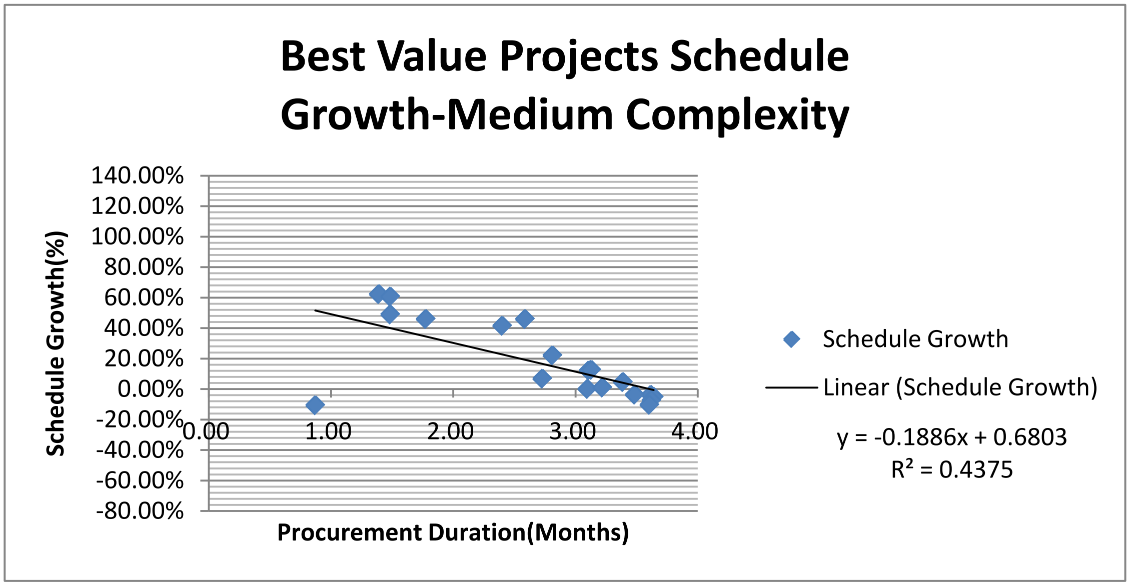
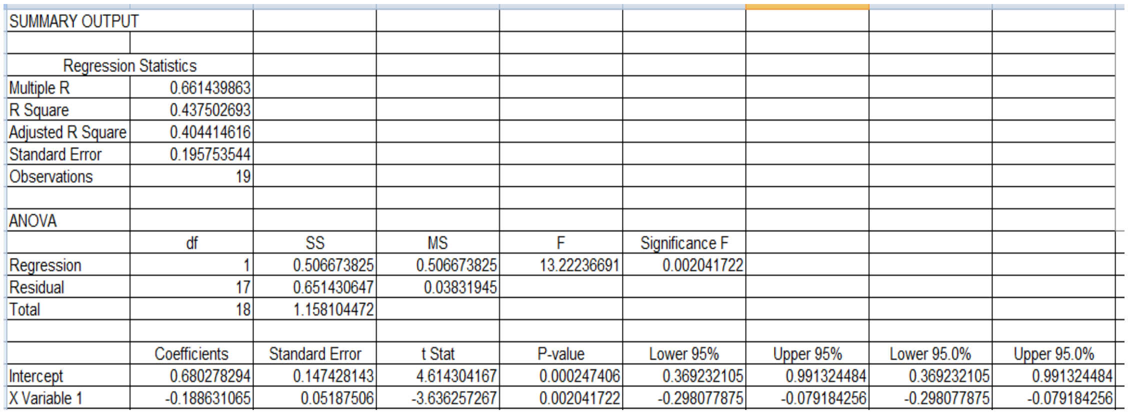


Fig.5.32 Best Value Projects Schedule Growth Data Distribution

for Medium Complexity Projects



SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.661439863							
R Square	0.437502693							
Adjusted R Square	0.404414616							
Standard Error	0.195753544							
Observations	19							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	0.506673825	0.506673825	13.22236691	0.002041722			
Residual	17	0.651430647	0.03831945					
Total	18	1.158104472						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.680278294	0.147428143	4.614304167	0.000247406	0.369232105	0.991324484	0.369232105	0.991324484
X Variable 1	-0.188631065	0.05187506	-3.636257267	0.002041722	-0.298077875	-0.079184256	-0.298077875	-0.079184256

Fig.5.33 Best Value Projects Schedule Growth Simulation Summary

for Medium Complexity Projects

The analysis results of total project time growth are very similar to the schedule growth analysis (Figures 5.34 and 5.35). The Pearson value is -0.6485 and standard error is 0.1728. Neither regression analysis shows a clear critical procurement duration value. The correlation equation is:

$$y = -0.1609x + 0.5832$$

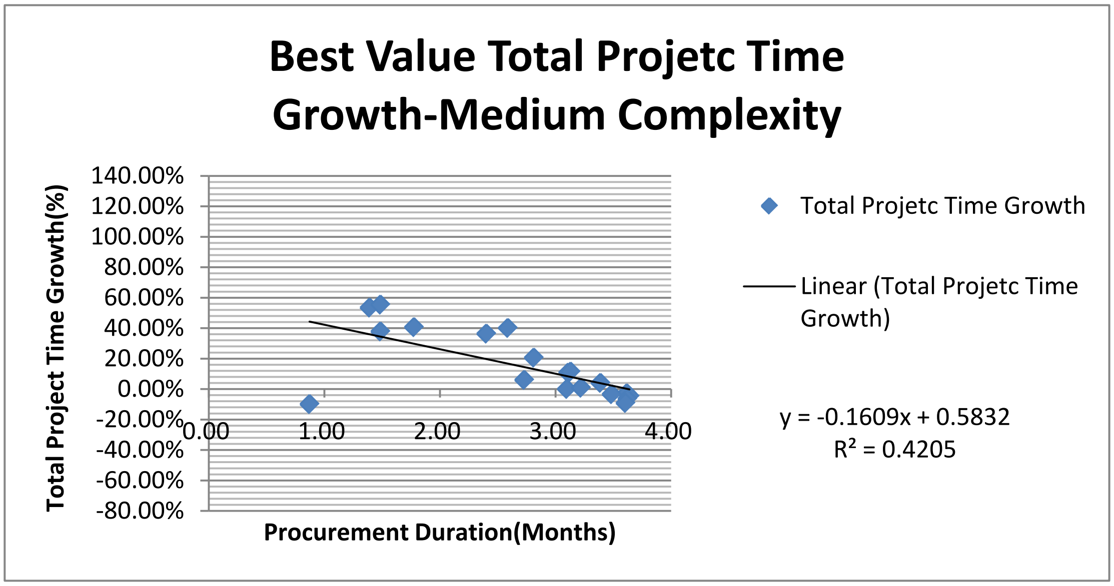
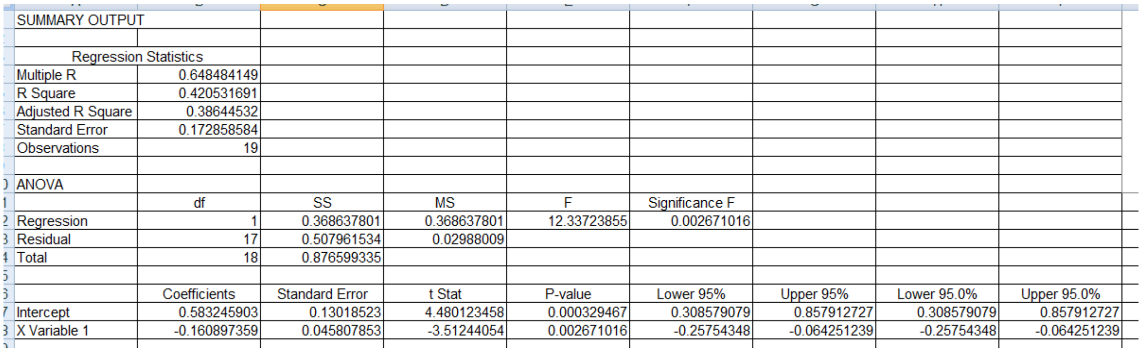


Fig.5.34 Best Value Projects Total Project Time Growth Data Distribution

for Medium Complexity Projects



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.648484149
R Square	0.420531691
Adjusted R Square	0.38644532
Standard Error	0.172858584
Observations	19

ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.368637801	0.368637801	12.33723855	0.002671016
Residual	17	0.507961534	0.02988009		
Total	18	0.876599335			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.583245903	0.13018523	4.480123458	0.000329467	0.308579079	0.857912727	0.308579079	0.857912727
X Variable 1	-0.160897359	0.045807853	-3.51244054	0.002671016	-0.25754348	-0.064251239	-0.25754348	-0.064251239

Fig.5.35 Best Value Projects Total Project Time Growth Simulation Summary

for Medium Complexity Projects

The low bid projects show the strongest linear correlation. The critical procurement duration value is 3.45 months. From the data distribution chart (Figure 5.36), there is a obvious trend. The Pearson value is -0.9626, which shows a very high reliability level of analysis. The simulation table (Figure 5.37) also gives very good analysis parameters, like standard error (0.087). For the total project time growth, the results are very close to the schedule growth analysis results (Figures 5.38 and 5.39). The critical procurement duration value is the same as 3.45 months. The Pearson value, R square value, adjusted R square value and standard error are very high. It shows a very strong linear correlation between the two factors like the schedule growth analysis. This linear correlation equation is conducted as:

$$y = -0.3382x + 1.171$$

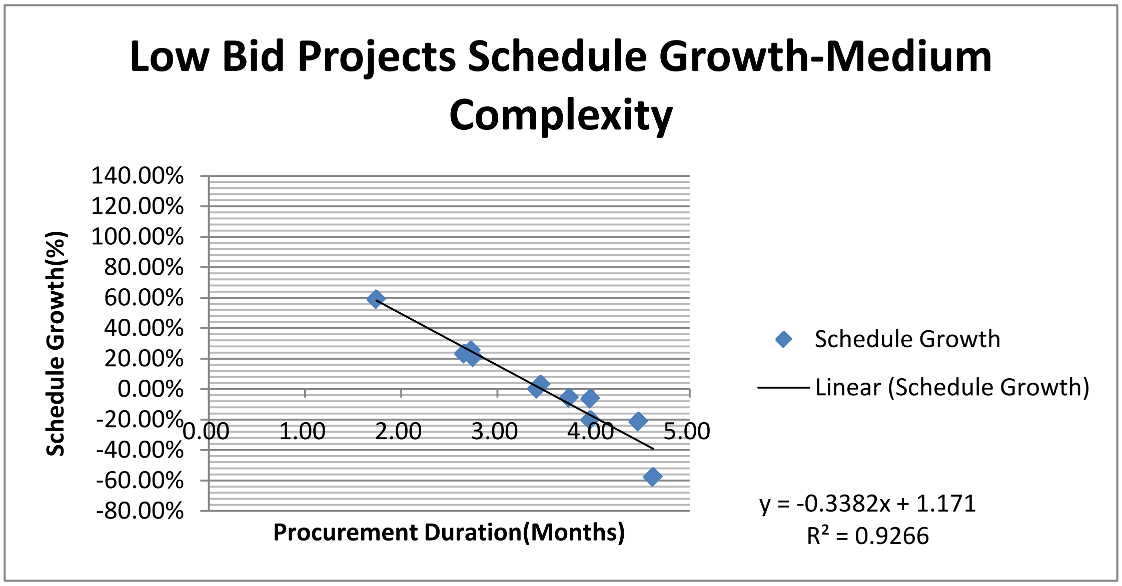
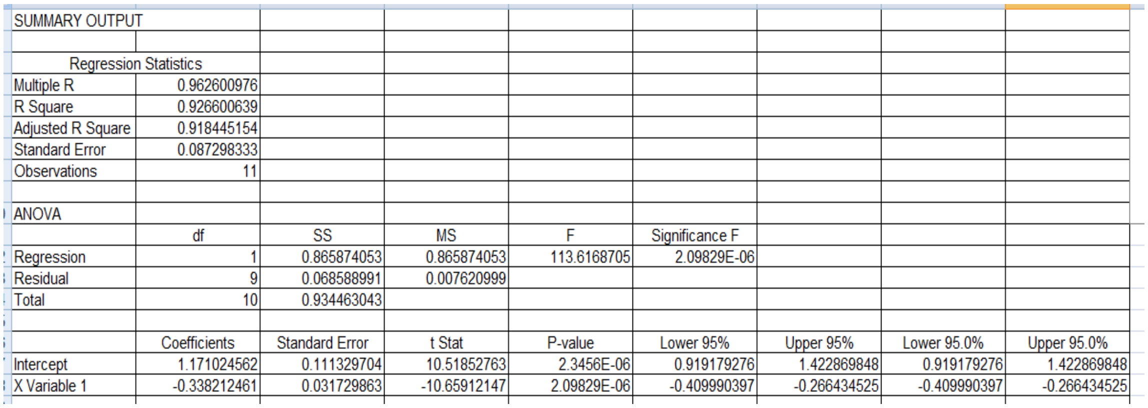


Fig.5.36 Low Bid Projects Schedule Growth Data Distribution

for Medium Complexity Projects



SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.962600976							
R Square	0.926600639							
Adjusted R Square	0.918445154							
Standard Error	0.087298333							
Observations	11							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	0.865874053	0.865874053	113.6168705	2.09829E-06			
Residual	9	0.068588991	0.007620999					
Total	10	0.934463043						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	1.171024562	0.111329704	10.51852763	2.3456E-06	0.919179276	1.422869848	0.919179276	1.422869848
X Variable 1	-0.338212461	0.031729863	-10.65912147	2.09829E-06	-0.409990397	-0.266434525	-0.409990397	-0.266434525

Fig.5.37 Low Bid Projects Schedule Growth Simulation Summary

for Medium Complexity Projects

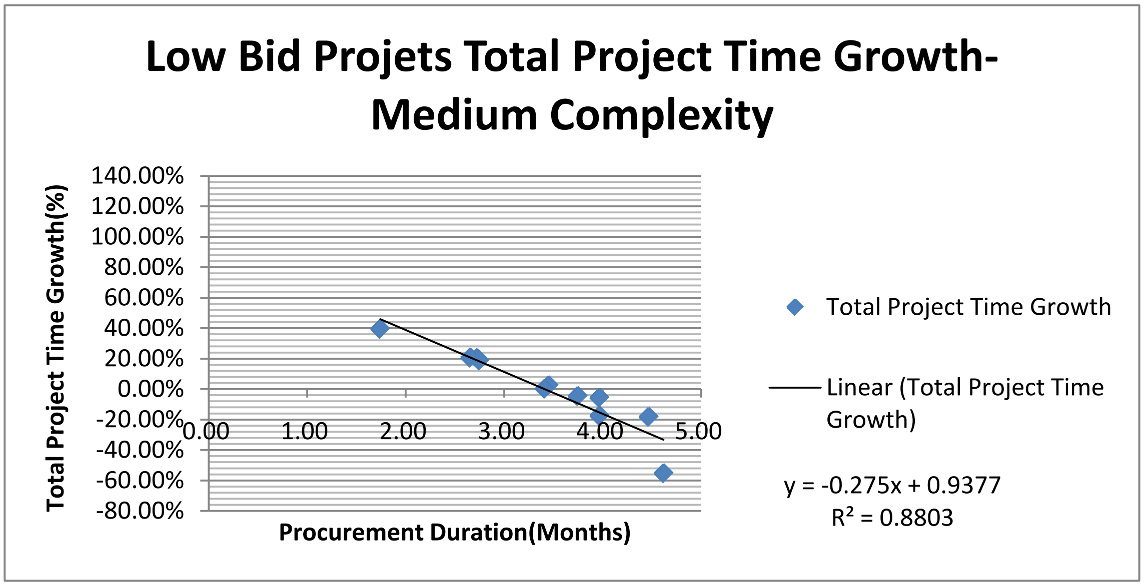
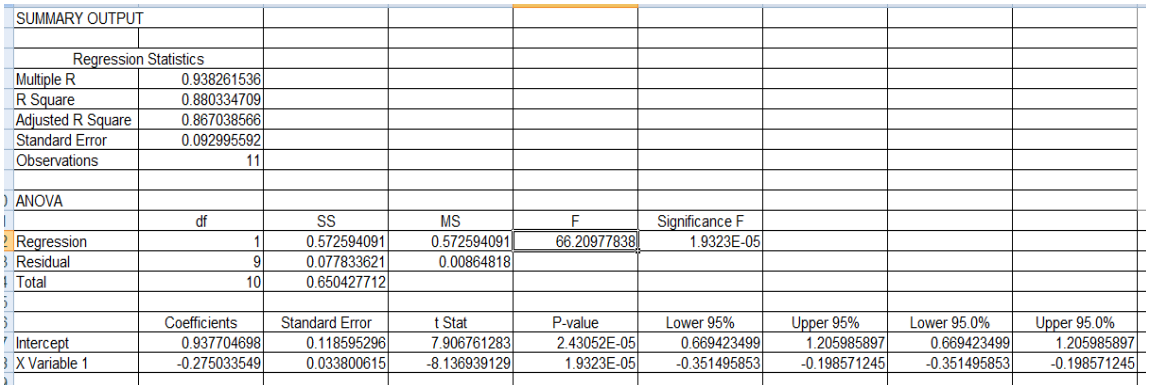


Fig.5.38 Low Bid Projects Total Project Time Growth Data Distribution

for Medium Complexity Projects



SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.938261536							
R Square	0.880334709							
Adjusted R Square	0.867038566							
Standard Error	0.092995592							
Observations	11							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	0.572594091	0.572594091	66.20977838	1.9323E-05			
Residual	9	0.077833621	0.00864818					
Total	10	0.650427712						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.937704698	0.118595296	7.906761283	2.43052E-05	0.669423499	1.205985897	0.669423499	1.205985897
X Variable 1	-0.275033549	0.033800615	-8.136939129	1.9323E-05	-0.351495853	-0.198571245	-0.351495853	-0.198571245

Fig.5.39 Low Bid Projects Total Project Time Growth Simulation Summary

for Medium Complexity Projects

Among the low complexity projects, the regression analysis is also conducted with the same process. The overall analysis results under low complexity level are the strongest. Each type of analysis shows a strong linear correlation between procurement duration and schedule performance.

The adjusted bid schedule growth data distribution (Figure 5.40) and total project time growth data distribution (Figure 5.42) have a Pearson value of -0.8793 and -0.8000 which are both high. They also have the same critical procurement duration value, 3.5 months. The schedule growth simulation (Figure 5.41) and total project time growth simulation (Figure 5.43) also show a good standard error which is 0.1213 and 0.0954. The simulations support very high reliabilities of linear correlation. Thus the linear correlation equation is:

$$y = -0.1824x + 0.6430$$

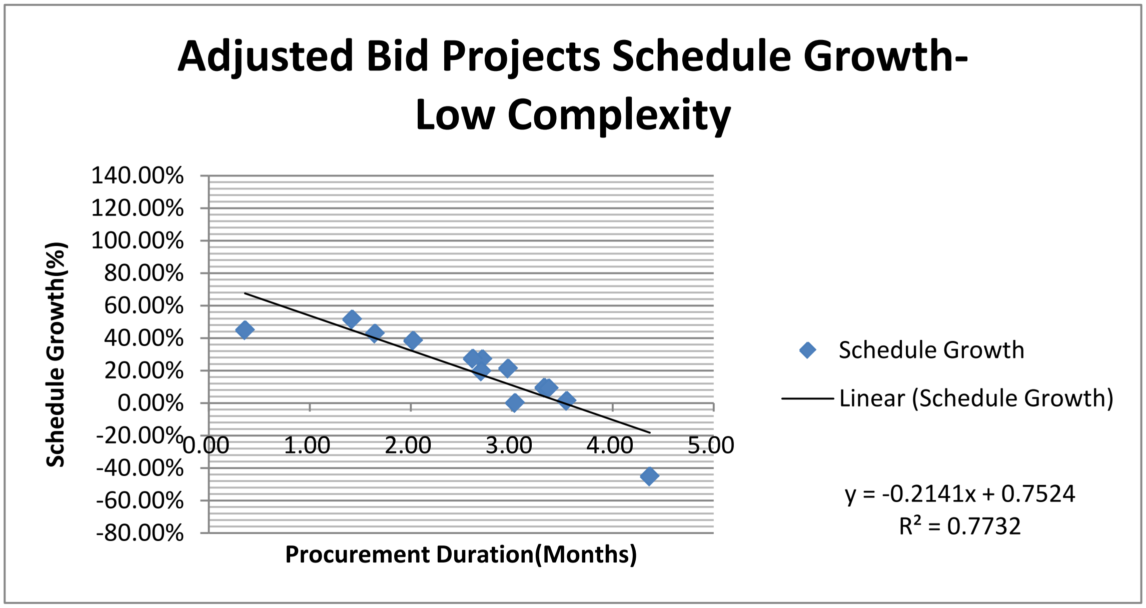
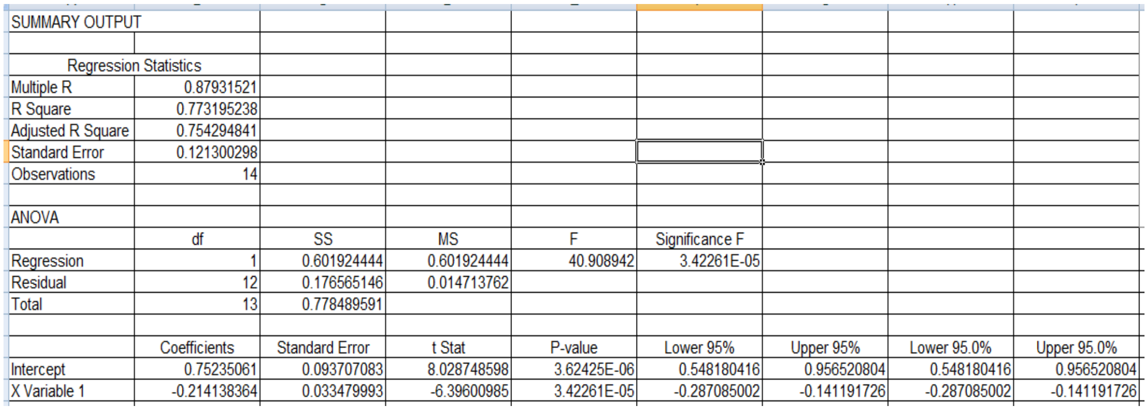


Fig.5.40 Adjusted Bid Projects Schedule Growth Data Distribution

for Low Complexity Projects



SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.87931521							
R Square	0.773195238							
Adjusted R Square	0.754294841							
Standard Error	0.121300298							
Observations	14							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	0.601924444	0.601924444	40.908942	3.42261E-05			
Residual	12	0.176565146	0.014713762					
Total	13	0.778489591						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.75235061	0.093707083	8.028748598	3.62425E-06	0.548180416	0.956520804	0.548180416	0.956520804
X Variable 1	-0.214138364	0.033479993	-6.39600985	3.42261E-05	-0.287085002	-0.141191726	-0.287085002	-0.141191726

Fig.5.41 Adjusted Bid Projects Schedule Growth Simulation Summary

for Low Complexity Projects

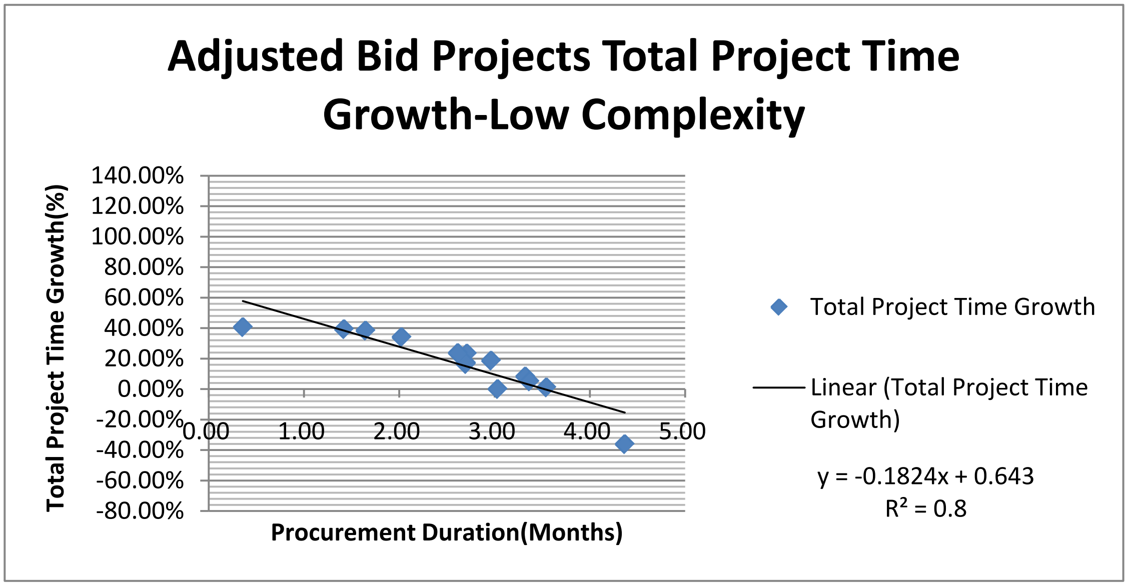
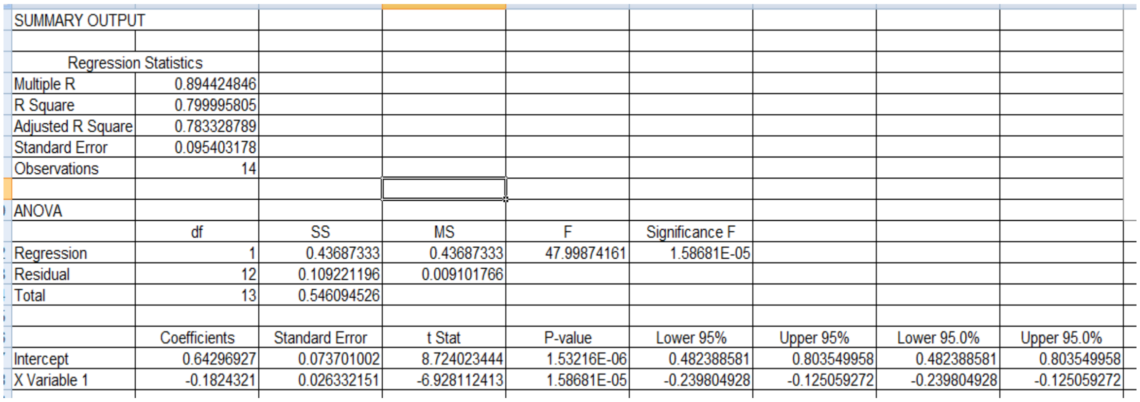


Fig.5.42 Adjusted Bid Projects Total Project Time Growth Data Distribution

for Low Complexity Projects



SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.894424846							
R Square	0.799995805							
Adjusted R Square	0.783328789							
Standard Error	0.095403178							
Observations	14							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	0.43687333	0.43687333	47.99874161	1.58681E-05			
Residual	12	0.109221196	0.009101766					
Total	13	0.546094526						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.64296927	0.073701002	8.724023444	1.53216E-06	0.482388581	0.803549958	0.482388581	0.803549958
X Variable 1	-0.1824321	0.026332151	-6.928112413	1.58681E-05	-0.239804928	-0.125059272	-0.239804928	-0.125059272

Fig.5.43 Adjusted Bid Projects Total Project Time Growth Simulation Summary for Low Complexity Projects

For the best value projects, the overall correlation is stronger than for adjusted bid. The schedule growth data distribution (Figure 5.44) and total project time growth spots distribution data distribution (Figure 5.46) indicate that there are very strong linear correlations. The critical procurement duration values are 3.45 months and 3.4 months. The Pearson values are also a little bit different. The schedule growth Pearson value is -0.9357 and the total project time growth Pearson value is -0.9369. The different simulation results (Figures 5.45 and 5.47) also prove that both analysis results are highly reliable. The linear correlation formula is listed below:

$$y = -0.2874x + 0.9813$$

The current analysis shows that linear correlation can be developed and reflected with best value more strongly than with adjusted bid projects with low complexity.

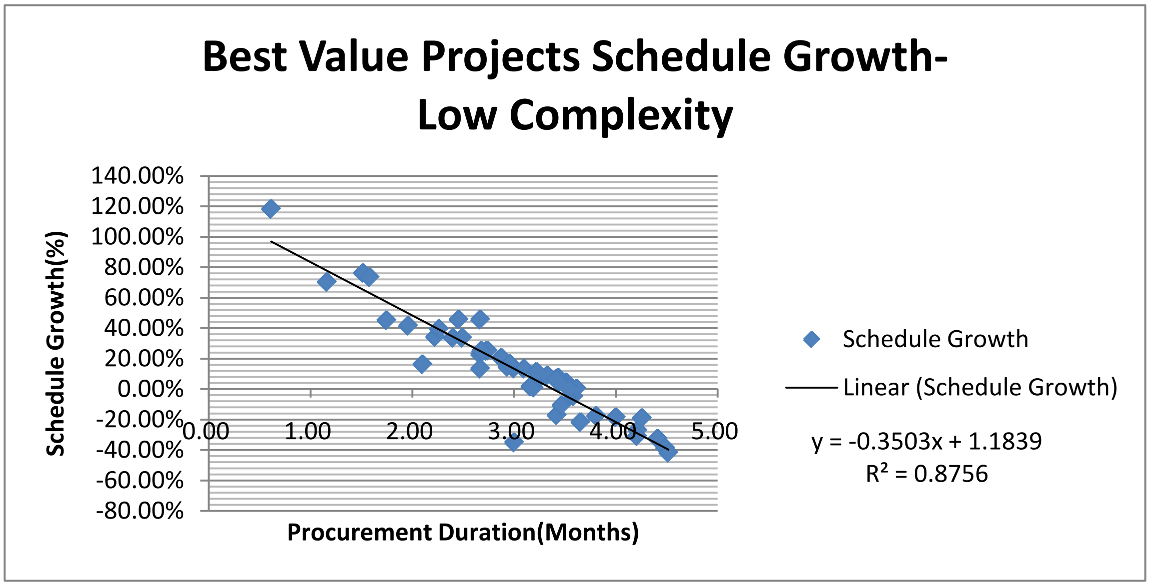
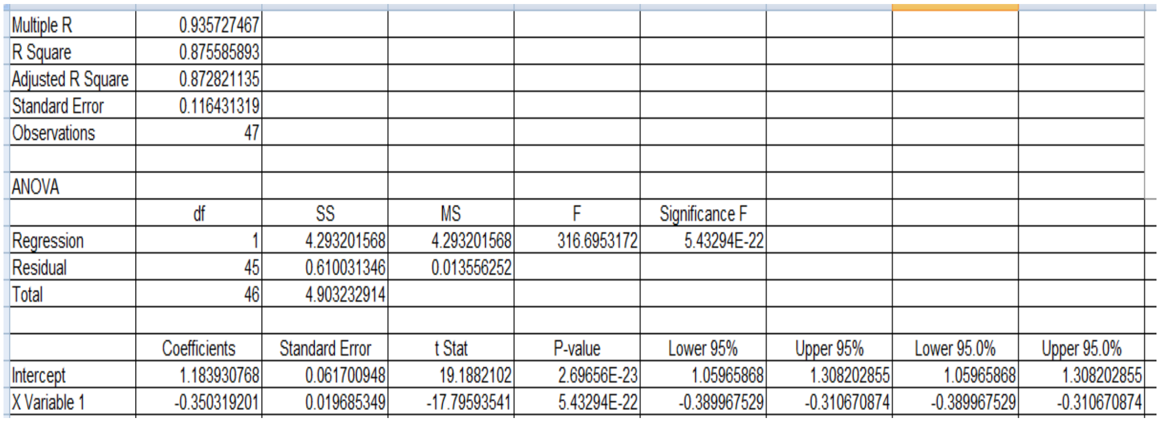


Fig.5.44 Best Value Projects Schedule Growth Data Distribution

for Low Complexity Projects



Multiple R	0.935727467							
R Square	0.875585893							
Adjusted R Square	0.872821135							
Standard Error	0.116431319							
Observations	47							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	4.293201568	4.293201568	316.6953172	5.43294E-22			
Residual	45	0.610031346	0.013556252					
Total	46	4.903232914						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	1.183930768	0.061700948	19.1882102	2.69656E-23	1.05965868	1.308202855	1.05965868	1.308202855
X Variable 1	-0.350319201	0.019685349	-17.79593541	5.43294E-22	-0.389967529	-0.310670874	-0.389967529	-0.310670874

Fig.5.45 Best Value Projects Schedule Growth Simulation Summary

for Low Complexity Projects

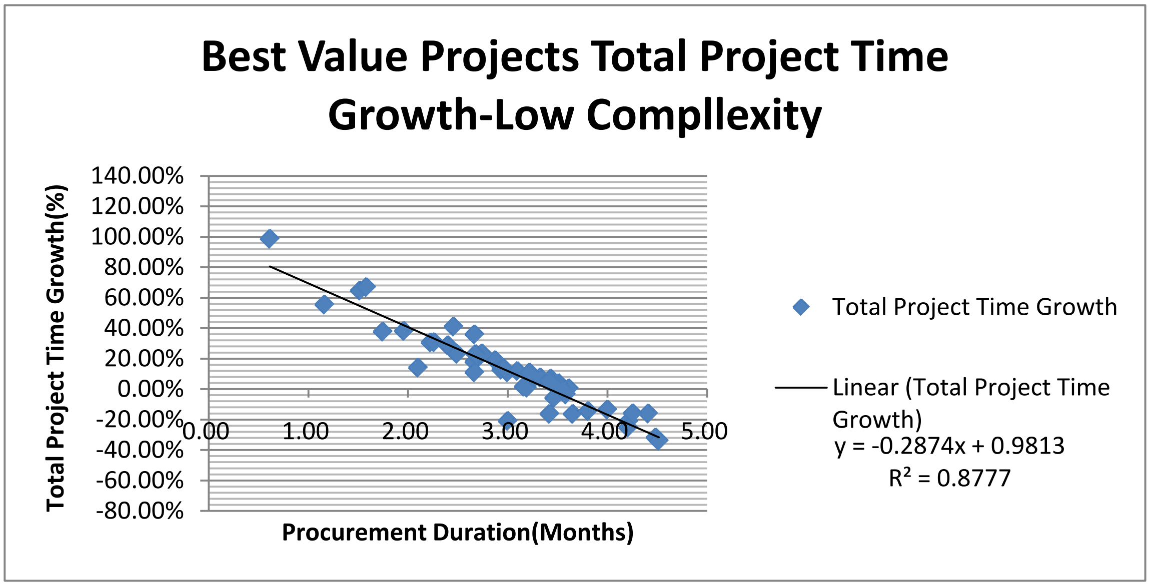
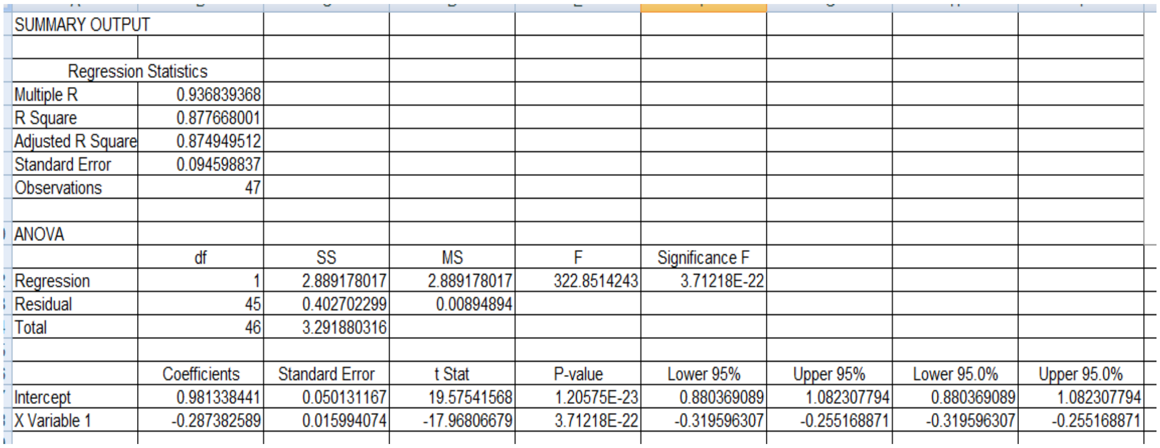


Fig.5.46 Best Value Projects Total Project Time Growth Spots Distribution for Low Complexity Projects



SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.936839368							
R Square	0.877668001							
Adjusted R Square	0.874949512							
Standard Error	0.094598837							
Observations	47							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	2.889178017	2.889178017	322.8514243	3.71218E-22			
Residual	45	0.402702299	0.00894894					
Total	46	3.291880316						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.981338441	0.050131167	19.57541568	1.20575E-23	0.880369089	1.082307794	0.880369089	1.082307794
X Variable 1	-0.287382589	0.015994074	-17.96806679	3.71218E-22	-0.319596307	-0.255168871	-0.319596307	-0.255168871

Fig.5.47 Best Value Projects Total Project Time Growth Simulation Summary for Low Complexity Projects

The strongest correlation results appear in low bid projects. The data distribution charts (Figures 5.48 and 5.50) show the strongest linear correlation. The schedule growth value will decrease fast along with procurement duration increasing. The critical procurement duration values are both 3.47 months. However, the Pearson value of schedule growth analysis is -0.9640 and this value is higher than total project time growth Pearson value, -0.9613. As a fact, -0.9640 is the highest value in all regression analysis. The following simulation tables (Figures 5.49 and 5.51) show that standard errors are only 0.0886 and 0.0754. The linear correlation formula is conducted as:

$$y = -0.3376x + 1.1555$$

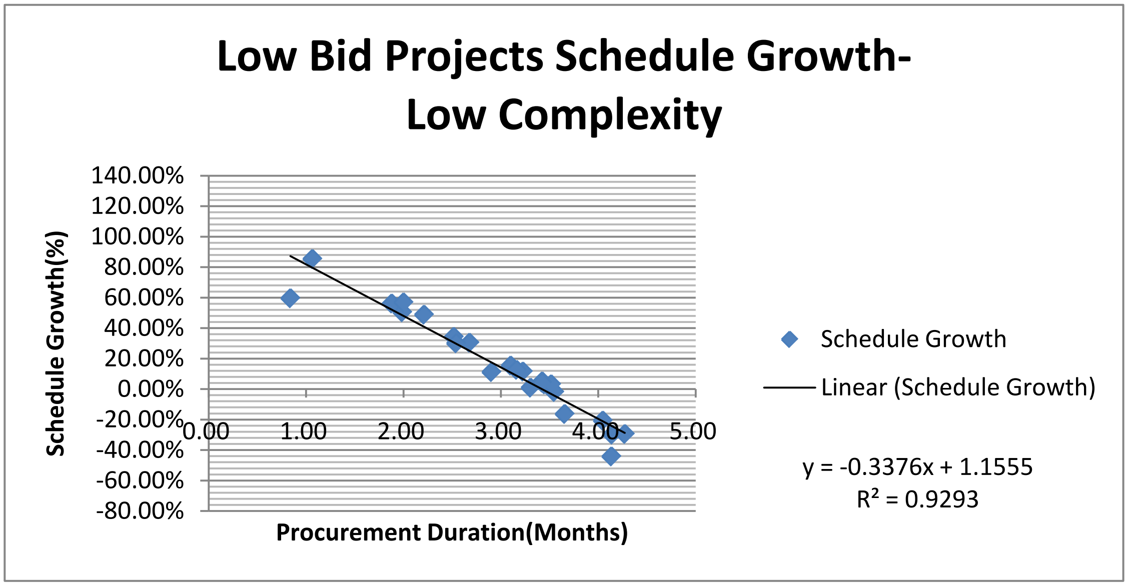
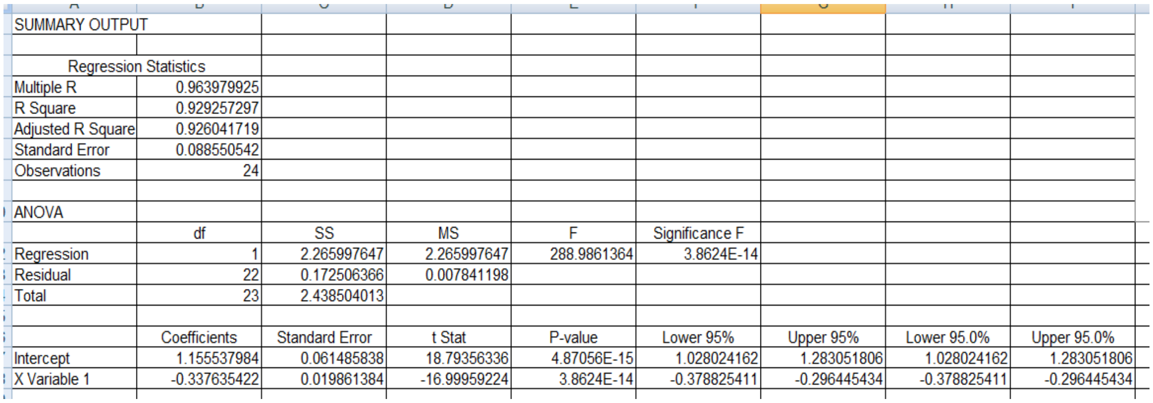


Fig.5.48 Low Bid Projects Schedule Growth Data Distribution

for Low Complexity Projects



SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.963979925							
R Square	0.929257297							
Adjusted R Square	0.926041719							
Standard Error	0.088550542							
Observations	24							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	2.265997647	2.265997647	288.9861364	3.8624E-14			
Residual	22	0.172506366	0.007841198					
Total	23	2.438504013						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	1.155537984	0.061485838	18.79356336	4.87056E-15	1.028024162	1.283051806	1.028024162	1.283051806
X Variable 1	-0.337635422	0.019861384	-16.99959224	3.8624E-14	-0.378825411	-0.296445434	-0.378825411	-0.296445434

Fig.5.49 Low Bid Projects Schedule Growth Simulation Summary

for Low Complexity Projects

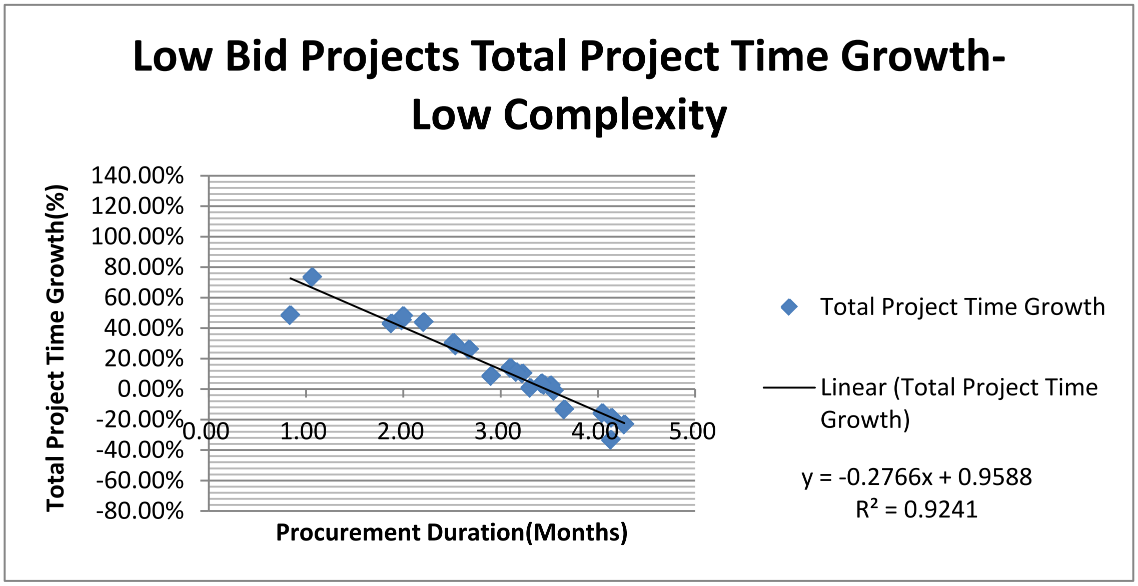
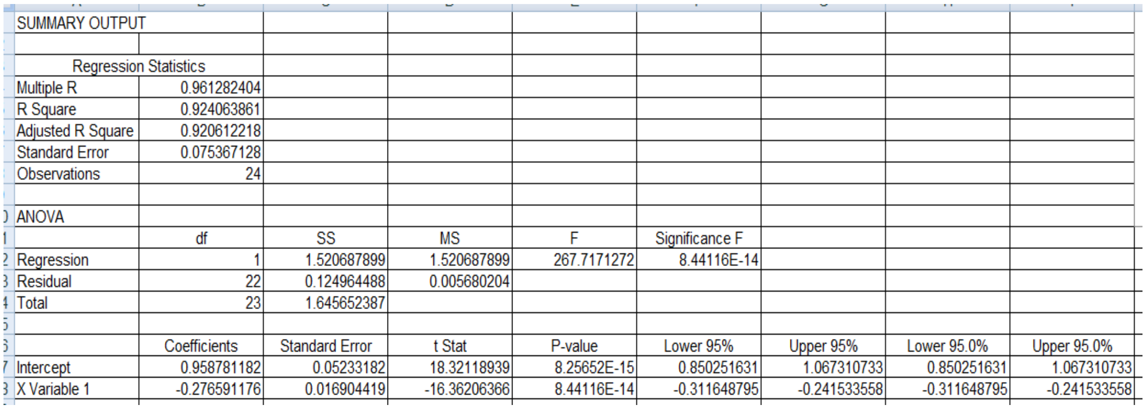


Fig.5.50 Low Bid Projects Total Project Time Growth Spots Distribution

for Low Complexity Projects



SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.961282404							
R Square	0.924063861							
Adjusted R Square	0.920612218							
Standard Error	0.075367128							
Observations	24							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	1.520687899	1.520687899	267.7171272	8.44116E-14			
Residual	22	0.124964488	0.005680204					
Total	23	1.645652387						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.958781182	0.05233182	18.32118939	8.25652E-15	0.850251631	1.067310733	0.850251631	1.067310733
X Variable 1	-0.276591176	0.016904419	-16.36206366	8.44116E-14	-0.311648795	-0.241533558	-0.311648795	-0.241533558

Fig.5.51 Low Bid Projects Total Project Time Growth Simulation Summary for Low Complexity Projects

In summary, this analysis, shows that the reflection degree of linear correlation between procurement duration and schedule performance is different with different complexity levels. The linear correlation is the weakest for high complexity projects and strongest for low complexity projects. Adjusted bid do not have a strong linear correlation but best value and low bid projects do have a strong linear correlation.

5.2 Procurement Duration and Cost Growth

The last regression analysis shows that there is a linear correlation between procurement duration and schedule growth. The following regression analysis focuses on procurement duration and cost growth. The same analysis methods and processes will be adopted as in the regression analysis of procurement duration and schedule growth.

The overall projects cost growth data distribution chart (Figure 5.52) doesn't show a strong linear trend between procurement duration and cost growth. The Pearson value is -0.2343 which means the linear correlation hypothesis is too weak to be accredited. The linear correlation simulation (Figure 5.53) shows that the R square value (0.0549) and adjusted R square value (0.0483) are very low and the standard error value is very high (0.1536). The simulation analysis proves

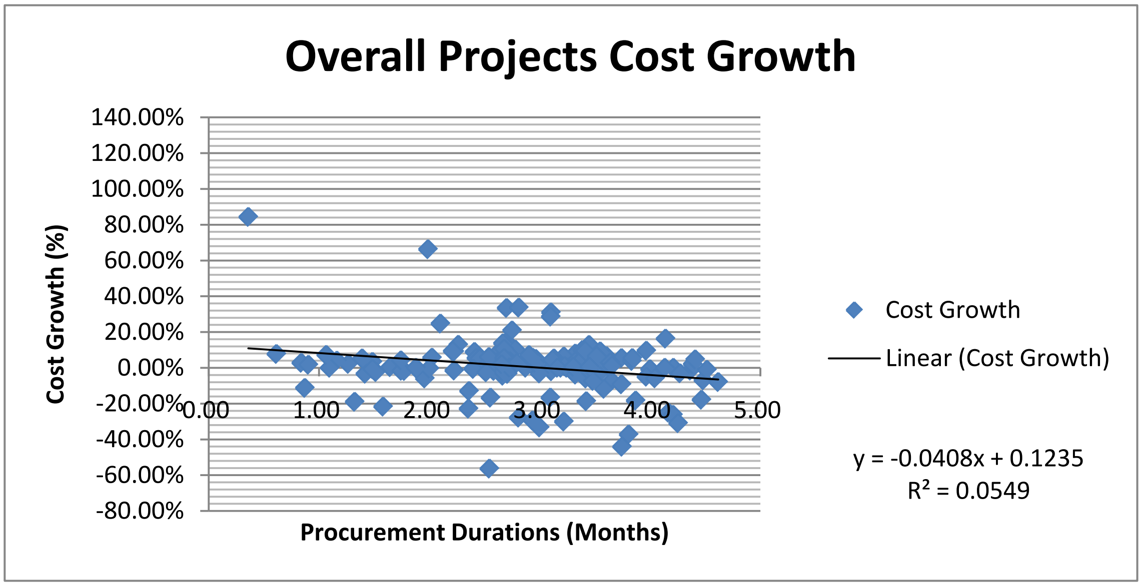
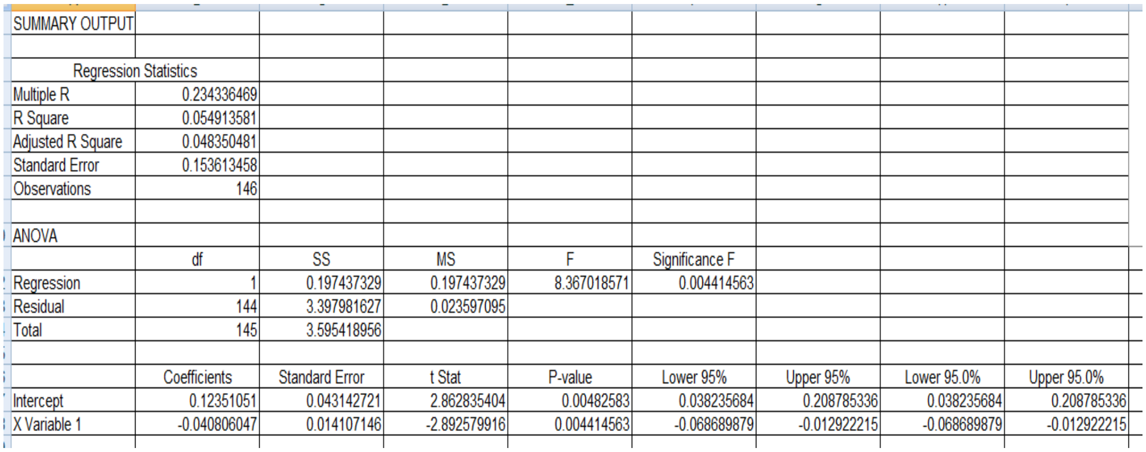


Fig.5.52 Overall Projects Cost Growth Data Distribution



SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.234336469							
R Square	0.054913581							
Adjusted R Square	0.048350481							
Standard Error	0.153613458							
Observations	146							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	0.197437329	0.197437329	8.367018571	0.004414563			
Residual	144	3.397981627	0.023597095					
Total	145	3.595418956						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.12351051	0.043142721	2.862835404	0.00482583	0.038235684	0.208785336	0.038235684	0.208785336
X Variable 1	-0.040806047	0.014107146	-2.892579916	0.004414563	-0.068689879	-0.012922215	-0.068689879	-0.012922215

Fig.5.53 Overall Projects Cost Growth Simulation Summary

that the linear correlation between the two factors is very weak.

The cost growth residual plot (Figure 5.54) shows that all data points are distributed randomly and “ruleless”. There is no indication that they have a relationship. Also, the normal distribution plot (Figure 5.55) shows the same situation, the cure is very flat and no peak point. No linear or non-linear correlation exists between procurement duration and cost growth.

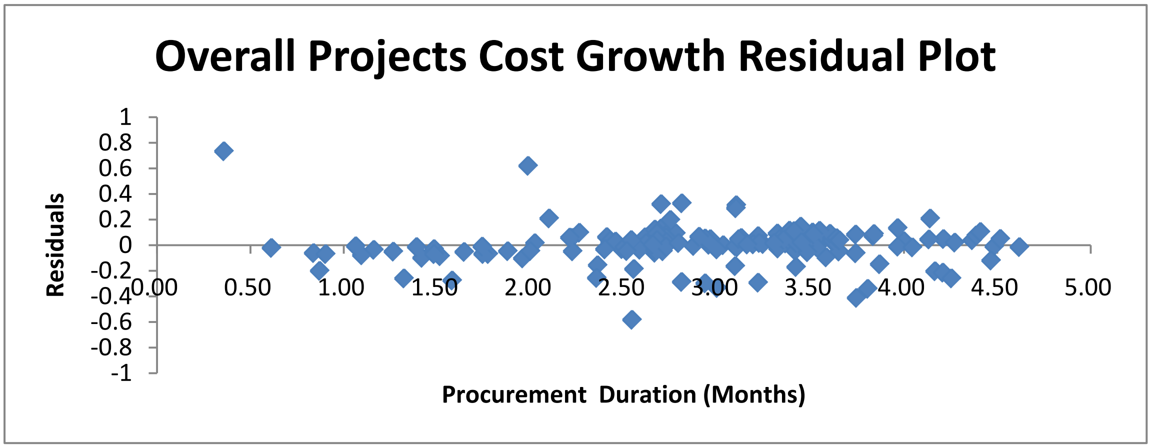


Fig.5.54 Overall Projects Cost Growth Residual Plot

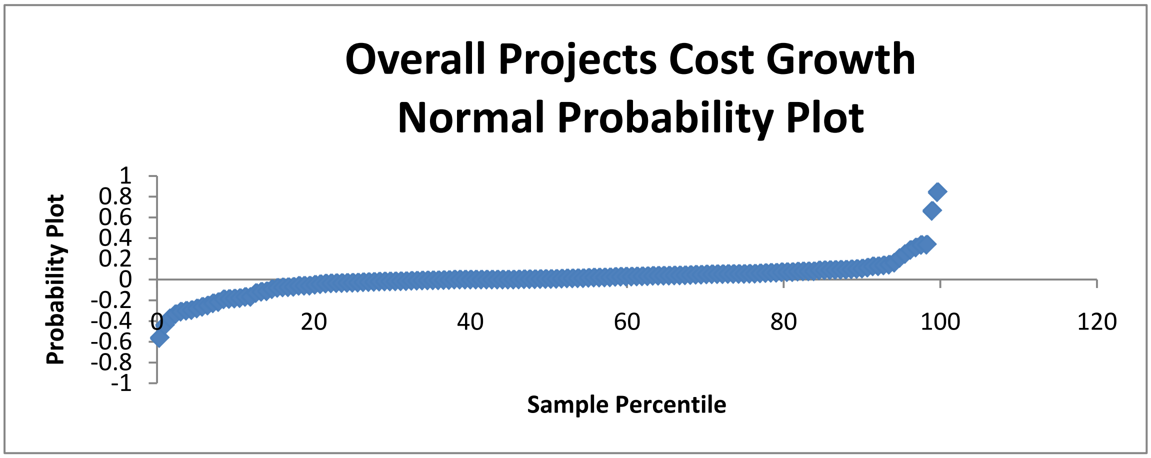


Fig.5.55 Overall Projects Cost Growth Probability Plot

5.2.1 Different Selection Methods Regression Analysis

Even though the overall projects analysis doesn't show any correlation between the two factors, the following analysis based on selection methods may support different conclusions. Three different selection methods data distribution charts (Figures 5.56, 5.57 and 5.58) illustrate similar results to the overall projects analysis. The Pearson values for the adjusted bid, best value and low bid projects are -0.4492, -0.090and -0.305. Those correlation coefficients are too low to show enough reliability. The correlation simulations also indicate very high standard error values which are 0.1935, 0.1466 and 0.1498. The different analysis parameters show that there isn't any linear correlation between procurement duration and cost growth in Design-Build Projects with any of the selection methods.

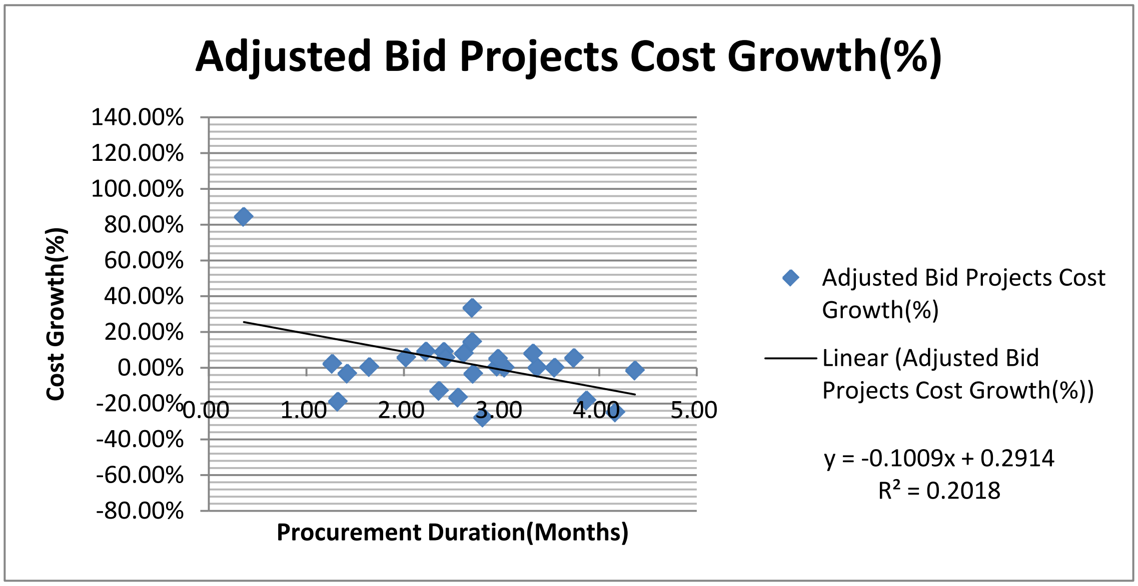


Fig.5.56 Adjusted Bid Projects Cost Growth Data Distribution

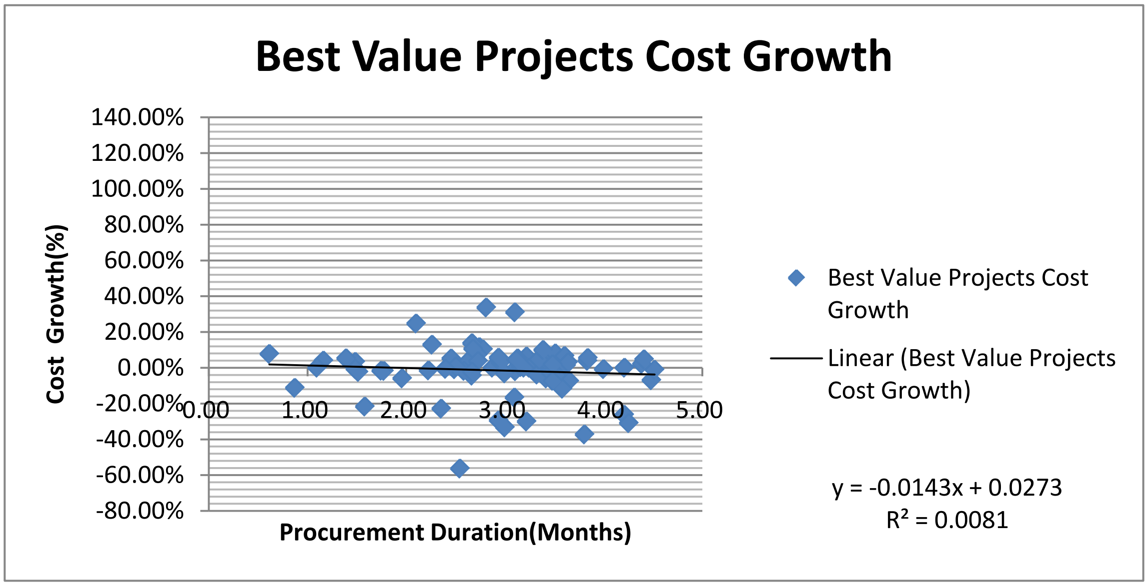


Fig.5.57 Best Value Projects Cost Growth Data Distribution

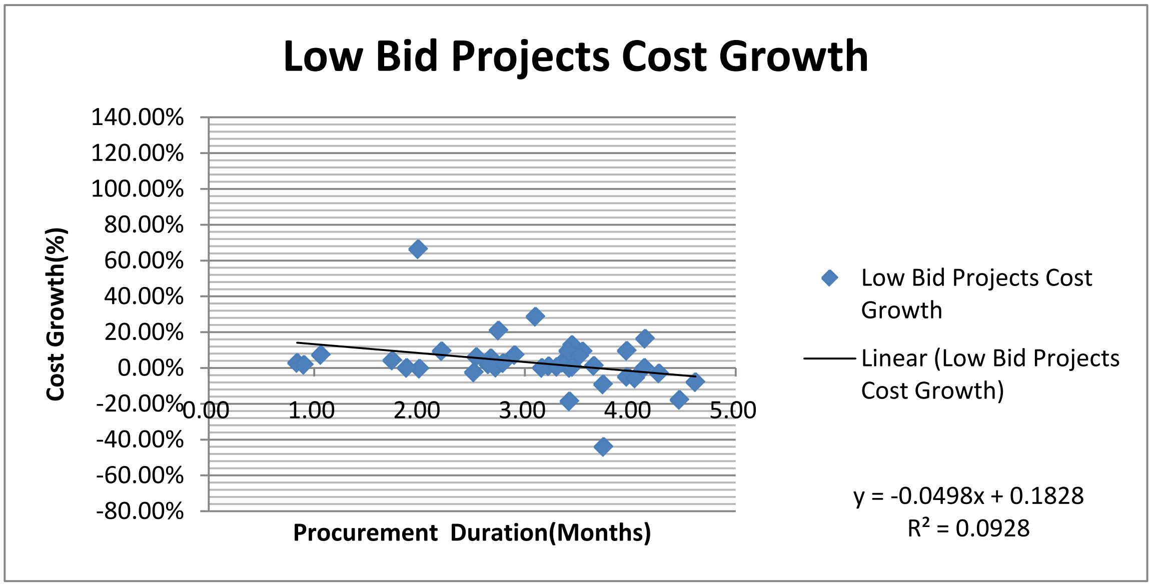


Fig.5.58 Low Bid Projects Cost Growth Data Distribution

The non linear correlation analysis also supports the same trend. The residual plot charts (Figures 5.59, 5.61 and 5.63) show the data points are very close to the X axis. The residual plots for adjusted bid projects, best value projects and low bid projects are very weak and they do not reflect any correlation. The three normal distribution plots (Figures 5.60, 5.62 and 5.64) don't show any normal distribution trend based on the current data points. The trends are all flat and don't show the peaks.

The current regression analysis shows that there isn't any relationship between procurement duration and cost growth in Design-Build projects with different selection methods. It seems that the selection method in procurement won't affect cost performance in Design-Build projects.

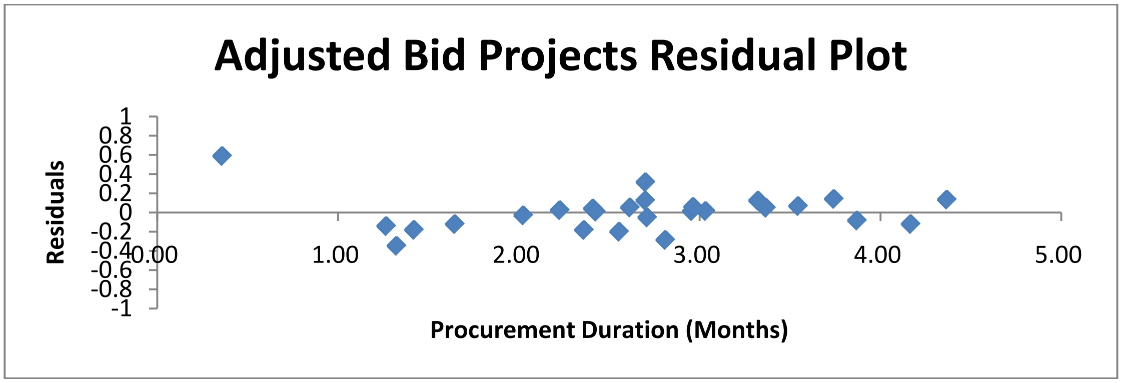


Fig.5.59 Adjusted Bid Projects Cost Growth Residual Plot

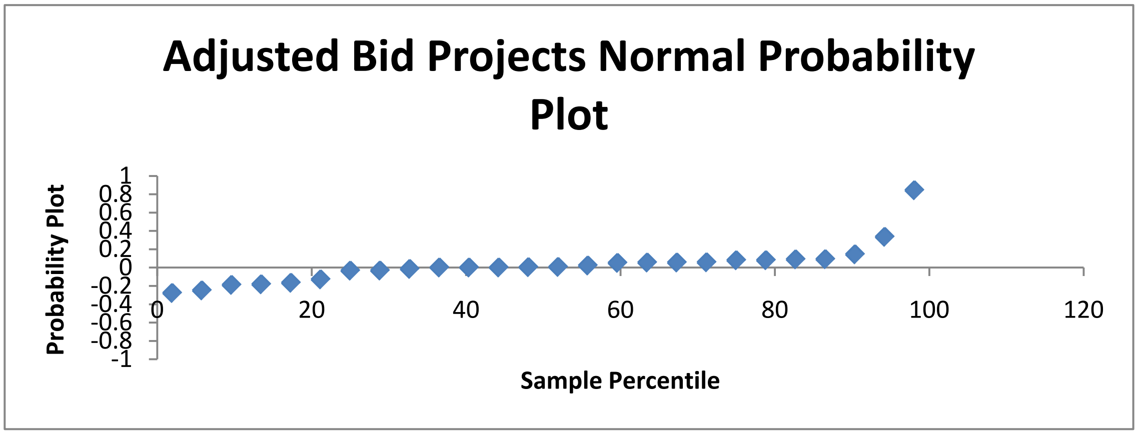


Fig.5.60 Adjusted Bid Projects Cost Growth Probability Plot

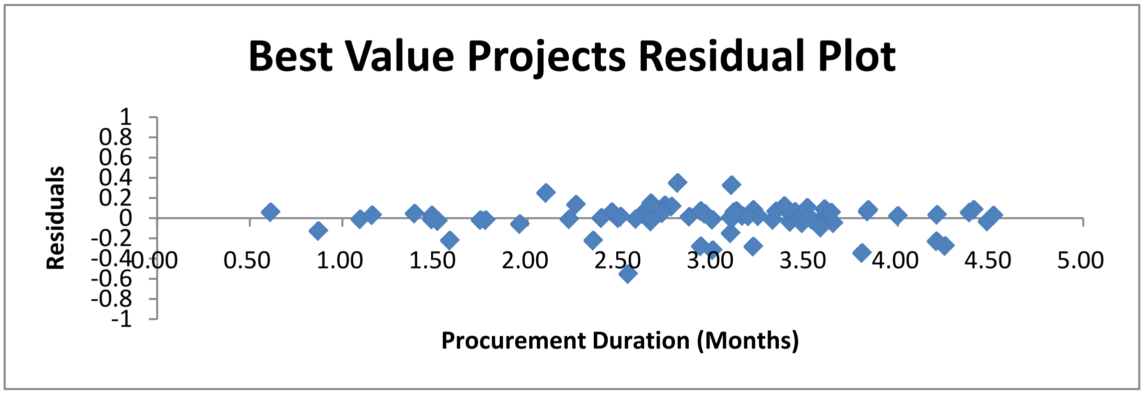


Fig.5.61 Best Value Projects Cost Growth Residual Plot

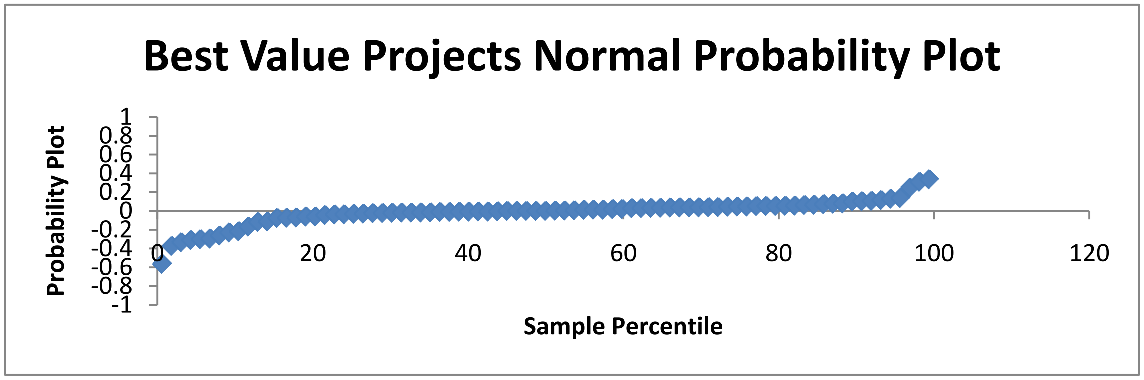


Fig.5.62 Best Value Projects Cost Growth Probability Plot

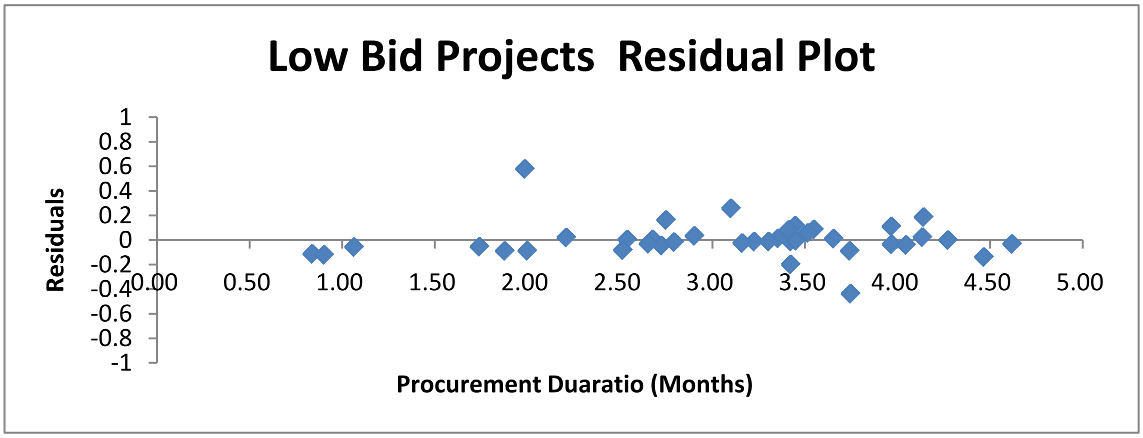


Fig.5.63 Low Bid Projects Cost Growth Residual Plot

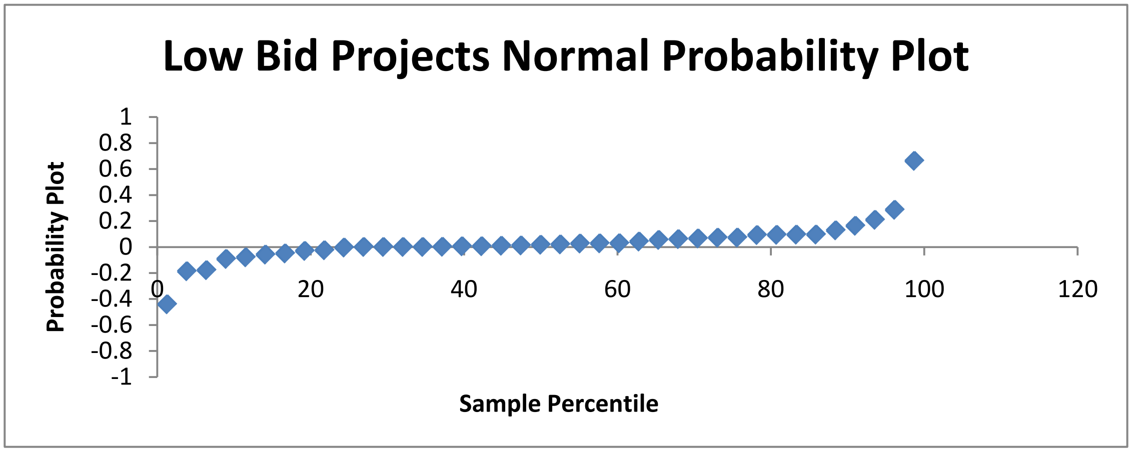


Fig.5.64 Low Bid Projects Cost Growth Probability Plot

5.2.2 Different Complexity Levels Based Regression Analysis

This regression analysis will focus on project complexity levels. The different complexity level based cost growth data distribution charts (Figures 5.65, 5.66 and 5.67) do not show any strong linear correlation between procurement duration and cost growth under different complexity levels. All the Pearson values are very weak, especially for high complexity level projects. The Pearson value for high complexity projects is +0.0381, which is the weakest one and it shows there is little linear relationship between the two factors. The other two Pearson values are very low too. The Pearson value for medium complexity projects is only 0.1099 and the Pearson value for low complexity projects is 0.3687. The regression analysis also shows that there is little linear correlation between these two factors because the R square value, and adjusted R value are very low but standard errors are very high.

The non linear regression analysis shows the same situation. The residual data charts (Figures 5.68, 5.70 and 5.72) indicate that there is no data bias for the factors. All residual plot points are randomly distributed around the standard axis. And that means the non linear correlation between two factors is very unclear and there is little relationship between those two factors under any different complexity level. Also, the three normal distributions charts (Figures 5.69, 5.71 and 5.73) show that the distribution trends are very flat. Most data are on the standard axis which means there is no bias and peak.

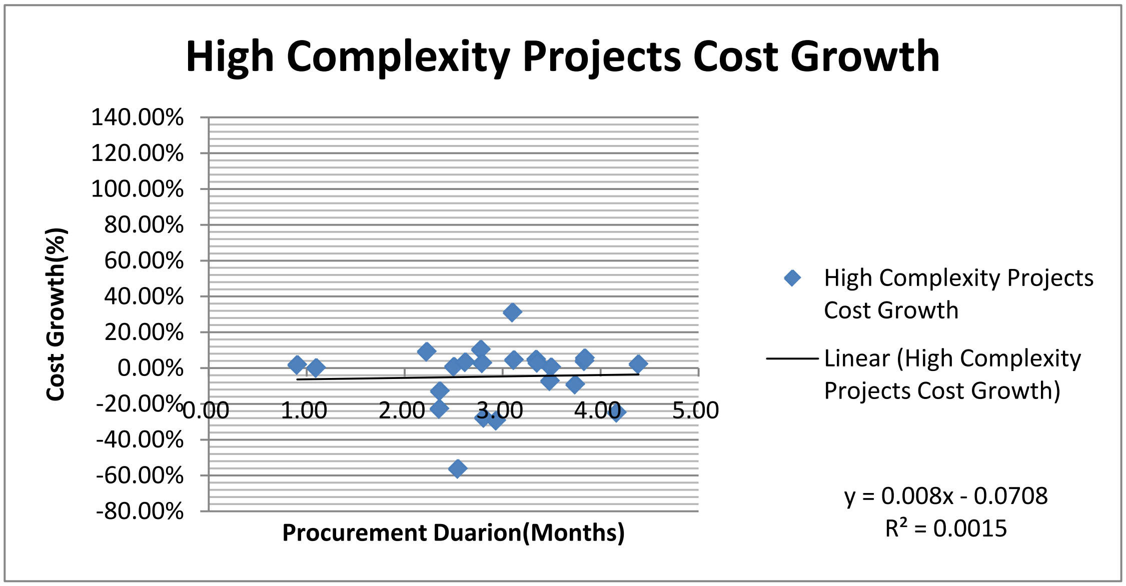


Fig.5.65 High Complexity Projects Cost Growth Data Distribution

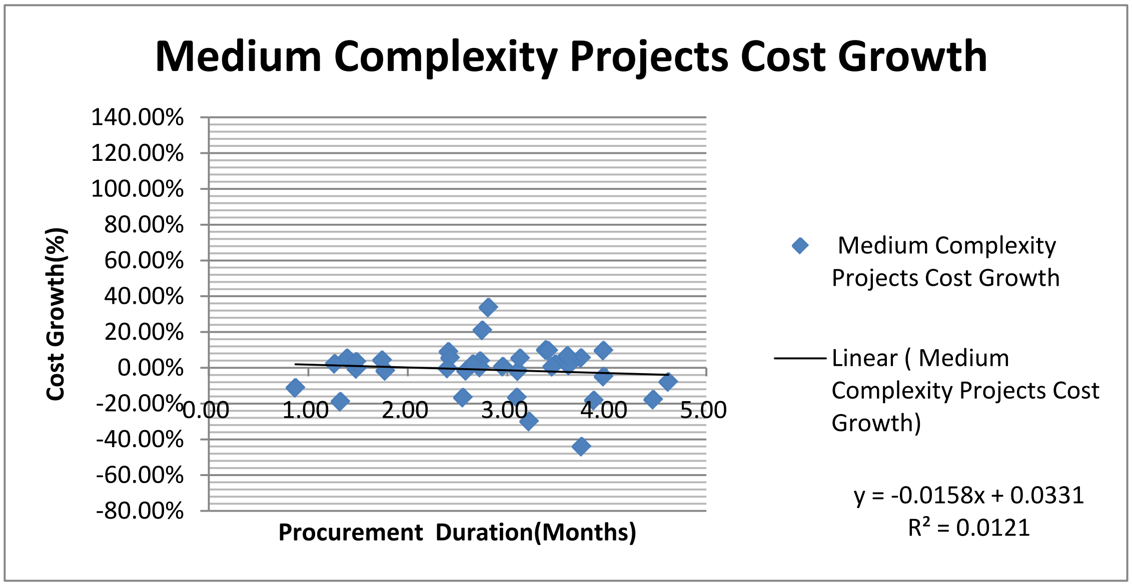


Fig.5.66 Medium Complexity Projects Cost Growth Data Distribution

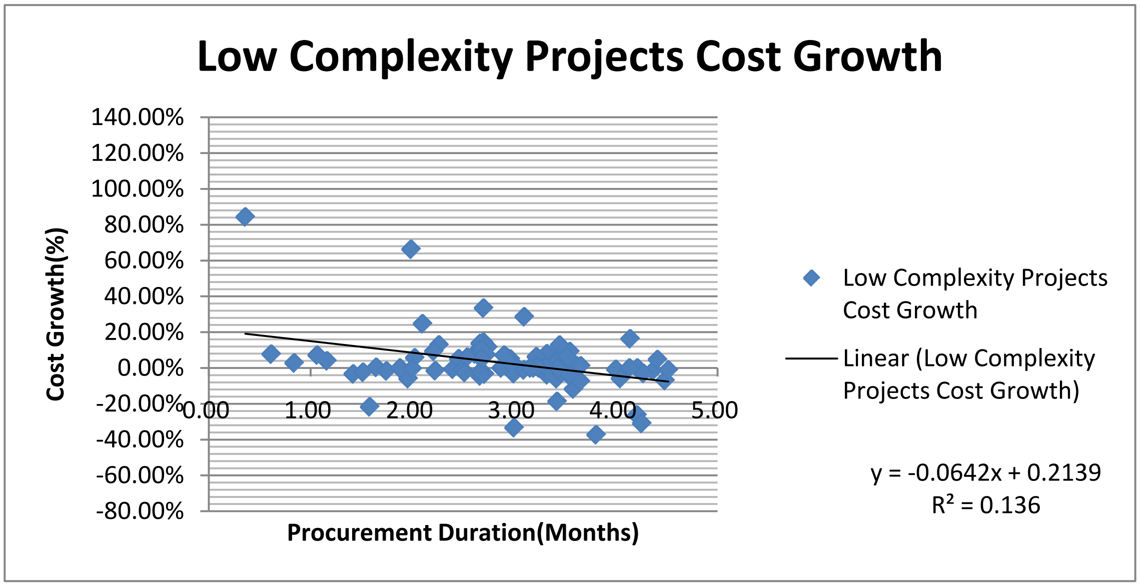


Fig.5.67 Low Complexity Projects Cost Growth Data Distribution

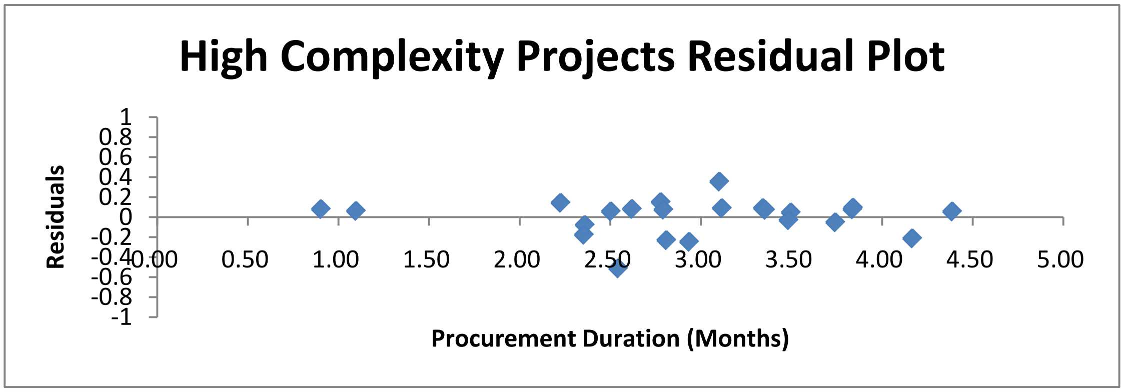


Fig.5.68 High Complexity Projects Cost Growth Residual Plot

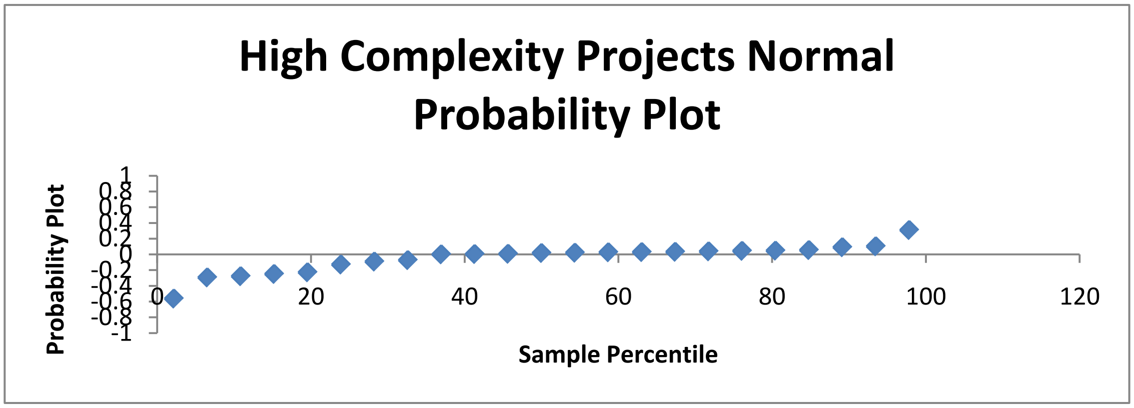


Fig.5.69 High Complexity Projects Cost Growth Probability Plot

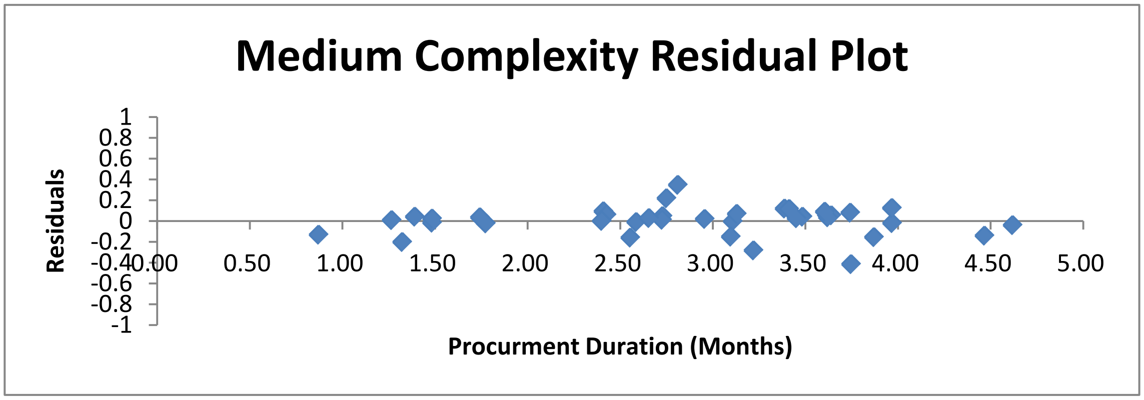


Fig.5.70 Medium Complexity Projects Cost Growth Residual Plot

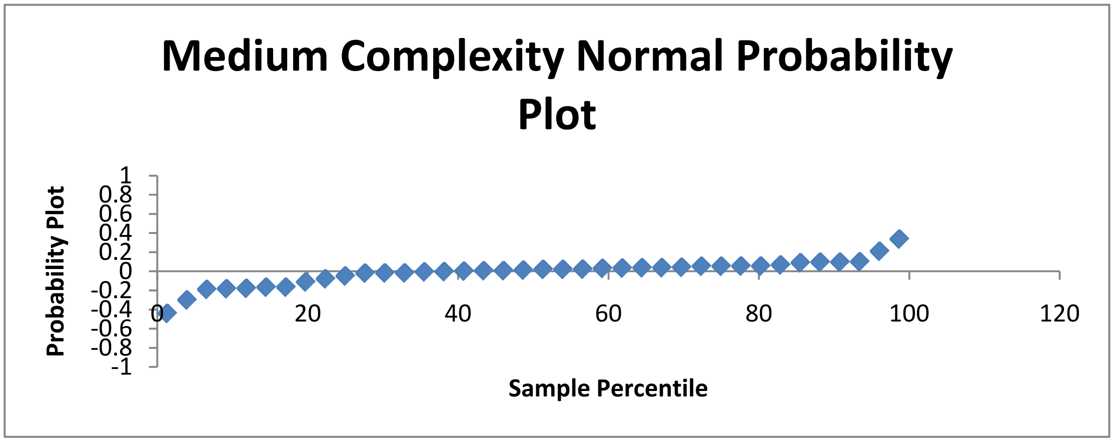


Fig.5.71 Medium Complexity Projects Cost Growth Probability Plot

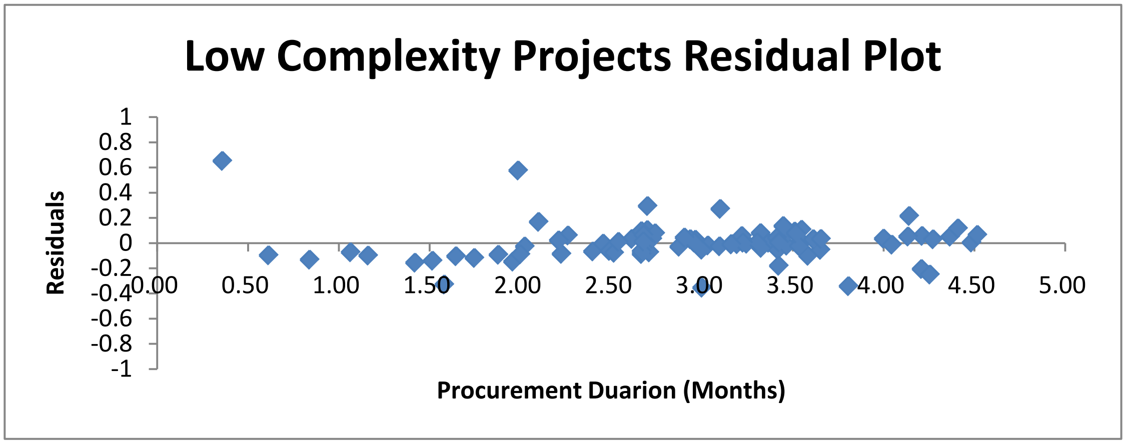


Fig.5.72 Low Complexity Projects Cost Growth Residual Plot

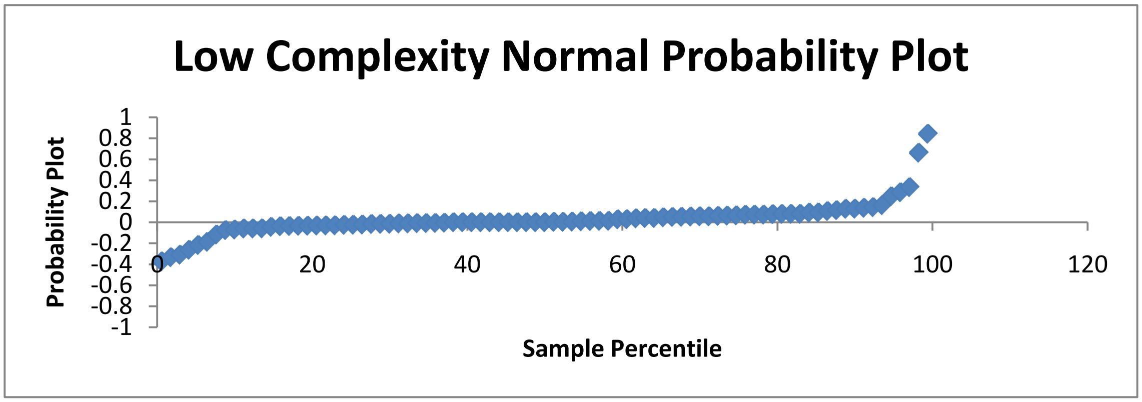


Fig.5.73 Low Complexity Projects Cost Growth Probability Plot

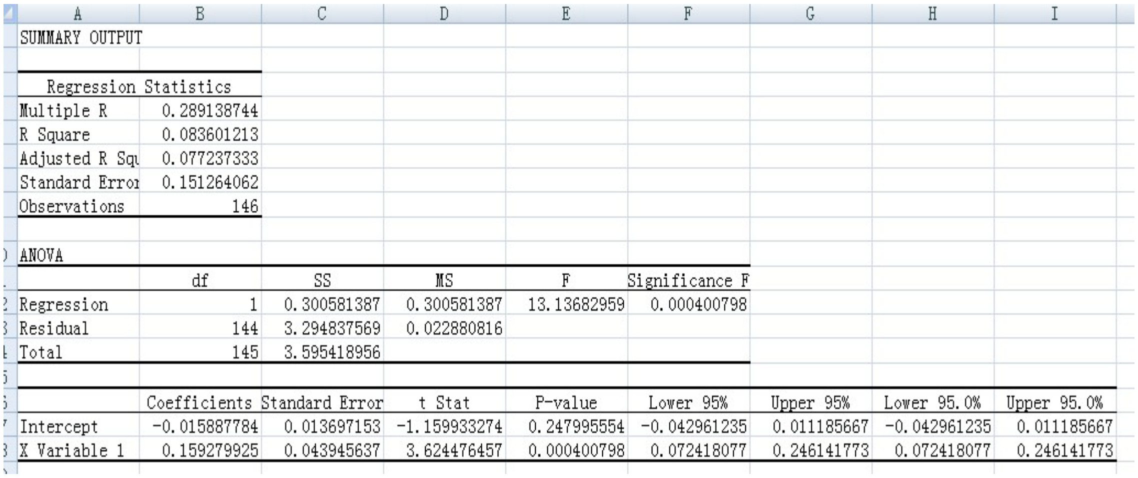
More analyses were conducted based on the different selection methods in procurement under different complexity levels. All the analysis results show that there is little linear correlation with low bid type and best value type under low complexity level and medium complexity level. The adjusted bid type shows the weakest analysis results under any complexity level. The different selection method analyses have the worst analysis results under medium complexity level and better analysis results under low complexity. All the Pearson values, R square values, adjusted values and standard errors in each analysis are too low to support enough reliability coefficients to prove a linear correlation between procurement duration and cost growth. Also, the non-linear analyses show that all analysis parameters have little bias in the residual plot distribution and a very flat trend in the normal distribution plot. Those results show that there is also no clear evidence to prove a strong non linear correlation between procurement duration and cost growth.

After careful research and multi-regression analysis, it can say that the procurement duration and cost growth does not have any relationship (linear or non-linear) in Design-Build projects. In conclusion, the hypothesis “the longer the procurement duration, the less cost growth value and more project success” is not proven.

5.3 Cost Growth and Schedule Growth Analysis

Besides the main analyses, additional analysis is conducted in this section. The correlation analysis between schedule growth and cost growth will be studied in this part in order to get a broader understanding and make the main research more integrated.

The linear regression analysis result (Figure 5.74) shows that the Person value is 0.29 which means there is very weak linear correlation between cost growth and schedule growth. Also, the data distribution chart (Figure 5.75) shows a very weak linear trend and the R square value is 0.0836 which is not strong enough to support the linear relationship.



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.289138744
R Square	0.083601213
Adjusted R Squ	0.077237333
Standard Error	0.151264062
Observations	146

ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.300581387	0.300581387	13.13682959	0.000400798
Residual	144	3.294837569	0.022880816		
Total	145	3.595418956			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-0.015887784	0.013697153	-1.159933274	0.247995554	-0.042961235	0.011185667	-0.042961235	0.011185667
X Variable 1	0.159279925	0.043945637	3.624476457	0.000400798	0.072418077	0.246141773	0.072418077	0.246141773

Fig. 5.74 The Overall Projects Cost Growth vs. schedule Growth Simulation Summary

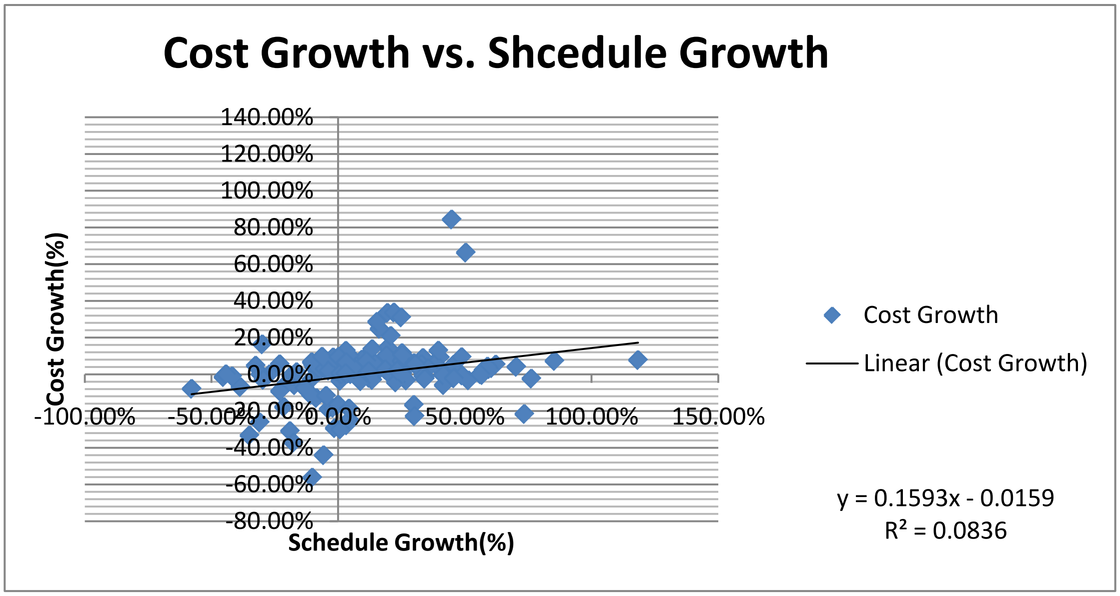


Fig. 5.75 Overall Projects Cost Growth vs. Schedule Growth Data Distribution

The normal probability plot chart (Figure 5.76) and residual plot chart (Figure 5.77) show that there is no normal distribution relationship between cost growth and schedule grow. The residual plot doesn't indicate any non-linear correlation.

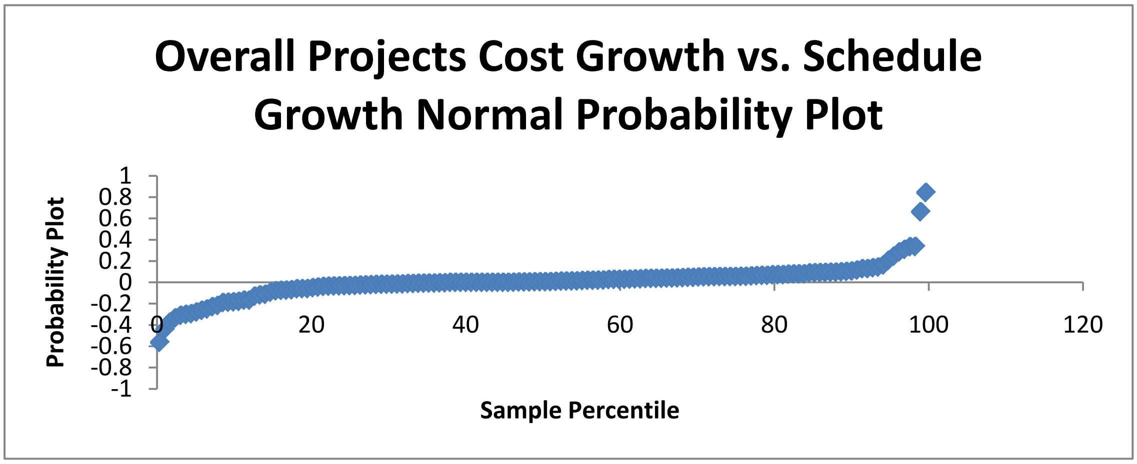


Fig. 5.76 Overall Projects Cost Growth vs. Schedule Growth Normal Probability Plot

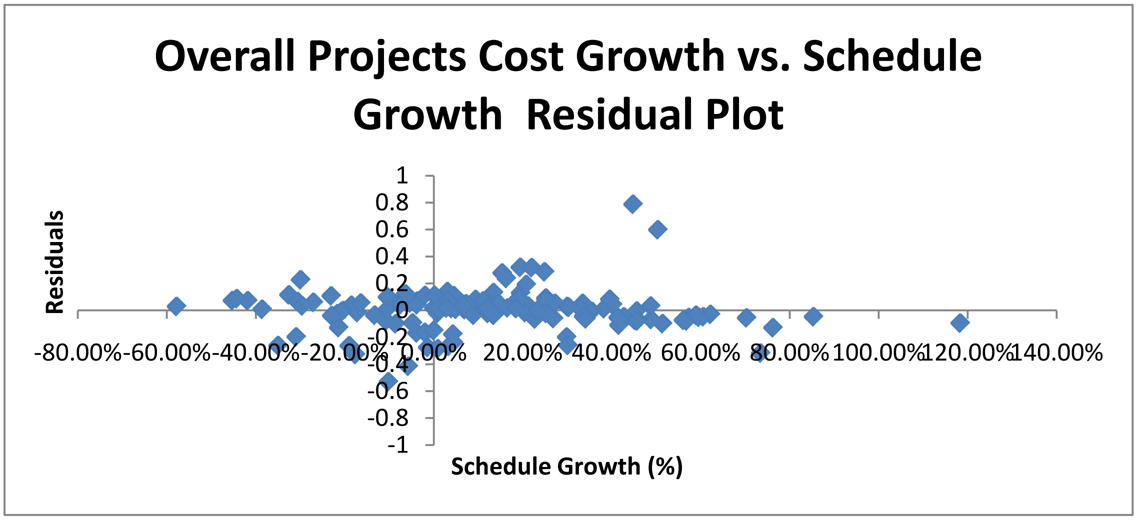


Fig. 5.77 Overall Projects Cost Growth vs. Schedule Residual Plot

Based on the additional analysis, it can be concluded that there is no relationship between cost growth and schedule growth in Design-Build projects.

CHAPTER 6. CONCLUSION

This study investigates the relationship between procurement duration and project success in Design-Build transportation projects. In this research, the project success is measured by cost growth and schedule growth. There are data from 146 Design-Build projects used in this research.

In the beginning of this research, some hypotheses were made and expected to be answered:

- The longer the procurement duration, the lower the awarded bidder’s schedule growth performance in construction.
- The longer the procurement duration, the lower the awarded bidder’s cost growth performance in construction.
- Different selection methods will affect the relationship between procurement duration and project success.
- Project complexity will affect the relationship between procurement duration and project success.

The main conclusions of this research are list below:

(1) There is a strong linear correlation between schedule growth and procurement duration in Design-Build transportation projects. The longer the procurement duration, the lower the project schedule growth.

(2) There is no relationship between procurement duration and cost growth.

The procurement duration won’t affect cost growth.

(3) There is no relationship between cost growth and schedule growth in Design-Build projects.

(4) There is a critical procurement duration value that exists. If procurement duration is below this value, most projects can’t be delivered on time. If the procurement duration is above this critical value, then most projects can be delivered on time or even earlier than the scheduled delivery time.

(5) The critical procurement duration value is not fixed. It depends on different procurement selection methods (Table 6.1). For all projects, the critical procurement duration value is 3.4 months. But the critical value under the adjusted bid selection method is 3.7 months. The critical value for best value and low bid based selection methods are 3.4 months and 3.5 months. All the analysis results show that the linear correlation between procurement duration and schedule growth exists in all Design-Build projects no matter what kind of selection method the agency adopts.

Table 6.1 Different Selection Methods Analysis Summary

	Overall	Adjusted Bid	Best Value	Low Bid
Average Procurement Duration	2.9 Months	2.7 Months	2.9 Months	3.1 Months
Schedule Growth	Strong Linear Correlation	Good Correlation	Better Correlation	Best Correlation
Critical Value	3.4 Months	3.7 Months	3.4 Months	3.5 Months
Cost Growth	No Correlation	Not Applicable	Not Applicable	Not Applicable

(6) This research shows that the degree of linear correlation between procurement duration and schedule performance is different with different complexity levels (Table 6.2). The average procurement durations are very close among different complexity levels, but low complexity projects have the smaller critical value. A linear correlation can not be shown for high complexity projects. The lack of design completion and a lot of uncertain factors in construction may cause this phenomenon. The procurement duration does not strongly affect schedule performance in high complexity Design-Build projects. A linear correlation can be shown for medium

complexity projects. In medium complexity projects, adjusted bid projects do not show a linear correlation but best value and low bid projects do show a linear correlation well especially for low bid. The low complexity level projects show the strongest linear correlation.

Table 6.2 Different Complexity Projects Analysis Summary

	Overall	High Complexity	Medium Complexity	Low Complexity
Average Procurement Duration	2.9 Months	3.0 Months	2.9 Months	2.9 Months
Schedule Growth	Strong Linear Correlation	No Correlation	Good Correlation	Best Correlation
Critical Value	3.4 Months	Not Applicable	3.5 Months	3.4 Months
Cost Growth	No Correlation	Not Applicable	Not Applicable	Not Applicable

(7) Even though the analysis results show that the Pearson value is too low to support a linear correlation between cost growth and procurement duration, the results are still significant. A comparison table is listed below (Table 6.3).

Different selection methods have different effects under different complexity levels. It is suggested to use adjusted bid type in high complexity if the public agency wants to control project cost. If procurement duration is long enough, adjusted bid can result in the least cost growth value for high complexity projects. It is also suggested to adopt low bid selection method in medium complexity projects if agencies want to limit delivery time and avoid unnecessary schedule growth.

Table 6.3 Selection Combination

	High Complexity	Medium Complexity	Low Complexity
Cost Emphasized Selection	Adjusted Bid		Best Value
Schedule Emphasize Selection		Low Bid	Low Bid Best Value
Both Emphasize Selection	Adjusted Bid	Low Bid	Best Value

Best value is the perfect choice in low complexity projects. Best value has the longest procurement duration but the least cost growth value, the least schedule growth value, and the least total project time growth value. Adjusted bid is strongly not recommended in low complexity projects. Adjusted bid has the shortest procurement duration value in low complexity projects which means the agency and design-builder can start to execute the contract quicker than other selection types. However, adjusted bid performs the worst when considering all projects. It has the largest cost growth value and schedule growth value. If an agency decides to choose this type for low complexity projects, they may have higher cost and schedule growth. Best value has better project performance than any other type. Best value also has the best schedule performance in high complexity projects. Due to the better overall performance of best value type, here it is strongly suggested that a public agency use best value in their future Design-Build projects, especially low complexity projects.

Some reasons may lead to these results:

(1) Companies have more incentive to save delivery time so that they can start other projects; so if they are given more time in procurement, they can get:

Better scheduling (more breakdown, overlapping)

Better planning

Advanced methods, equipment and materials

(2) Companies and DOTs do not share the cost so less attention is paid on price bid.

(3) DOTs have no incentive to bring in their projects under cost.

This paper researched the relationship between procurement duration and project success in Design-Build. There is no evidence to show that procurement duration and cost growth, or cost growth and schedule growth have any sort of correlation. A longer procurement duration won’t bring lower cost growth. However, the research shows that there is a very strong linear correlation between procurement duration and schedule performance in Design-Build projects. The effect of this linear correlation will vary with different procurement selection methods and project complexity. The recommendation is for agencies to pay more attention to their procurement durations and to adopt appropriate selection methods under different complexity levels in Design-Build projects in order to reduce the schedule growth and improve project success in the future.

Appendix A

The appendix A includes all the projects that used in this research. 146 highway projects are collected and analyzed in this research. The appendix table includes individual project name, RFP issue party, RFP issue date, RFP due date, contract price, actual price, contracted days, actual construction days, data source and award method.

All the data are summarized in the following table. Most data come from Florida DOT and other state DOTs. All the data are collected through four sources: state DOTs, benchmarking study, D-B effectiveness research, and some public website.

No.	Project Name	Issued Party	RFP Issue Date	RFP Due Date	Contract Price(	Actual Price(	Contracted Days(	Actual Days	Source	Award Method
1	Mid-Corridor Project	Alabama Corrid	1/21/1998	7/1/1998	697.64	712.00	1305	1201	Alabama Corridor	Best Value
2	The Whittier Access Proje	Alaska DOT and	6/30/1997	11/4/1997	80.00	60.00	698	729	Alaska DOT and P	Adjusted Bid
3	US 60 DB Widening Peojec	Arizona DOT	2/18/2001	4/29/2001	239.00	208.00	852	779	Bemchmarking Stu	Adjust Bid
4	Southeast Corridor Multi-M	Colorado DOT	11/1/2000	3/23/2001	1840.00	1670.00	2577	1986	Colorado DOT	Upset Limit
5	I-95 Milling & ResurfacingF	Florida DOT	2003/8/1	10/10/2003	2.74	2.74	89	97	D-B Effectiveness	Adjusted Bid
6	SR-9/I-95 NB/SB Martin C	Florida DOT	2002/11/26	2/28/2003	13.17	14.34	460	614	Florida DOT	Adjusted Bid
7	SR-9/I-95/HOV from Brow	Florida DOT	2003/2/4	5/1/2003	15.14	15.23	540	657	Florida DOT	Adjusted Bid
8	South Florida rail Corridor	Florida DOT	2002/12/28	3/1/2003	1.46	1.41	401	509	Florida DOT	Adjusted Bid
9	SR-9/I-95/I-595 ITS Phase	Florida DOT	2003/8/25	11/21/2003	2.75	2.76	763	1089	Florida DOT	Adjusted Bid
10	SR-7/US-441 Noisewalls	Florida DOT	2004/11/1	12/17/2004	1.60	1.83	241	288	Florida DOT	Adjusted Bid
11	Guard rail at 8 interchang	Florida DOT	2005/12/27	4/7/2006	5.06	4.98	400	219	Florida DOT	Adjusted Bid
12	Broward County ITS Pow	Florida DOT	2007/6/28	9/8/2007	1.40	1.40	450	450	Florida DOT	Adjusted Bid
13	I-4 St. Johns River to Sax	Florida DOT	2000/8/1	11/29/2000	101.93	111.16	1090	1528	Florida DOT	Adjusted Bid
14	Intergate Intelligent Transp	Florida DOT	2001/1/20	2/28/2001	0.70	1.29	375	543	Florida DOT	Adjusted Bid
15	SR 400 (I-4) Auxilary lane	Florida DOT	2001/11/27	1/16/2002	3.95	5.27	365	436	Florida DOT	Adjusted Bid
16	Reconstruction I-95 from	Florida DOT	2002/1/10	4/15/2002	16.90	17.82	420	558	Florida DOT	Adjusted Bid
17	I-4 - Median GuardrailINTE	Florida DOT	2004/11/1	1/5/2005	3.60	3.48	210	318	Florida DOT	Adjusted Bid
18	I-75 (WIM) - S.B. Administ	Florida DOT	2005/11/11	1/1/2006	2.27	2.27	315	319	Florida DOT	Adjusted Bid
19	ATMS SR-5/US-1 SW 17	Florida DOT	2006/2/25	4/27/2006	6.00	6.34	483	668	Florida DOT	Adjusted Bid
20	ADD LANES @ LEESBUR	Florida DOT	2005/1/3	3/29/2005	9.99	10.78	550	700	Florida DOT	Adjusted Bid
21	SUNNAV ITS: TPKMAINLI	Florida DOT	2005/5/7	8/7/2005	13.39	13.68	389	612	Florida DOT	Adjusted Bid
22	SAWGRASS ORTRAMPC	Florida DOT	2006/5/6	8/22/2006	13.84	14.59	603	543	Florida DOT	Adjusted Bid
23	SAWGRASS ORTSMART	Florida DOT	2007/4/29	6/14/2007	3.59	3.77	340	412	Florida DOT	Adjusted Bid
24	Bird Road and Homestead	Florida DOT	2007/1/21	5/5/2007	15.33	12.77	154	200	Florida DOT	Adjusted Bid
25	SOUTH FLORIDA ARTERI	Florida DOT	2007/10/17	12/4/2007	2.01	2.17	340	372	Florida DOT	Adjusted Bid
26	I-4 St. Johns River to Saxo	Florida DOT	8/4/2000	11/29/2000	22.00	17.97	1100	1078	Florida DOT	Adjusted Score
27	Milling & Resurfacing of Int	Florida DOT	9/10/2003	11/12/2003	7.45	9.29	380	442	Florida DOT	Best Value
28	I-75(SR93) Panasoffkee C	Florida DOT	8/15/2000	10/10/2000	16.00	14.20	730	652	Florida DOT	Best Value
29	US1 (SR5) Milling & Resurf	Florlda DOT	10/1/2000	1/3/2001	30.00	25.00	1222	1222	Florlda DOT	Best Value
30	Bay County Hathaway Bri	Florida DOT	6/8/2006	7/7/2006	5.64	6.29	365	457	Florida DOT	Best Value
31	I-75AT SR82 INTERCHAN	Florida DOT	2004/4/28	5/30/2004	1.45	1.45	365	440	State DOT Design-	Best Value
32	SR60 PEACE CREEKFROM	Florida DOT	2000/8/1	10/17/2000	3.87	3.87	281	205	Florida DOT	Best Value
33	I-75FROMA TBEERIDGE R	Florida DOT	2002/1/7	4/5/2002	1.49	1.56	86	58	Florida DOT	Best Value
34	US 41US-41 (SR90) FROM	Florida DOT	2002/4/17	6/3/2002	4.47	4.53	424	456	Florida DOT	Best Value
35	I-4I-4, from East of US 98 t	Florida DOT	2001/10/14	2/23/2002	72.76	73.03	900	936	Florida DOT	Best Value
36	SR 80 (PALM BCH BLV)S	Florida DOT	2002/1/2	4/16/2002	14.99	14.72	800	1167	Florida DOT	Best Value
37	I-4I-4 FROMW OF MEMOR	Florida DOT	2002/3/1	6/4/2002	59.60	65.70	1100	1310	Florida DOT	Best Value
38	US 441US-441 FROM CSX	Florida DOT	2002/1/3	4/16/2002	12.70	12.45	780	875	Florida DOT	Best Value
39	I-4I-4 FROM SR 557 TO O	Florida DOT	2002/3/16	6/21/2002	62.15	64.51	1095	991	Florida DOT	Best Value
40	LAKE OKEECHOBEE S CE	Florida DOT	2002/5/7	7/20/2002	4.58	4.26	350	215	Florida DOT	Best Value
41	SR 70SR 70	Florida DOT	2002/7/1	2002/9/4	2.39	2.35	323	469	Florida DOT	Best Value
42	I-75 ALLIGATOR ALLEY I-	Florida DOT	2002/9/2	11/19/2002	4.16	4.01	340	343	Florida DOT	Best Value
43	SR70FROMLAKEWOOD	Florida DOT	2003/5/9	6/17/2003	9.04	9.61	794	884	Florida DOT	Best Value
44	POLK COUNTY LAKELAN	Florida DOT	2004/2/16	4/25/2004	6.47	6.40	515	584	Florida DOT	Best Value

45	I-75INTERSECTION 75 A T	Florida DOT	2004/4/8	5/12/2004	2.18	2.05	365	517	Florida DOT	Best Value
46	GUARDRAIL IMPROVEME	Florida DOT	2004/6/17	9/1/2004	5.62	6.39	335	380	Florida DOT	Best Value
47	HURRICANE CHARLEY I-7	Florida DOT	2004/11/2	12/20/2004	1.58	1.53	200	227	Florida DOT	Best Value
48	SR 70FROM SE TURKEY	Florida DOT	2007/3/4	4/12/2007	4.30	4.61	323	404	Florida DOT	Best Value
49	I-75 FULL DECK PANELRE	Florida DOT	2006/11/4	12/10/2006	2.29	2.32	226	227	Florida DOT	Best Value
50	I-95FROM FROM INTL GO	Florida DOT	2002/1/18	3/6/2002	25.60	26.44	500	803	Florida DOT	Best Value
51	I-95FROM FROM S. OF S	Florida DOT	2002/1/20	4/12/2002	24.50	25.79	500	811	Florida DOT	Best Value
52	SR 9A FROM BEACH BLV	Florida DOT	2003/3/27	6/26/2003	31.14	32.77	900	1013	Florida DOT	Best Value
53	SR 9B-FENCINGST. JOHN	Florida DOT	2005/7/25	9/21/2005	0.80	0.74	180	141	Florida DOT	Best Value
54	RAIL TRAIL/CLAY CO.FR	Florida DOT	2007/4/16	6/27/2007	1.29	1.29	330	353	Florida DOT	Best Value
55	SR 9B FENCING-PH IIFRO	Florida DOT	2006/12/15	1/24/2007	0.30	0.20	60	39	Florida DOT	Best Value
56	FLORIDA WELCOME CEN	Florida DOT	2000/3/1	4/20/2000	5.87	5.89	542	551	Florida DOT	Best Value
57	HATHAWAY BRIDGE REP	Florida DOT	2000/2/23	6/7/2000	81.52	84.13	1065	1444	Florida DOT	Best Value
58	SR 10 (US 90-A)(9 MILE	Florida DOT	2000/8/2	10/17/2000	2.91	2.84	421	742	Florida DOT	Best Value
59	SR 10 (US 90)MERRITTS	Florida DOT	2004/8/28	10/14/2004	3.55	2.78	475	824	Florida DOT	Best Value
60	SR 196 MAIN/BAYFRONT	Florida DOT	2005/8/22	11/11/2005	6.99	6.93	175	234	Florida DOT	Best Value
61	BAY COUNTY REGIONAL	Florida DOT	2005/10/27	12/2/2005	5.64	6.24	365	457	Florida DOT	Best Value
62	I-95 Pump Station form Ive	Florida DOT	2001/7/14	10/17/2001	10.98	11.38	260	250	Florida DOT	Best Value
63	SR-80/Hooker Hwy from	Florida DOT	2002/1/13	4/20/2002	9.14	9.48	410	437	Florida DOT	Best Value
64	SR-25/US-27 from Dade	Florida DOT	2002/1/20	3/22/2002	4.87	5.01	295	344	Florida DOT	Best Value
65	SR-A-1-1 Lyons Bridge fr	Florida DOT	2003/5/5	7/22/2003	0.50	0.47	1580	1309	Florida DOT	Best Value
66	SR-708/VA Warehouse fr	Florida DOT	2005/1/19	3/4/2005	1.32	1.30	365	490	Florida DOT	Best value
67	I-75/I-595 West Video Mo	Florida DOT	2006/6/15	10/21/2006	14.45	14.39	912	1290	Florida DOT	Best Value
68	SR-704/Royal Park Bridge	Florida DOT	2004/11/18	1/10/2005	1.31	1.26	290	316	Florida DOT	Best Value
69	SR-862/I-595 Eller Drive/U	Florida DOT	2005/2/3	3/18/2005	7.43	7.73	690	719	Florida DOT	Best Value
70	CONSTRUCT MISSING GA	Florida DOT	2005/2/13	4/4/2005	0.90	0.86	180	221	Florida DOT	Best Value
71	SFRC Noise Wall from Da	Florida DOT	2006/3/18	6/27/2006	5.26	5.20	440	256	Florida DOT	Best Value
72	New bridge construction	Florida DOT	2007/4/16	8/3/2007	6.40	4.72	485	335	Florida DOT	Best Value
73	I-75 over Lake Panasofke	Florida DOT	2000/6/20	10/1/2000	19.28	19.51	600	555	Florida DOT	Best Value
74	I-95/ SR 528 ITS Hurican	Florida DOT	2001/4/1	6/1/2001	3.50	3.78	385	402	Florida DOT	Best Value
75	I-95 Palm Bay Rest Area's	Florida DOT	2001/8/11	11/5/2001	9.29	9.66	320	545	Florida DOT	Best Value
76	I-4FROM E OF SR 44 TO	Florida DOT	2003/5/26	9/11/2003	5.10	5.06	297	242	Florida DOT	Best Value
77	I-4 - Design & Install Doub	Florida DOT	2004/10/22	12/1/2004	3.79	3.79	325	328	Florida DOT	Best Value
78	I-95, Add 2 lanes Exist 4	Florida DOT	2006/5/7	9/1/2006	148.00	156.06	950	731	Florida DOT	Best Value
79	I-75 Install guardrail in me	Florida DOT	2007/12/17	3/25/2008	2.04	1.98	123	110	Florida DOT	Best Value
80	SR 826 E-W, ITS PH 1, US	Florida DOT	2002/3/18	5/24/2002	6.00	6.31	585	852	Florida DOT	Best Value
81	DESIGN BUILD SR 997/KR	Florida DOT	2003/3/3	5/7/2003	5.44	6.14	225	314	Florida DOT	Best Value
82	ITS : SR-112(I-195) / SR-	Florida DOT	2004/1/19	4/12/2004	14.65	14.39	580	846	Florida DOT	Best Value
83	JEWFISH CK BR#900047J	Florida DOT	2004/4/22	7/22/2004	147.77	154.70	1592	1533	Florida DOT	Best Value
84	Depressed Section Okee	Florida DOT	2004/12/5	2/24/2005	34.90	36.19	590	630	Florida DOT	Best Value
85	RECONST: SR-5/US-1: N	Florida DOT	2006/1/5	4/12/2006	40.47	43.13	730	654	Florida DOT	Best Value
86	I-395/SR A1A ATMS Desi	Florida DOT	2007/7/4	10/9/2007	7.56	5.22	510	413	Florida DOT	Best Value
87	SR 5/BRICKELL AVENUE	Florida DOT	2008/7/28	10/6/2008	0.34	0.30	210	200	Florida DOT	Best Value
88	US 19 (SR 55)FROM FRO	Florida DOT	2001/5/21	7/8/2001	4.93	5.31	240	524	Florida DOT	Best Value
89	I-75 (SR 93A) (40846025	Florida DOT	2001/7/3	8/8/2001	2.13	2.25	240	275	Florida DOT	Best Value

90	US 19 (SR55)FROM 38TH	Florida DOT	2003/11/1	1/22/2004	14.81	16.28	641	670	Florida DOT	Best Value
91	THOMAS B. MANUELFRO	Florida DOT	2000/10/1	12/31/2000	25.55	34.14	1299	1585	Florida DOT	Best Value
92	SUNNAV ITS: TPKMAINLIN	Florida DOT	2005/5/2	8/16/2005	11.95	11.87	360	536	Florida DOT	Best Value
93	WIDEN SAWGRASS (SR8	Florida DOT	2005/6/4	9/8/2005	57.17	57.56	699	876	Florida DOT	Best Value
94	BROWARD COUNTY CAM	Florida DOT	2005/10/10	12/1/2005	1.50	1.49	300	401	Florida DOT	Best Value
95	FIBER OPTIC STUDY & DE	Florida DOT	2006/5/1	6/27/2006	3.15	3.08	208	303	Florida DOT	Best Value
96	SUNCOAST PARKWAY (	Florida DOT	2007/9/4	12/13/2007	8.69	5.45	472	389	Florida DOT	Best Value
97	LAKE OKEECHOBEEFRON	Florida DOT	2003/1/3	1/31/2003	6.96	7.38	570	741	Florida DOT	Low Bid
98	I-75 FULL DECK PANELI-7	Florida DOT	2002/9/15	12/1/2002	8.85	8.81	410	643	Florida DOT	Low Bid
99	HURRICANE CHARLEY CH	Florida DOT	2005/6/15	7/26/2005	3.97	4.34	365	543	Florida DOT	Low Bid
100	HOPKINS CREEKFROM PE	Florida DOT	2003/2/1	3/19/2003	3.88	4.16	280	519	Florida DOT	Low Bid
101	Santa Rosa & Escambia C	Florida DOT	2005/9/1	10/15/2005	0.15	0.15	120	126	Florida DOT	Low Bid
102	SR 30 (US 98)OVER ICCW	Florida DOT	2007/11/13	2/1/2008	3.93	3.81	298	210	Florida DOT	Low Bid
103	I-95 Project 7 from North c	Florida DOT	2002/1/23	5/15/2002	67.30	69.24	1500	1598	Florida DOT	Low Bid
104	SR-822/Sheridan Street #	Florida DOT	2002/10/26	12/18/2002	2.15	2.17	410	457	Florida DOT	Low Bid
105	SR-732/Jensen Beach Ca	Florida DOT	2003/10/17	12/21/2003	3.56	3.47	500	671	Florida DOT	Low Bid
106	SR-844/14th Street Bascu	Florida DOT	2005/3/28	5/27/2005	4.80	5.06	349	455	Florida DOT	Low Bid
107	SR-9/I-95 Weigh in Motion	Florida DOT	2006/10/12	2/23/2007	23.75	19.51	800	629	Florida DOT	Low Bid
108	I-4 Auxiliary LaneI-4 from	Florida DOT	2001/2/5	5/13/2001	13.96	13.98	400	501	Florida DOT	Low Bid
109	I-4 Interim Auxiliary Lanes	Florida DOT	2001/3/22	6/25/2001	57.70	59.22	825	978	Florida DOT	Low Bid
110	I-95 (SR9) Safty Improven	Florida DOT	2002/1/13	3/7/2002	2.16	2.22	230	367	Florida DOT	Low Bid
111	Construct Sound Walls fo	Florida DOT	2002/5/1	6/10/2002	2.99	2.99	310	349	Florida DOT	Low Bid
112	SR46 Wildlife crossingSR	Florida DOT	2003/1/2	2/20/2003	1.75	1.76	345	348	Florida DOT	Low Bid
113	I-95 Mill, Resurface, upgra	Florida DOT	2004/3/19	6/21/2004	11.55	12.03	190	302	Florida DOT	Low Bid
114	I-75 - Design & Install Dou	Florida DOT	2005/5/5	6/24/2005	5.16	5.82	360	371	Florida DOT	Low Bid
115	SR 500 US 441FROM W/	Florida DOT	2006/11/21	1/15/2007	1.72	1.74	250	209	Florida DOT	Low Bid
116	I-95 - Install Guardrail in M	Florida DOT	2004/12/1	1/31/2005	7.39	6.01	280	292	Florida DOT	Low Bid
117	I-95 - DASH Extension III -	Florida DOT	2004/10/7	1/1/2005	21.41	21.83	670	826	Florida DOT	Low Bid
118	SR 464OVER CSXRR	Florida DOT	2007/4/1	7/11/2007	24.50	23.28	650	518	Florida DOT	Low Bid
119	I-4- ITS- US27 to Osceola	Florida DOT	2008/2/1	4/25/2008	1.53	1.44	270	214	Florida DOT	Low Bid
120	SR 590 (COACHMAN RD)	Florida DOT	2002/3/28	5/8/2002	0.42	0.45	135	150	Florida DOT	Low Bid
121	SKYWAY VIDEOFROM M	Florida DOT	2001/12/8	1/9/2002	0.77	1.28	270	406	Florida DOT	Low Bid
122	UPPER TPA BAY TRAIL (4	Florida DOT	2002/3/28	5/22/2002	1.22	1.22	180	281	Florida DOT	Low Bid
123	Design BuildDesign Build	Florida DOT	2004/5/22	8/18/2004	4.47	4.88	153	150	Florida DOT	Low Bid
124	I-75 (SR 93A)OVER SR 67	Florida DOT	2005/5/8	7/27/2005	2.64	3.07	137	96	Florida DOT	Low Bid
125	BOCA RATON TOLLS DA	Florida DOT	2000/12/18	2/13/2001	2.80	3.60	540	623	Florida DOT	Low Bid
126	WEST PALM SERVICEPLA	Florida DOT	2005/9/24	12/6/2005	10.16	12.28	630	761	Florida DOT	Low Bid
127	SAWGRASS EXPRESSW	Florida DOT	2006/7/1	9/20/2006	26.19	28.69	710	665	Florida DOT	Low Bid
128	DEERFIELD MAINLINES/W	Florida DOT	2006/9/4	11/20/2006	39.20	42.92	623	624	Florida DOT	Low Bid
129	Bath-Woolw ich bridge rep	Maine DOT	5/18/1997	8/15/1997	66.00	46.60	1025	1011	State DOT Design-	Best Value
130	I-295 Commercial Street C	Maine DOT	1/7/2003	37695.00	18.20	18.75	548	519	Maine DOT	Best value
131	New Bridge over Kennebe	Maine DOT	4/1/1997	35626.00	46.60	47.50	1095	1054	Maine DOT	Best value
132	US113 from US50 to MD58	Maryland DOT	1998/7/13	1998/11/4	18.50	10.34	490	462	MD DOT	Low Bid
133	MD32 at Samford Rd, inter	Maryland DOT	1999/10/17	2000/3/1	6.10	6.50	420	433	MD DOT	Low Bid
134	MD695 from I-97 to MD10,	Maryland DOT	2000/6/26	2000/10/30	9.40	9.40	384	214	MD DOT	Low Bid

135	US50 from US301to MD41	Maryland DOT	2000/10/10	2001/1/23	18.90	19.00	516	531	MD DOT	Low Bid
136	Route 3 North Project	Massachusetts	4/13/1998	7/16/1998	385.00	402.00	1878	2015	Benchmarking Stud	Best Value
137	US70 Hondo Valley Ruidos	New Mexico DO	11/26/2001	3/29/2002	126.00	165.00	883	1103	Benchmarking Stud	Best Value
138	I-26 Project	North Carolina D	1/10/2002	4/3/2002	116.00	83.70	1131	1169	North Carolina DOT	Adjust Bid
139	US 64 Project	North Carolina D	2/21/2002	5/8/2002	300.00	131.02	1127	1012	North Carolina DOT	Best Value
140	District 1 Warren Co, Expre	Pennsylvania D	4/13/2000	36678.00	17.60	16.20	1081	456	State DOT Design-	Modified DB
141	IM 229-2(50)2	South Dakota D	1/7/2000	3/16/2000	40.00	32.40	501	482	South Dakota DOT	Adjusted Bid
142	I-15 rescomstruction Proje	Utah DOT	10/1/1996	1/15/1997	1430.00	1325.00	1726	1497	Utah DOT	Best Value
143	Route 288	Virginia DOT	7/14/2001	8/10/2001	236.00	240.00	1064	1192	Benchmaring Study	VA PPTA
144	Everett Hov	Washington DO	12/01/2004	3/11/2005	63.00	48.60	882	1148	Washington DOT	Best Value
145	Kirkland Stage1	Washington DO	7/15/2005	8/17/2005	263.40	263.40	1131	785	Washington DOT	Best Value
146	SR 500 & Thurston Way	Washington DO	9/7/2000	12/13/2000	32.50	22.73	652	658	Washington DOT	Best Value

Appendix B

The appendix B includes all the projects that not used in this research. Those highway projects are collected but miss some information for the research. The table includes some of the individual project name, RFP issue party, RFP issue date, RFP due date, contract price, actual price, contracted days, actual construction days, data source and award method.

All the data are summarized in the following table. Most data come from Florida DOT and other state DOTs. All the data are collected through four sources: state DOTs, benchmarking study, D-B effectiveness research, and some public website.

No.	Project Name	Issued Party	RFP Issue Date	RFP Due Date	Estimated/ Contra	Actual Price	Contract Start/Ex	Contract End Dat	Actual Start Date
1	Mid-Corridor Project	Alabama Corrido	1/21/1998	7/1/1998	$697,641,951 (lir	$ 712million	6/6/1999	within 1305 days	6/6/1999
2	The Whittier Access Project-Tu	Alaska DOT and	6/30/1997	11/4/1997	$80 million	$60 million	6/3/1998	5/1/2000	6/3/1998
3	re-construction Cortaro Road In	Arizona DOT	4/11/1997	6/13/1997		$2.80 million			
4	Southeast Corridor Multi-Modal	Colorado DOT	11/1/2000	3/23/2001	$ 1840 million	$1670 million	6/10/2001	6/30/2008	6/10/2001
5	Re-construction and upgrading	D.C. Department	11/28/2001	2/27/2002	$10,000,000	$34 milliom			
6	Bay County Hathaway Bridge P	Florida DOT				$ 40 Million			4/13/2003
7	I-4(SR400) Six Laning (us17-92	Florida DOT	8/4/2000	11/29/2000	$ 22 million	$17.97 Million		1100 calendar da	12/2/2000
8	Milling & Resurfacing of Intersta	Florida DOT	9/10/2003	11/12/2003	$ 7.45miilion	$ 9.29Million		380 calendar day	11/26/2003
9	I-75(SR93) Panasoffkee Creek	Florida DOT	8/15/2000	10/10/2000	$ 16 million	$14.2Million		730 calendar day	10/20/2000
10	US1 (SR5) Milling & Resurfacing	Florlda DOT	10/1/2000	1/3/2001	$ 30 Million	$ 25 Million	1/25/2001	5/31/2004	1/25/2001
11	Interchange	Florida DOT				$ 2.05 million			
12	Resurfacing	Florida DOT				$ 0.64 million			
13	Pedestrain overpass	Florida DOT				$ 3.25 million			
14	Add Lanes & Rehab Pavement	Florida DOT				$ 3.68 million			
15	Widen bridge	Florida DOT				$ 19.28 million			
16	Sound Walls	Florida DOT				$ 9.39 million			
17	I-95 Glynn Co., Horse Stamp Ch	Georgia DOT				$ 27.50 million			
18	US 60 DB Widening Peoject	Arizona DOT	2/18/2001	4/29/2001	$239 million	$208 million	6/1/2001	10/1/2003	6/1/2001
19	I-295 Commercial Street Connec	Maine DOT	1/7/2003	3/15/2003	$18.2M	$18.75M	6/1/2003	11/30/2004	6/1/2003
20	New Bridge over Kennebec Riv	Maine DOT	4/1/1997	7/15/1997	$46.6M	47.5million	10/1/1997	9/30/2000	10/1/1997
21	New Highway in Aris County	Maine DOT	3/14/1997	7/28/1997					
22	Bath-Woolwich bridge replacem	Maine DOT	5/18/1997	8/15/1997	$66 million	$46.60 million	9/10/1997	7/1/2000	12/15/1997
23	US113 from US50 to MD589, fo	Maryland DOT				$10.34 million			
24	MD32 at Samford Rd, interchg c	Maryland DOT				$6.50 million			
25	MD695 from I-97 to MD10, wide	Maryland DOT				$9.40 million			
26	US50 from US301to MD410, wid	Maryland DOT				$19.00 million			
27	Route 3 North Project	Massachusetts	4/13/1998	7/16/1998	$385 million	$402 million	8/10/1998	10/1/2003	9/25/1998
28	Salem-Keizer Area High Priority	Mid-Willamette Valley Council			$100,000				
29	Dyluth Street Project	Minnesota DOT	11/13/2001	1/16/2002					
30	Trunk Highway Project	Minnesota DOT	4/1/2001	5/15/2001					
31	I-494 West Metro	Minnesota DOT				$110 million			
32	Hwy 52 in Oronoco	Minnesota DOT				$37 million			
33	10/32 Hawley	Minnesota DOT				$ 8.6 million			
34	ROC52	Minnesota DOT				$ 232 million			
35	Route 9 Project	New Jersey DOT				$ 57.94 million			
36	Route I-280 Access Ramps	New Jersey DOT				$ 4.60 million			
37	Local bridge Projects 11th Ave	New Jersey DOT				$1.83 million			
38	Local bridge Projects Bordentov	New Jersey DOT				$ 1.51 million			
39	Local bridge Projects Oakview	New Jersey DOT				$2.77 million			
40	Route 29 Improvements - Tunne	New Jersey DOT				$ 70.93 million			
41	Routes 50 & 322 Interchange re	New Jersey DOT				$ 8.42 million			
42	US70 Hondo Valley Ruidoso Do	New Mexico DO	11/26/2001	3/29/2002	$126 million	$ 165 million	5/1/2002	9/30/2004	4/21/2003

43	I-26 Project	North Carolina D	1/10/2002	4/3/2002	$116 million	$83.70 million	5/27/2002	7/1/2005	6/3/2002
44	US 64 Project	North Carolina D	2/21/2002	5/8/2002	$ 300million	$131.02 million	7/1/2002	8/1/2005	9/22/2002
45	CARAT ITS project	North Carolina DOT				$ 13.75 million			
46	SR70	Ohio DOT					2/21/2001	6/30/2002	
47	CHP / CLA-68-0.0024.441 ; 1.2	Ohio DOT			$13.90 million	$ 13.90 million	5/31/1998	11/11/2000	5/13/1998
48	MED-IR271-0.00, complete pave	Ohio DOT				$ 17.31 million			
49	STA-IR077-11.85, add 3rd lane	Ohio DOT				$ 24 million			
50	CUY-IR480-19.93, noisewall ret	Ohio DOT				$ 2.52 milliom			
51	MAH-11-16.04, bridge Deck rep	Ohio DOT				$ 4.14 million			
52	ATH-33-10.41, bridge Deck reh	Ohio DOT				$ 1.8 million			
53	TUS-77-3.94, Pavement & bridg	Ohio DOT				$ 9.19 million			
54	BEL-70-16.60, Sign Upgrading	Ohio DOT				$ 0.83 million			
55	POR-224-0.00, resurfacing and	Ohio DOT				$ 3.7 million			
56	FRA-71-14.39, Pavement rehab	Ohio DOT				$ 3.68 million			
57	SUM-77-22.32, tower Lighting	Ohio DOT				$ 1.67 million			
58	District 1 Warren Co, Expressw	Pennsylvania DO	4/13/2000	6/1/2000	17.6million	16.2million	7/17/2000	7/3/2003	7/17/2000
59	District 3-0 Tioga 0015-F13 037	Pennsylvania DOT				$ 8.6 million			
60	District 4-0 Susquehanna 0706-	Pennsylvania DOT				$ 2.4million			
61	District 5-0 Lehigh 0078-07M En	Pennsylvania DOT				$ 3.1 million			
62	District 8-0 Cumberland 0081 Se	Pennsylvania DOT				$ 9 million			
63	District 8-0 York 30 Expressw a	Pennsylvania DOT				$ 2.6 million			
64	District 9-0 Bedford 30-13B Eve	Pennsylvania DOT				$ 0.5 million			
65	District 9-0 Somerset 0219-023	Pennsylvania DOT				$ 10.7 million			
66	Bridge Replacement - Wateree	South Carolina DOT				$ 7.86 million			
67	Carolina Bays Parkway	South Carolina DOT				$ 225.40 million			
68	IM 229-2(50)2	South Dakota DO	1/7/2000	3/16/2000	$40,000,000	$ 32.40 million	4/18/2000	9/1/201	
69	SH 183 A	Texas DOT	12/27/1999		$158 million	$ 172 million			
70	SH130	Texas DOT	2/21/2000	8/23/2001	$1034 million	$ 972.8 million	10/1/2003	4/30/2008	11/5/2003
71	Natchez Trace Parkway	U.S. DOT Easter	8/27/2001	10/30/2001	$5,000,000-10,000,000				
72	I-15 rescomstruction Project	Utah DOT	10/1/1996	1/15/1997	$1.43billion	$ 1325 million	4/15/1997	1/5/2002	6/9/1997
73	ITS Traffic Operations Center p	Utah DOT				$ 4.57 million			
74	Safety rest area / Welcome Cer	Utah DOT				$ 2.65 million			
75	I-85 Project	Virginia DOT				$2.65 million			
76	Route 288	Virginia DOT	7/14/2001	8/10/2001	$236 million	$ 240 million	10/2/2001	8/31/2004	10/2/2001
77	Everett Hov	Washington DOT	12/01/2004	3/11/2005	$63million	$48.6 million	5/2/2005	10/1/2007	5/2/2005
78	Kirkland Stage1	Washington DOT	7/15/2005	8/17/2005	$263.4million	$263.4million	9/15/2005	10/20/2008	10/1/2005
79	SR 500 & Thurston Way	Washington DOT	9/7/2000	12/13/2000	$32.5milliom	$ 22.73 million	12/18/2000	10/1/2002	12/18/2000
80	ITP Project	Washington DOT	12/1/2004	4/8/2005	$165million		5/30/2005	12/1/2008	

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