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Relationship between procurement duration and project performance in design-build water/wastewater projects

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RELATIONSHIP BETWEEN PROCUREMENT DURATION AND PROJECT PERFORMANCE IN DESIGN-BUILD WATER/WASTEWATER PROJECTS

BY

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THESIS

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DEDICATION

My family motivated me to work hard on this thesis. I wish to thank my mother who currently lives in China. She encourages me to pursue my academic career in the U.S. After my father passed away in November 2008, her main concern was upon my life and academic achievement. Without her encouragement, I would not be able to finish the thesis needed to attain my master’s degree. During the first semester of my master’s study in the U.S, my father died of liver cancer. I came back to China only one day before he passed away. He expected two obligations of me: one was to look after my mother, and the other was to be successful in my studies. My father is now watching over me in heaven, and would be proud of me in meeting these obligations. This thesis is dedicated to my parents. I will love them forever.

I would also like to thank my friends in the Civil Engineering Department and proofreaders. Their ideas and assistance gave me new insight in how I should write my thesis.

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ABSTRACT OF THESIS

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ABSTRACT

The design-build (DB) project delivery system (PDS) has been widely applied and studied in the construction industry. Its advantages include shortened project duration, lowered risk to the owner, improved project performance, and possibly reduced cost. Researchers have also studied the factors related to the improved performance in DB projects, especially in the building and transportation industries. Compared to the building and highway industries, the application of DB in water/wastewater (WW) projects has been rarely studied before.

One of the potential factors that may influence project performance is procurement duration (PD). By focusing on DB applied to WW projects, this study explored the relationship between PD (from Request for Proposal issue date to proposal due date) and project success. The project success criteria was defined as cost and schedule growth, which were objective measurements and thus provided more convincing data analysis. Project data was collected through an on-line questionnaire given to owners and Design-Builders who had experience in DB WW projects. The data was used to analyze how PD impacts project performance in terms of cost and schedule growth. The relationships between PD and performance in DB WW projects were compared to DB transportation projects. Both similarities and differences were found. To explore the reasons of these similarities and differences, content analysis was conducted to compare the DB WW and transportation procurement documents. Variables were defined and analyzed based on their frequency of use within procurement documents. Hypotheses were given based on the similarities and differences found between DB WW and transportation projects' procurement items as to which might influence the project success. Related suggestions were provided for owners in the DB WW industry regarding the time given for design-builders to prepare proposals and items that should be required in the DB proposal.

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List of Acronyms

ASCE: American Society of Civil Engineering

ATD: actual total duration

BV: Best Value

CA: Content Analysis

CC: Correlation Coefficient

CG: Cost Growth

CMAR: Construction Management at Risk

DB: Design-Build

DBB: Design-Bid-Build

DBFO: Design-Build-Finance-Operate

DBIA: Design-Build Institute of America

DBSG: Design-Build Schedule Growth

ITB: Invitation to Bid

PAC: Project Actual Cost

PD: Procurement Duration (days)

PDD: Proposal Due Date

PDF: Procurement Duration Factor

PDS: Project Delivery System

QBS: Qualification-Based Selection

RFP: Request for Proposal

RFQ: Request for Qualification

SOQ: Statement of Qualification

TSG: Total Schedule Growth

WDBC: Water Design-Build Council

WW: Water/Wastewater

CHAPTER ONE

INTRODUCTION

The design-build (DB) project delivery system (PDS) is different from other PDSs, such as Design-Bid-Build (DBB) and Construction Management at Risk (CMAR), since in DB the owner has a single contract with the DB entity (the design-builder) for both project design and construction (see Appendix A for a list of acronyms). DB has been used for centuries in both the public and the private sector, but the earliest documented DB application in the public-sector in the 20th century in the United States was in 1968 for school districts throughout the Midwest (Molenaar, Songer and Barash 1999). Architecture, engineering and construction have experienced a significant change in project delivery since the 1990s, and there has been a dramatic increase in the number of DB projects in the public sector, especially with the authorization of DB in federal, state and local law (Molenaar et al. 2003).

Previous research such as Konchar and Sanvido (1998) using data analysis in building and highway sectors shows that DB improves project performance compared to DBB and CMAR. Further research such as Songer and Molenaar (1997) was then conducted on how DB impacts project success as well as factors contributing to DB project success. Most of these studies were based on surveys in the building and heavy highway sectors, due to the large amount of data available for DB projects in these sectors. Unlike the federal building sector and the state transportation projects, the water and wastewater (WW) industry consists of many utilities that build facilities less frequently (Molenaar, Bogus and Priestley 2004). In the WW industry, DB projects usually need to incorporate a series of plans, including regulatory compliance, quality control, risk management, health and safety, and coordination with state and federal agencies (Blair and Russell 2006). DB is gaining popularity in the WW industry, but there is still a lack of research in this area. According to the Water Design-Build Council (2009), about 20%-30% of all U.S WW projects already use DB, and this percentage tends to grow every year.

What needs to be explored consists of mainly two aspects. One is the contribution of DB to the success of WW projects. The other is the identification of factors that influence project performance and to what extent these factors influence it. This study assumes that procurement duration (PD) is one of the factors that influences project success, and aims to find the relation between PD and project success through data analysis. The PD is defined as the time given for design-builders to prepare DB proposals.

1.1 Characteristics of Design-Build

There are many variations of DB that are used for project delivery. Some DB projects may have a finance and operation phase (Design-Build-Finance-Operate). In DBFO, the Design-Builder is responsible for design and construction as it is in DB, but it also assumes some of the risks and duties in financing and operation (Ladre et al. 2006). In both DB and DBFO, the owner transfers the responsibility of the design-construction coordination and risks in design, quality, budget and schedule to the Design-Builder (Ladre et al. 2006).

The features of DB can be better described through a comparison with two other main PDSs - DBB and CMAR. Table 1.1 is a comparison of the three PDSs from the standpoints of the owner, the contractor and the design team.

Table 1.1. Project Delivery Systems

Delivery System / Participants	Design-Bid-Build	Design-Build	CM at Risk
Owner	Separately contracts for design and construction services	A single contract for both design and construction services	Separately contracts for design and construction management services
Designer	Develops drawings for the owner, may assist the owner in selecting contractors	Works on the same team with the contractor, design can be checked periodically before completion	Interacts with the contractor during design
Contractor	Bids on completed project design, contracts directly with owner, has little interaction with designer	Has more influence in the design because is part of design-build team, construction may start before design is complete	The contractor is involved in the design and responsible for construction

DB differs from DBB and CMAR in that it creates a single contract between the owner and Design-Builder, thus releasing the owner from the responsibility to guarantee the correctness of plans and specifications to the contractor, as the designer is now on the same team with the contractor. Figure 1.1 illustrates the relationship among owner, general contractor and architect/engineer (A/E) under the three main PDSs.

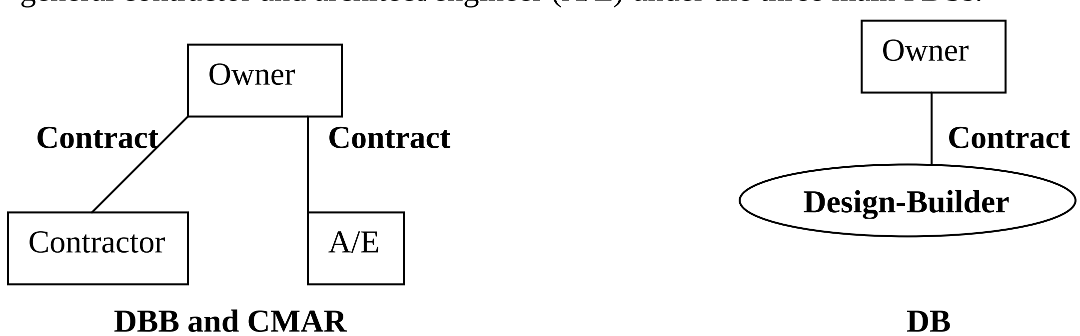


Figure 2.1. Contractual Relationship within Project Delivery Systems

Figure 1.2 illustrates the communications of projects participants under DBB and DB.

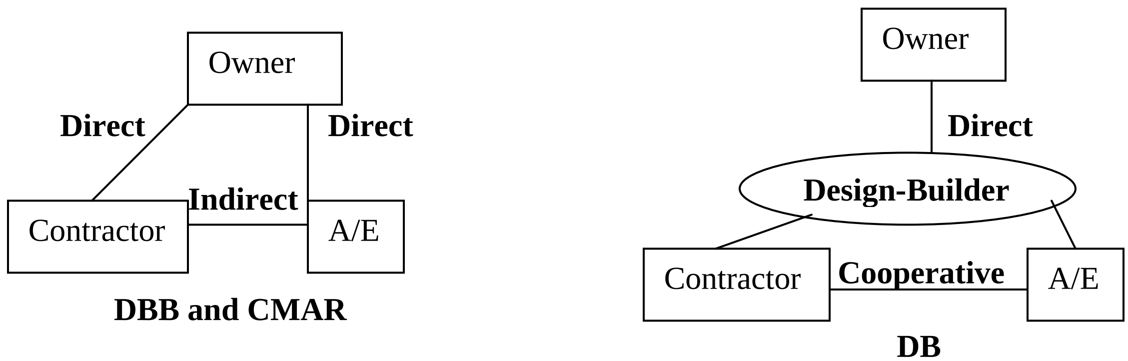


Figure 3.2. Connections within Project Delivery Systems

According to Figure 1.1 and 1.2, the contractor and A/E cooperate to form a Design-Builder, who has a single contract with the owner. Either the contractor or the A/E has the prime contractual relationship through the DB entity. The contractor and A/E communicate with the owner through the DB team.

1.2 Construction Procurement

Procurement is the process where the owner selects engineering and construction services. The A/E and contractor, who use their expertise and techniques to turn a pre-planned project into a real product, have a fundamental influence on the project's final success. The procurement process comes before the project execution, and at the later stages or after the project pre-planning. Figure 1.2 shows the curve of influence and expenditure during the project delivery process.

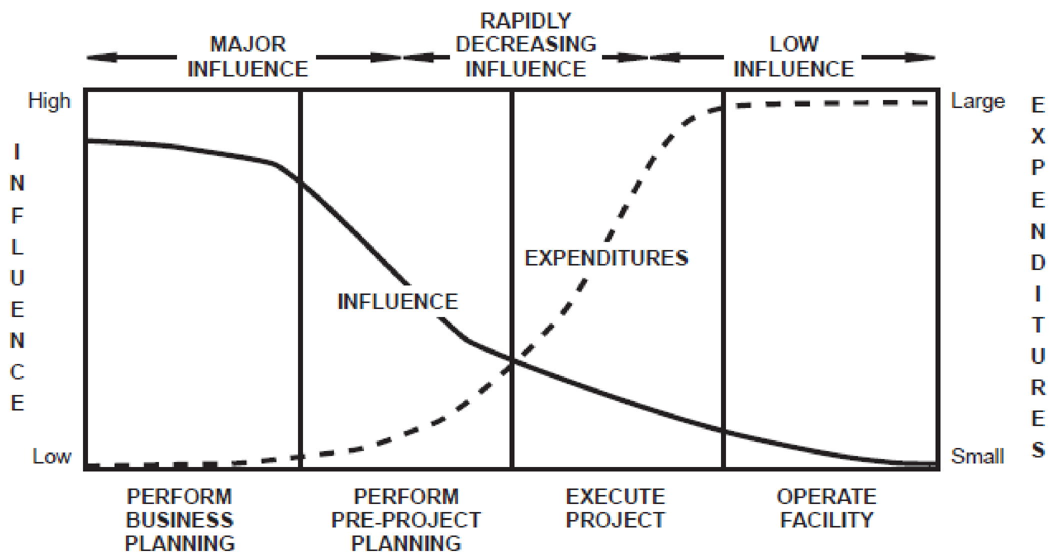


Figure 1.3. Influence and Expenditures Curve for the Project Life Cycle (CII,1994)

Figure 1.3 shows that at an earlier stage in the project life cycle there is a higher level of influence and lower expenditure. Since the procurement is at a relatively early stage, it is assumed to have a high influence on project success.

The procurement process in DB projects usually differs from traditional DBB projects due to the different PDS. The integrated DB system makes an owner procure a single design-build entity. By comparison, with DBB, the owner first procures design services with an A/E firm, and then after design completion the owner procures construction services. More definitions of DB procurement process, method and selection criteria will be introduced in Chapter 2-Literature Review.

1.3 Description of the Research

This research aims to analyze the relationship between PD and project performance for DB projects in the WW industry.

1.3.1 Motivation of the Study

Unlike the building and transportation industries, there are few studies in the DB WW sector. Questions concerning DB in WW include: Does DB improve project performance in the WW industry as it does in other industries? What contributes to the improvement for DB WW projects? How can owners who use DB optimize the project characteristics to improve final performance? These questions are especially important for owners who are planning to adopt DB delivery for WW projects. Procurement, as a significant period during the project delivery process, is assumed to have some influence on a project's final performance. Thus, a question arises about what efforts the owner can take during the procurement process to maximize project performance.

1.3.2 Research Goal and Objectives

The main goal of this research is to find out the relationship between PD and project performance for WW projects.

The main goal of the research consists of these objectives:

1. To define project performance and PD for DB WW projects. The project performance, or project success, has been widely studied in previous research (See Chapter 2). It is a prerequisite to select a series of appropriate performance indexes for this research, either from these previous studies or using new definitions. Another prerequisite is the measurement of project PD, which is related to the DB WW procurement process. The data collection cannot be conducted before defining the project performance and PD.
2. To collect data on the project performance and PD. This research includes a quantitative study, based on data collection and analysis. Data related to project

performance and PD were collected from owners and Design-Builders in the WW industry.

3. To determine the relationship between PD and project performance. It is the goal of the research to determine if there is a correlation between project performance metrics and PD. Statistical tests were conducted to analyze the relationship.
4. To compare the relationship between project performance and PD in WW projects with that relationship in transportation projects, the similarities and differences will be analyzed through a qualitative content analysis (CA).
5. To provide suggestions for owners and Design-Builders in the WW industry. The results and conclusion of the study may provide some useful advice for project participants especially owners.

1.3.3 Research Approach

The research steps outline the study process, from planning to final conclusion. The following steps were completed for this study:

1. Reviewed literature on relevant topics, such as DB delivery method, project performance, factors that impact project performance, DB project procurement processes.
2. Defined project performance and PD, since few studies have been conducted on what factors impact WW project performance, or to what extent these factors impact performance.
3. Collected data on project performance and PD. Similar to most previous studies on the relationship of project performance and its influencing factors, the questionnaire survey was selected as the data collection instrument.

4. Analyzed the data from the survey. The data were used to calculate the correlation coefficient between PD and project performance in terms of cost and schedule change. The data were also categorized based on their project size (i.e., project cost), for respective analysis of the linear relationship between PD and project performance.
5. Compared the data analysis of PD and project performance in WW industry with that in transportation projects. Used CA on the Request for Proposals/Invitation to Bid (RFP/ITB) documents to explore the differences between these two types of projects.
6. Provided conclusions and recommendations. Conclusions were reached based on the analysis of the linear relation between PD and performance as well as CA. WW project owners and Design-Builders may apply these conclusions during the procurement.

1.3.4 Summary

This study consists of two research methods. The first method is correlation relationship data analysis. The second is CA to find the differences and similarities in the RFP/ITB documents between WW and transportation projects. The research results will be used to indicate whether the time given for design-builders to prepare proposals is an influencing factor of project success. The research will also provide a comparison of WW and transportation project RFP/ITB documents to illustrate how WW projects differ from transportation projects.

CHAPTER TWO

BACKGROUND LITERATURE REVIEW

The literature review is an essential step before applying methodologies to study the relationship between PD and project performance in DB WW projects. The literature review is divided into the following parts: definition of project success measures, the DB impact on project performance, factors that influence project performance, and the procurement process in DB projects.

Previous studies on project success measurements are listed in this chapter, and the frequency of these measurements that are used in previous studies is summarized. The most frequently used measurements will be selected for the definition of project performance in this study. The impact of the DB method's impact on project performance is compared with other PDSs (e.g. DBB). Previous studies are listed which compared DB and other delivery methods based on project performance.

Previous research on influencing factors of project success was also reviewed. The influencing factors are categorized, and a table is used to summarize the methodologies, project types, and findings in these studies. Lastly, the procurement characteristics in DB projects are summarized and compared to DBB, with a focus on procurement process, methods, and the typical DB procurement formats- RFQ and RFP.

This chapter does not provide a detailed explanation of the DB process or its history. Additional background on DB can be found in Beard et al. (2001) among other references. Research on the relationship between PD and DB success in transportation projects by Chen (2009) is also used as a reference for this study on WW projects, to check if there are consistent research results between transportation and WW projects.

2.1 Measurement of Project Success

There is no standardized definition of project success. Each study may use a unique success measurement system based on the data available. Project success is usually defined depending on the project type, project phase, project representatives and participants, etc. The project success criteria can be evaluated through performance measures developed from research literature (Chan, Scott and Lam 2002). Before studying DB project performance, the success variables need to be defined in terms of performance measurements.

2.1.1 Project Success Definition

Success, which can be subjective, may vary from different project participants' points of view. An owner may care more about budget, completion date and satisfaction of operation; constructors are concerned more about the profitability; and architects are likely to treat the aesthetics as the main performance criteria.

The performance criteria can also be classified as those based on project outcomes (timeline, budget, quality, etc), project execution (safety, change orders, claims and disputes, etc), and those after the execution (life cycle cost, operation and maintenance characteristics, etc).

According to the Construction Industry Institute's (CII's) research in Pre-project planning (1994), there were considerable disagreements among different groups of project representatives concerning the relative importance of success factors. The project managers as a group are most concerned with the execution phase of the project; the operation managers are most concerned with the downstream results of the planning and execution phases; and the business managers appear to be more concerned with the overall project from a macro level rather than how well it is executed or operated.

The measurement of project success according to different classifications is summarized in Fig. 2.1.

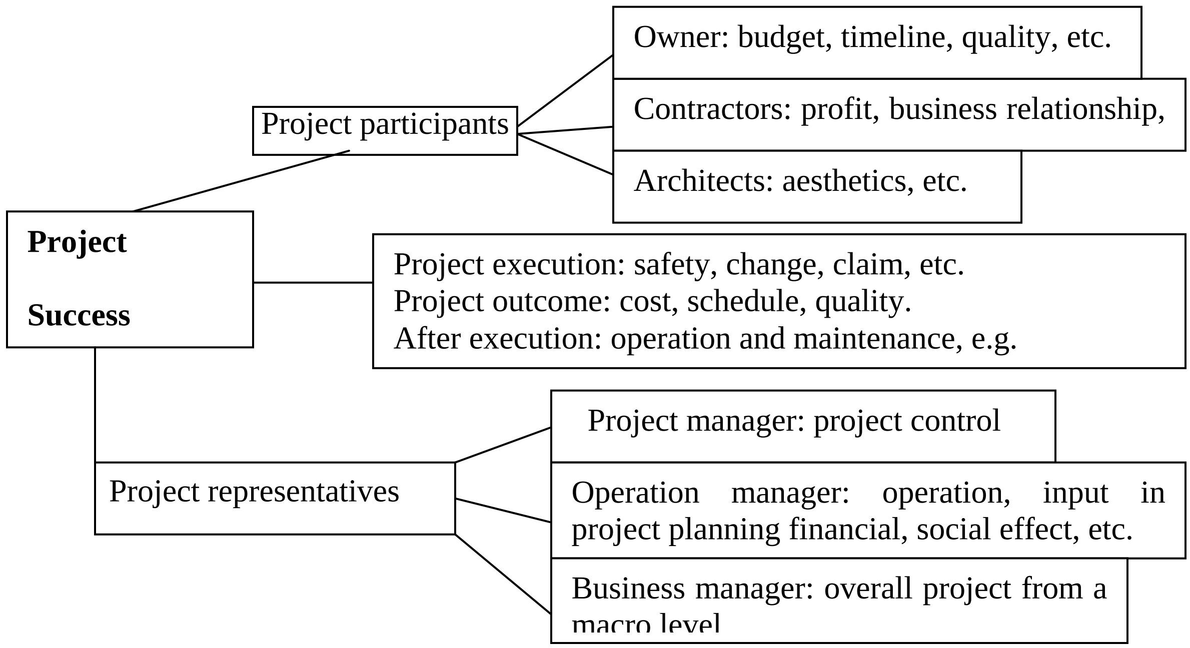


Figure 4.1. Project Success Measurements Based on Different Classifications

The most common criteria of project success are concerned with project control, including budget, schedule control and quality; some other project success issues include safety, environmental impact, change orders, etc. Each of these criteria may be decomposed to measurable indexes, either objective or subjective. For example, the cost criteria can be measured in an objective way, in terms of cost change by comparing the actual cost with budget, while the quality criteria is probably measured in a subjective way according to the project end-user's satisfaction. Schedule, cost and quality are the most commonly used project success measurements.

2.1.2 Project Performance Measurements

The project performance, as a reflection of project success, is the common goal for all of the project participants. Performance needs to be defined through a series of measurements. A lot of previous research has studied performance measurements.

Table 2.1 summarizes previous studies regarding project performance measurements.

Table 2.1.Project Success Measurements

Performance Metrics in Konchar and Sanvido (1998)'s study	
Metrics	**Measurement method**
Cost	Unit Cost ($/m²) = (Final Project Cost / Area) / Cost Index
	Cost Growth (%) = $\frac{\text{Final Project Cost – Contract Project Cost}}{\text{Contract Project Cost}}$
	Intensity [($/m²)/month] = (Unit Cost / Total Time)
Schedule	Construction Speed (m²/month) = Area [(As-Built Construction End Date - As-Built Construction Start Date)/30]
	Delivery Speed (m²/month) = Area / Total Time / 30
	Schedule Growth (%) = [(Total Time – Total As-Planned Time)/Total As-Built Time]*100
Quality	Turnover Quality: High, medium and low, with a zero-five-ten scale
	System Quality: roof, structure, foundation, etc.
	Equipment quality: did not meet, met, or exceed expectations, with a zero-five-ten scale

Design-Build Project Performance defined by Molenaar et al. (1999)	
Measures	**Measurement scale**
Budget Performance	Under budget (>5%, 3% to 5%, 1% to 2%)
	On budget
	Over budget (-2% to -1%, -5% to -3%, <-5%)
Schedule Performance	Under schedule (>6%, 3% to 5%, 1% to 2%)
	On schedule
	Over schedule (-2% to -1%, -5% to -3%, <-6%)
Conforms to Expectations	1= did not conform, 6 = better than expected
Administrative Burden	1= high, 6= low

<table>
<tr><th colspan="3">Table 2.1 (cont.)</th></tr>
<tr><td>Owner Satisfaction</td><td colspan="2">1= not satisfied, 6= better than expected</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3">Reclassification of Success Variables (Gibson and Hamilton 1994, Griffith 1999)</td></tr>
<tr><td>Variable</td><td colspan="2">Range</td></tr>
<tr><td rowspan="3">Budget achievement
(Measured against authorization cost budget)</td><td colspan="2">Under authorization budget</td></tr>
<tr><td colspan="2">At authorization budget</td></tr>
<tr><td colspan="2">Over authorization budget</td></tr>
<tr><td rowspan="3">Schedule performance
(Measured against authorization schedule)</td><td colspan="2">Under authorization schedule</td></tr>
<tr><td colspan="2">At authorization schedule</td></tr>
<tr><td colspan="2">Over authorization schedule</td></tr>
<tr><td rowspan="3">Percent design capacity attained after 6 months of operation
(measured against planned capacity)</td><td colspan="2">Over 100% of planned</td></tr>
<tr><td colspan="2">100% of planned</td></tr>
<tr><td colspan="2">Under 100% of planned</td></tr>
<tr><td rowspan="3">Plant utilization after 6 months of operation
(measured against planned utilization)</td><td colspan="2">Over 100% of planned</td></tr>
<tr><td colspan="2">100% of planned</td></tr>
<tr><td colspan="2">Under 100% of planned</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3">Metrics of project change in terms of cost, schedule and productivity Ibbs et al. (2003)’s study</td></tr>
<tr><td>Metrics</td><td colspan="2">Measurement</td></tr>
<tr><td>Cost Change</td><td>$\frac{\text{Final cost} - \text{Initial budget}}{\text{Initial budget}}$</td><td>Three possible analysis: total change in cost, cost change in design, and cost change in construction</td></tr>
<tr><td>Schedule Change</td><td>$\frac{\text{Total time used} - \text{Initial estimated time}}{\text{Initial estimated time}}$</td><td>Three analysis similar: total time, design time, construction time</td></tr>
<tr><td>Productivity</td><td colspan="2">In the form of labor productivity, which was calculated by the person surveyed</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3">Project Success Measurement by Hughes et al. (2004)</td></tr>
<tr><td>Measures</td><td colspan="2">Definition</td></tr>
<tr><td rowspan="4">Cost</td><td colspan="2">Overall project cost performance based on goals, targets, or expectations</td></tr>
<tr><td colspan="2">Rework costs</td></tr>
<tr><td colspan="2">Budget contingencies</td></tr>
<tr><td colspan="2">Net profit targets</td></tr>
<tr><td rowspan="3">Schedule</td><td colspan="2">Overall project schedule performance based on goals, targets, or expectations</td></tr>
<tr><td colspan="2">Management of material, equipment, and labor availability</td></tr>
<tr><td colspan="2">Schedule float management</td></tr>
</table>

Table 2.1 (cont.)	
Quality	Overall project quality performance based on goals, targets, or expectations
	Customer satisfaction from the direct feedback and the opportunity for follow-on work
	The customer's true goals and expectations according to contract performance incentives

Performance Measures (Ling et al, 2008)		
Measures	**Description**	**Measurement scale (1-7)**
Cost performance	Actual cost verse budget	1=overrun budget by > 5%
		4=cost same as budget
		7=savings below budget by >5%
Time performance	Actual time/schedule verse budget	1=late finish by > 5%
		4=finish on time
		7=early finish by >5%
Quality performance	Output quality of your service (e.g. technical quality, workmanship)	1=expectations not met
		4=expectations met
		7= exceed expectations
Owner satisfaction	Satisfaction with AEC firm service	The same as above
Profit Margin	AEC firms' Profit margin derived from service	The same as above

Success Criteria of Design/Build projects (Chan, Scott and Lam 2002)				
		Previous studies		
Types D/B project success criteria		**Chan (2000)**	**Ndekugri and Turner (1994)**	**Songer and Molenaar (1996,1997)**
Objective	Objective Time, Cost, Quality	√	√	√
	Safety	√		
Subjective	Meeting specification/ employer's requirements			√
	Conformance to expectation of project team members			√
	Satisfaction of project team members		√	√
	Functionality	√		

	Table 2.1 (cont.)			
	Aesthetics		√	
	Reduction in dispute		√	√

In Konchar and Sanvido (1998)'s study comparing three main PDSs in building projects, cost, schedule and quality are the three performance metric categories. Most of the performance measurements in Konchar and Sanvido (1998)'s study are only applicable in the building industry, such as the unit cost, delivery speed, etc. The performance metrics established by Konchar and Sanvido (1998) were then used by Ling (2004) to predict the performance of DB and DBB projects.

Molenaar et al. (1999) defined performance in public DB projects. It was also based on cost, schedule and quality. Quality was measured in terms of conformation to users' expectations, administrative burden, and owner satisfaction with the overall project. The projects surveyed include heavy highway (5%), industrial (8%), environmental (1%) and building (86%).

Griffith (1999)'s study of project success index for capital facility projects applied Gibson and Hamilton (1994)'s definition of 8 major categories and 52 subcategories of success variables. After a statistical test for index reliability, four variables were used as a success index-budget achievement, schedule performance, percent design capacity attained, and plant utilization.

Ibbs et al (2003) used cost, schedule and productivity as metrics to analyze the project change in DB, DBB and other PDSs.

Hughes et al. (2004) used an open-ended questionnaire survey to find six predominant project success categories (cost, schedule, quality, performance, safety, and operation environment). The six categories were divided into subcategories. Each subcategory's importance for the project overall success was indicated as low, medium and high.

Ling et al. (2008) used five performance measures for project success, based on Konchar and Sanvido (1998), Chan et al (2000), and Ling (2004)'s studies. These measurements were also used in Ling, Ibbs and Hoo (2006)'s study of architectural, engineering, and construction (AEC) firms' project success in China.

In Hale et al. (2009)'s study of the comparison of DB and DBB PDSs for the military projects in Naval Facilities Engineering Command, cost and schedule were the two categories used to measure the performance in DBB and DB projects. Time growth in number of days was used instead of a percentage of project duration. Cost growth as a percentage of total project cost was also used as a cost performance measurement.

Chan, Scott and Lam (2002) also summarized previous studies on project success measurements.

According to Chan et al. (2002), although Songer and Molenaar (1997) concluded that the performance criteria for DB project success are the same as projects in the generic sense, a more comprehensive list forms the assessment framework of success in DB projects (Fig 2.2).

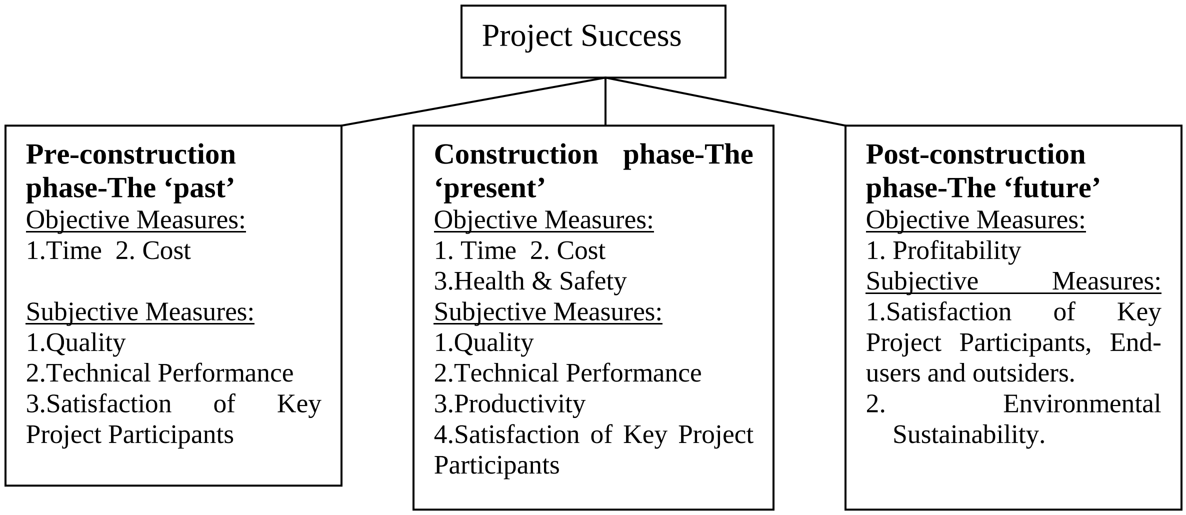


Figure 2.2. Assessment Framework for Project Success of Design/build Projects (Chan,Scott and Lam 2002)

2.1.3 Definition of Project Success for Design-Build Water/Wastewater Projects

Most of the project performance measurements are defined from building (commercial, industrial, residential and military) and transportation projects, while WW projects have rarely been studied. Some of the measurements in previous studies are not applicable to WW projects, such as the delivery speed using the construction area (sq ft).

In Bogus, Shane and Molenaar (2009)'s study of project performance between DB and DBB WW projects, the cost growth, schedule growth, number and value of change orders, and quality items (including owner satisfaction) were defined as performance measurements.

Figure 2.3 summarizes the project performance measurements based on the literature review of previous studies. This sample of literature is representative of project success measurements. The frequency of each project success measurement is illustrated in the bar chart below.

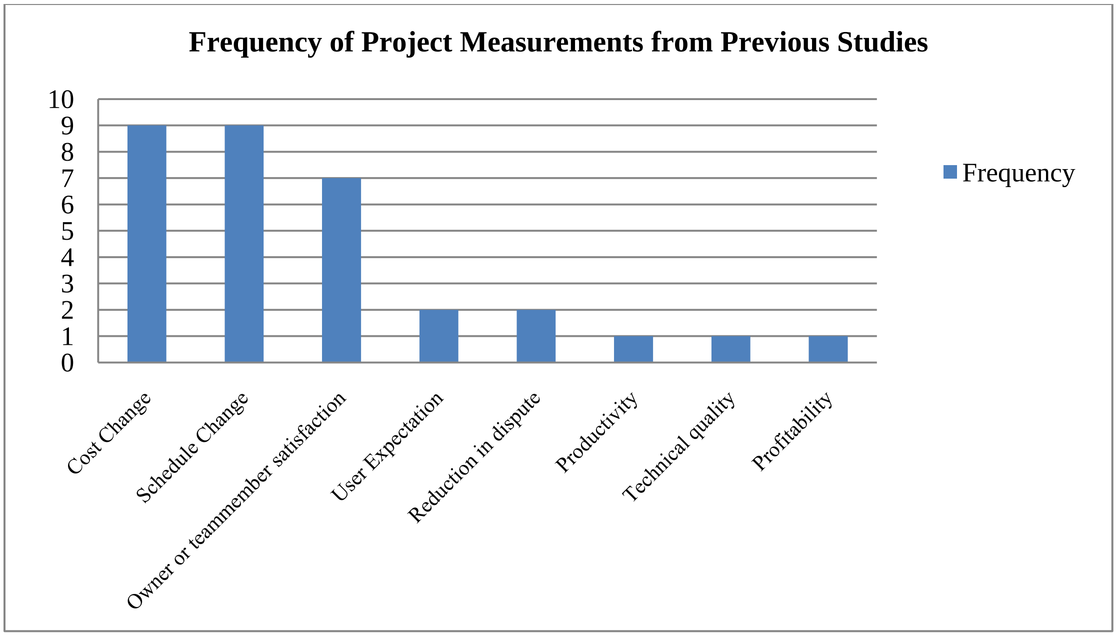


Figure 2.3. Frequency of Project Performance Measurements from Previous Studies

Figure 2.3 indicates that cost and schedule change are the most commonly used project performance measurements.

2.2 Design-Build's Impact on Project Performance

Many studies had compared the project performance of DB with other PDSs (e.g., DBB). Konchar and Sanvido (1998) compared the project performance among the main three PDSs, using data from 351 U.S building projects. The data analysis indicated that DB improved project performance in terms of unit cost, construction speed, delivery speed, cost growth and schedule growth, when compared to DBB and CMAR. In this study, multivariate analyses were conducted to find out the variables that accounted for the variation of project unit cost, construction speed, delivery speed, cost growth, and schedule growth. Roth (1996), Songer and Molenaar (2006), Molenaar et al. (1999), Ibbs et al. (2003), Warne (2005), FHWA (2006), Shrestha et al. (2007) Hale, Shrestha, Gibson and Migliaccio (2009) also studied the performance difference between DB and DBB projects. The project types include building, highway and industrial. All the studies showed improved cost and schedule performance in DB projects. Hale (2009) listed all of the previous findings on the comparison between DB and DBB as shown in Table 2.1.

Table 2.2. Research Done on DB and DBB Comparison (Adapted from Hale et al 2009)

Researchers	**Methods**	**Sample Size**	**Project Types**	**Project Size**	**Major findings**
Roth (1996)	DB	6	Navy child care facilities	N/A	Cost growth for DB was lower than that for DBB
	DBB	6			
Songer and Molenaar (1996)	DB	108	Industrial, building, and highways	N/A	Reduced cost and shortened duration were the top ranked factors for selecting DB methods
	DBB	N/A			
Konchar and Sanvido (1998)	DB	155	Industrial and buildings	N/A	Unit cost was 6% and cost growth was 5.2% less in DB. Schedule Growth 11.4% less in DB.
	DBB	116			
Molenaar et al. (1999)	DB	104	Industrial, buildings, and highways	N/A	59% of DB projects were within 2% or better of the established budget. 77% of DB projects were within 2% or better of the established schedule.
	DBB	N/A			
Allen (2002)	DB	17	Military Construction	N/A	Time Growth, Cost Growth, and Award Growth were respectively -4%, 3% and -2%, compared to 56%, 21% and 7% in DBB projects.
	DBB	16			
Ibbs et al.(2003)	DB	24	Buildings	$5M to $1B	Cost Growth for DB was 7.8% higher than that for DBB. Schedule Growth for DB was 2.4% lower than that for DBB.
	DBB	30			
Warne (2005)	DB	21	Highway projects	$83M to $1.3B	76% of DB projects were finished ahead of schedule. DB offered greater price certainty and reduced cost growth
	DBB	N/A			

Table 2.2 (cont.)					
Researchers	**Methods**	**Sample Size**	**Project Types**	**Project Size**	**Major findings**
FHWA (2006)	DB	11	Highway projects	$5M to $20M	Cost growth for DB was 3.8% higher than that for DBB. Schedule growth for DB was 9% lower than that for DBB.
	DBB	11			
Shrestha et al. (2007)	DB	4	Highway projects	$50M to $1.3B	Cost growth for DB was 9.6% lower than that for DBB. Schedule growth for DB was 5.2% higher than that for DBB
	DBB	7			
Hale et al. (2009)	DB	38	Military buildings	$3.7M to $37.6M	The mean cost growth was about 2% for DB, and 4% for DBB projects. Mean project duration for DB is about 50% as that for DBB, mean time growth for DB was about 2.4% lower than DBB projects.
	DBB	39			

Gransberg (2006) summarized the study conducted by the Centre for Strategic in Construction at the University of Reading (UK) pertaining to the evaluation of DB project performance. The study found that DB projects were 12% faster in construction speed, 30% faster in overall delivery speed, 13% cheaper, and they performed better in meeting quality requirements for sophisticated projects than DBB. The previous studies have verified the enhanced performance in DB projects in terms of cost and schedule.

Cost and schedule growth are the two most frequently used performance measurements for DB projects. Compared to other measurements, such as quality, these two are more objective. Cost and schedule control are the two most significant project goals, resulting in their use for project performance measurements in this study. The project types studied in Table 2.2 include building, highway and industrial. However, until recently little research has been done using data from the WW industry. A study by Bogus, Shane and Molenaar (2009) compared the performance between DB and DBB WW projects in terms of cost, schedule, and quality. Table 2.3 is a summary of the research.

Table 2.3. Comparison of DB and DBB Water/ Wastewater Project Performance

Researchers	Methods	Sample Size	Project Size	Major Findings
Bogus, Shane and Molenaar (2009)	DB	31	From \$2.4M to \$330M	Overall schedule growth in DB was significantly less than that in DBB, no significant differences were found in cost growth or quality
	DBB	69		

In this study, DB was found to perform significantly better than DBB in terms of schedule growth and there was no significant difference between DB and DBB regarding cost and quality. In addition, DB outperformed DBB in the percentage of projects completed on time and within budget. The intensity (dollar amount spent for the project per month) in DB (\$1.5M/month) is significantly higher than that in DBB (\$0.6M/month). Figure 2.4 summarizes the previous studies on DB and DBB comparisons based on cost and schedule growth.

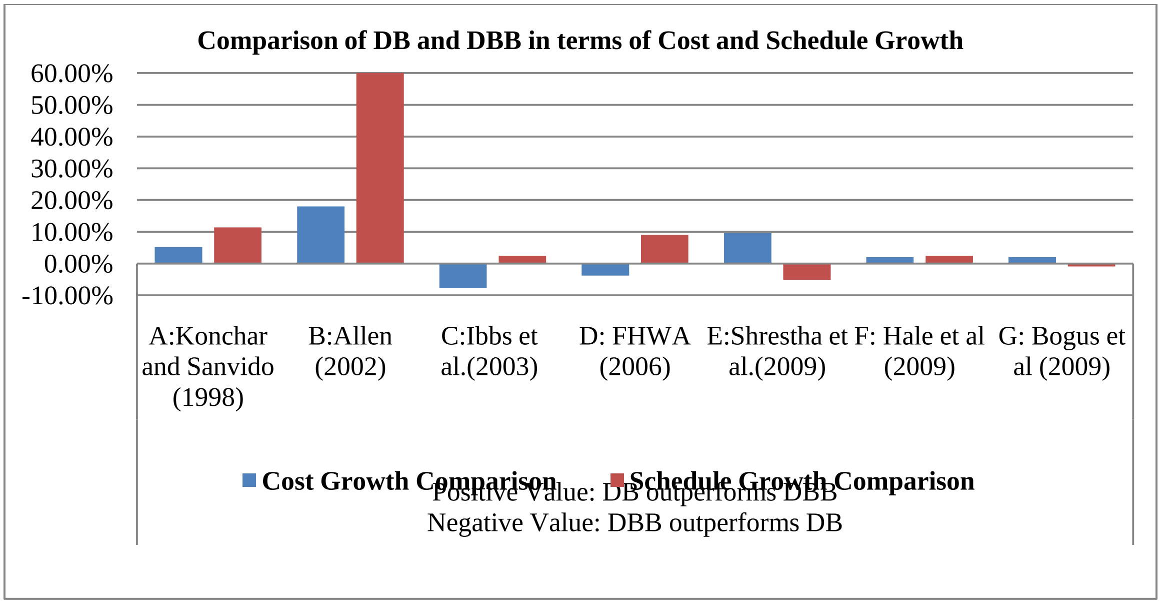


Figure 2.4. Comparisons of DB and DBB in Terms of Cost and Schedule Growth

In Figure 2.4, a positive value indicates that DB outperforms DBB. In contrast, a negative value or percentage shows that DBB outperformed DB, when the cost or schedule growth in DB is higher than that in DBB. Figure 2.4 indicates that the comparison results of DB and DBB are not consistent with respect to either cost growth or schedule growth. The growth of cost and schedule are not the only project performance measurements. There are also some other measurements that can be used to describe project performance. For example, the percentage of the amount of projects finished within budget and schedule is also a measurement. In Bogus et al. (2009)'s study of WW projects, DB was concluded to outperform DBB in light of the fact that more DB projects were finished within the budget and schedule, without significant differences in quality compared to DBB.

2.3 Project Performance Influencing Factors

It is questionable as to what contributes to project performance. To answer this question, factors impacting project performance need to be defined and tested. A common way to study the performance influencing factors is to hypothesize the potential factors and then collect data to analyze the extent that these factors influence project performance. Table 2.4 illustrates previous studies of factors related to project performance.

Table 2.4 Summary of Previous Studies on Factors that Impact Project Performance

Researchers	Influencing factors	Methodology	Project sample	Major findings
CII (1994)	Pre-planning	Telephone interviews and questionnaire survey	62 industrial projects, from $4M to $350M	A well-performed pre-project planning can reduce total project cost by 20%, reduce schedule by 39%, and improve project predictability in terms of cost, schedule and operation performance.
Songer and Molenaar (1997)	15 project characteristics	Literature review, unstructured interviews, owner survey, structured interviews	N/A	Project success criteria and 15 major project characteristics are defined, their significances are ranked, in public DB sector.
Pocock, Liu, and Tang (1997)	Designer/ Builder interaction	Data collection and regression analysis	38 military construction projects	There was a direct relation between project interaction and performance.
Molenaar, Songer, Barash (1999)	Owner experience, design completion, design/builder selection, contract award methods	Case study questionnaire	104 DB public sector projects, 86% are building projects	Two-step DB method delivers the best overall budget and schedule performance, compared to one-step and qualification.

Table 2.4 (cont.)				
Researchers	**Influencing factors**	**Methodology**	**Project sample**	**Major findings**
Molenaar, Songer (1998)	4 main categories for DB selection, decomposed to 44 measurable characteristics	Multiattribute analysis and case study data collection	104 public projects, 86% are building, from \$0.29M to \$780M.	There were significant findings in all 4 areas of project, owner, market and relationship, while owner is the most critical to project success.
Chan, Ho and Tam (2001)	Inter-organizational teamwork, project participants' job satisfaction, project participants' view on DB	Questionnaire survey	19 DB public projects in Hong Kong	If inter-organizational teamwork is fostered in DB projects, a successful project outcome would be achieved.
Ling (2004)	60 potential factors based on three categories: project, owner/consultant and contractor characteristics	Data collection through questionnaire and correlation studies	65 DBB building projects	Contractors play a bigger role in bringing project success, compared to owner and consults, while project characteristics play a more role in some other performance metrics.
Ling, Chan, Chong Ee (2004)	59 potential factors, which can be categorized based on the project, owners, consultants, and contractors	Questionnaire survey and multi-linear regression analysis	54 DBB and 33 DB building projects	Significant variables that affect different aspects of DB and DBB project performance were identified.
Wardani, Messner, Horman (2005)	Procurement methods	Questionnaire survey	76 U.S DB projects in the building and industrial sector	No one DB procurement method outperformed others with regard to all performance metrics. However, the procurement method's impact on a single metric does vary.
Ling, Ibbs, Hoo (2006)	7 categories of factors were defined, each category was divided into variables	Questionnaire survey and data correlation analysis	73 AEC firms in China	The firm's ability to understand the client's requirements affect the most number of success measures. Two other variables also have a large effect on project success

Table 2.4 (cont.)				
Researchers	**Influencing factors**	**Methodology**	**Project sample**	**Major findings**
Cheng,Li and Fox (2007)	Demographic and job performance category	Questionnaire survey, correlation analysis	N/A	Research suggest the essence of task dimensions of job performance for maximizing project performance and the strong predictive power of job nature and firm size on the task category
Ling, Low, Wang, and Egbelakin (2008)	Project Management actions: scope, time, cost, risk, quality, human resources, communications, procurement	On-line questionnaire survey	33 AEC firms with projects in China performance by foreign in	Explanatory variables that significantly affect project performance were identified. Five predictive models were built.
Lam, Chan, Chan (2008)	42 success variables within 9 categories	Questionnaires targeting DB participants	92 responses of DB participants in Hong Kong construction industry	DB project success is attributed to a large number of factors, including the project nature, project management action, and the application of innovative management approaches

Content analysis was used to count the frequency of these influencing factor categories (Table 2.5).

Table 2.5. Frequency of Influencing Factor Categories in Previous Studies

Categories of influencing factors	Frequency
Project participant characteristics (e.g. effort skill, experience, organization, communication)	10
Project characteristics (project size, e.g.)	8
Procurement (method, contract type, etc)	7
Project management action	5
Economic, social and financial condition	4
Technology and approach	3
Planning	2

Table 2.5 indicates that procurement, project characteristics and project participants' characteristics are the three most frequently used categories. Although in some of the studies, procurement method (one-step, two-step, qualification, e.g.) and contract type

(lump-sum, guaranteed maximum price, e.g.) are categorized into project characteristics, the procurement method and contract type are separated from project characteristics in this study. The variables for these three categories are summarized in Table 2.6.

Table 2.6 Frequency of Variables in Procurement, Project Characteristics and Project Participants Characteristics

Variables within each of the three categories	Frequency
Project characteristics	
Project size or complexity	7
Project cost	1
Project duration	1
Project type	3
Project delivery system	3
Project participant characteristics	
Owner and owner representative capabilities, organization and experience	6
Construction team's capabilities, technical skills and experience	7
Design /engineer/consultant's capabilities, technical skills and experience	6
Owner's input in the project	3
Contractor's input in the project	1
Communication of project participants	7
Procurement	
Contract type	3
Level of design at the time of bid or proposal	4
Project scope definition when bidder or design-builder is hired	3
The time for bidder or design-builder to prepare proposal/bid	2
Bidder or design-builder selection criteria	4
Existence of proposer/bidder prequalification	4
Procurement method or procedure	4
Number of bidders or proposers	3
Flexibility of contract period during the bid or proposal evaluation	3

Nearly all of these studies used questionnaire surveys to collect data for analysis. Regression and correlation analysis were frequently applied to analyze the relationship between these factors and project performance. These factors also include objective and subjective measurements, and the latter are more frequently used for quantification. For example, a dependent variable measurement of 1 to 6 may be used to describe the project complexity. Table 2.4 also provides the study results on the impact that those factors have on project performance. Most studies use correlation analysis to quantify the impact. Some factors influencing project performance were identified, including designer-builder interaction, pre-planning effort, owner and contractor's capabilities and experience.

Among the 13 previous studies, the building industry is mostly frequently used for the study of performance influencing factors. Few studies have used projects from the WW or other infrastructure industry. Among these 13 previous studies, 8 of them were related to DB projects. Based on these study results, it is reasonable to select procurement as a possible influence on DB project performance.

2.4 Procurement under Design-Build

The procurement features, in terms of process, methods, and formats, may vary fundamentally in different PDSs. For instance, in contrast to DBB, the lowest price or hard bid is not a common method used in DB procurement. In this study, literature concerning procurement in DB PDS defined the DB project procurement characteristics as procurement methods, selection process, and two typical procurement vehicles-RFQ and RFP.

2.4.1 Procurement Methods

Beard et al. (2001) describes the procurement methods and selection criteria for integrated PDSs (Table 2.7). The selection methods are generally categorized as qualification-based, price-based, and best value.

Table 2.7 Procurement Options under Combined Design and Construction Contracts (Adapted from Beard,2001.)

Subjective and Qualitative Factor(s)			**Best Value: Subjective, Qualitative, and Quantitative**				**Price- Based**	
Sole Source	QBS	Negotiated Source Selection	Compet-itive Negotia-tion	Weighted Criteria	Fixed Budget / Best Design	Adjust-ed Low Bid	Two-Step Sealed Bidding	Low First Cost Bidding
Bilateral Discussions Choice Based on Qualitative/ Subjective Factors			Formal Discussions-Choice Based on a Combination of Qualitative and Quantitative Factors		Unilateral Choice, Based on Qualitative and Quantitative Factors		Unilateral Choice, Based on Single Quantitative Factor	

Lowest bid (a price-based selection method) is not a common method for procurement in DB projects, because the owner typically chooses to procure the Design-Builder based on pre-qualification or a combination of qualification and price rather than competitive price. Wardani et al. (2006) defined the typical DB procurement methods as sole source selection, best value, qualification-based, and low-bid.

(1) **Sole Source Selection**

According to Beard et al. (2001), both private and public owners may use the sole source method, especially when an owner has a long-term working relationship with the design-builder. Past performance, reputation, technical and managerial qualifications are the usual selection criteria. The procurement documents used in sole-source selection are either a direct purchase request or a sole-source contract agreement (Beard et al., 2001). The lack of price competition can discourage public owners from selecting the sole source method in DB projects (Molenaar and Gransberg 2001, Wardani et al. 2006).

(2) **Qualification-Based Selection (QBS)**

Under QBS, owners usually publish a RFQ, and design-builders respond with a Statement of Qualification (SOQ) for the owner's evaluation. The selection of design-builders is primarily based on qualitative criteria such as past performance, reputation, technical competence, etc (Wardani et al. 2006). In Wardani et al. (2006)'s study, the procurement method was QBS when the non-cost criteria represented 50% or more of the qualification evaluation. Past performance and previous experience in similar types of projects are the top selection criteria (Beard et al., 2001). According to Beard et al. (2001), in public projects, the scoring matrix for design-builder selection may include:

- Past experience with integrated services delivery;
- Past experience with other members of the team;
- Approach to problem solving, creative strategies, and innovation;
- Quality assurance planning and management;
- Key personnel dedicated to the project;
- Financial solidity and management skills.

(3) Best Value Selection

In the best value approach, a design-builder's qualifications and price proposal are both considered, but the owner may view the level of importance between them differently in DB projects. The RFP is usually published by the owner to advertise the DB project, and design-builders respond to the RFP with a proposal submittal, which is reviewed by the owner. Negotiations may take place after the proposal submittal, and there may be a prequalification of the design-builder based on technical criteria before the final selection (Wardani et al. 2006). In Beard et al. (2001)'s study, the following four types of procurement options can be categorized as a best value approach.

- Negotiated source selection with discussions

According to Beard et al. (2001), in this type of approach, design-builders are allowed to "bargain" on technical requirements, schedule, price, type of contract and its provisions, and other project-related issues. They also have an opportunity to revise offers before contract award.

- Source selection with formal review (no discussions)

Owners may award contracts to the most favorable initial proposal without discussions, selecting the best proposal on the basis of information that is contained within or appended to the RFP (Beard, 2001). A two-phase selection procedure may be used in this approach.

- Fixed budget/best technical response or design

According to Beard (2001), the owner establishes the contract price prior to the procurement. Design-builders only need to submit qualifications and technical proposals, with all price offers equal.

- Weighted criteria

In this approach, the design-builders usually respond to the RFP with separate qualitative and price proposals. A design-builder's response to each evaluation factor will be scored. The design-builder with the highest total score will be awarded the contract.

A two-step process is usually used in the best value approach. In some projects, a three-step process may be used. Compared to the twp-step process, there is an additional step for the prospective proposers to revise their proposals upon the suggestions of the owner's evaluation committee. The proposers will submit the best and final offer (BAFO) after the revision. The owner may highlight that the purpose of the BAFO step is not to lower proposers' price, but to have the proposals most responsive to owner's requirements.

(4) Low-Bid Selection

The Low-Bid approach can be divided into adjusted low bid and low first cost.

- Adjusted low bid

Although owners weight most points in price, the design-builders' price score will be adjusted by their qualitative score. Usually, the final score can be acquired by dividing the price score by the qualitative score. Qualitative scores can be a number from 0 to 1, and a lower qualitative score is given to a design-builder with better qualitative performance.

- Low first cost

It is the same approach used in DBB projects, with little incentives for bidders to use creative construction technologies.

Levy (2006) defined similar ways of procurement methods as: direct selection, best value, equivalent design/low bid, fixed-price design, and adjusted low bid.

2.4.2 Procurement Process

The procurement process here refers to DB projects that use best value to select design-builders based on the proposal evaluation. According to Levy (2006), public and private agencies use similar procedures to initiate a DB project:

- Program definition by the owner
- RFQ
- RFP
- Pre-proposal Q&A conference followed by the issuance of Addendas, if necessary
- Proposal submission and evaluation

- Post-proposal interview
- Contract award
- Start of design and construction post-award process

The ASCE (2008) also described a similar project sequencing in DB projects:

- Project requirements definition and conceptual design
- RFP preparation
- Proposal preparation by design-builders
- Proposal evaluation and award
- DB execution
- Facility to owner

The DB procurement processes described by Levy (2006) and ASCE (2008) are similar except that Levy (2006) included the pre-qualification action through RFQ, pre-proposal conference, and post-proposal interview, which frequently happens in design-builder selection.

The initial step to start the procurement is to define the project scope and/or conceptual design. According to ASCE (2008), an owner may either have its own staff or hire consultants to develop the conceptual design. The design-builder will be responsible for the final stage of design - Designer-of-Recorder, which means the design-builder will perform the follow-on design in its proposal. Alternatively, the owner might require design-builders to develop their own conceptual designs as part of their proposals. As a basis for DB proposals, the owner must articulate the value of the project performance and expectations for completed facilities (ASCE, 2008). ASCE (2008) mentioned that the descriptions of the owner’s values and expectations determine the owner’s control of project outcomes. Examples of owner's values and preferences may include partnership and cooperation, operability and maintainability, aesthetics, public participation, and environmental sensitivity. Owner's expectations include facility specifics such as size, capacity, and function, quality assurance and control, regulatory compliance, project schedules, and budgets. More definitions of the owner's descriptions of its values and expectations contribute to more control over the project outcome.

The next step in DB procurement after project definition and conceptual design is to prepare project proposals. Depending on the owner and project characteristics, the selection process may be one-step (RFQ or RFP), two-step (RFQ and RFP) or even more steps. In a two-step selection, it is not unusual that the owner has a pre-qualification step to remove disqualified design-builders from the list. The prequalification exercise is to evaluate the capabilities of proposers according to qualification criteria. The number of short-listed design-builders for DB projects is usually 3 to 5 (Palaneeswaran et al, 2000).

Molenaar et al. (1999) categorized the DB procurement types (as shown in Table 2.8).

Table 2.8 Summary of DB Type (Source from Molenaar et al. 1999)

Type of DB	Level of design completion before procurement (%)	Prequalification of bidders	Award criteria
One-step	0-50	No	Low-bid or best value
Two-step	0-35	Yes	Best value
Qualifications-based	0-10	Yes	Qualification or best value

A single-stage evaluation is recommended for projects where requirements can be easily defined, while a two-step selection process that includes both prequalification of design-builders and an evaluation stage is recommended for highly sophisticated projects (Palaneeswaran et al, 2000).

A two-step selection consists of RFQ and RFP. According to Beard et al. (2001), the importance of an RFQ includes: (1) it attracts best-qualified design-builders to the procurement process, and (2) it states the project objectives to be accomplished and describes the necessary information and criteria that will be used to determine the best-qualified design-builders. An RFP is the primary contractual document between the owner and the proposer, representing the owner's last convenient opportunity to broadly define its needs, requirements, and limitations before engaging in the competitive process (Beard et al., 2001). Proposal evaluation is the next step after the design-builder's proposal submittal, and must be outlined before the RFQ/RFP is written (Gransberg et al, 2006). The design-builders' proposals will be evaluated by an owner's committee, and scored based on how well the proposal meets RFQ and RFP requirements. The evaluation criteria may vary in different projects, and is usually published in the RFP. Before awarding the contract, the owner may have interviews with potential design-builders. Gransberg et al. (2006) illustrates examples of the four options of a procurement process as a continuum (Figure 2.5):

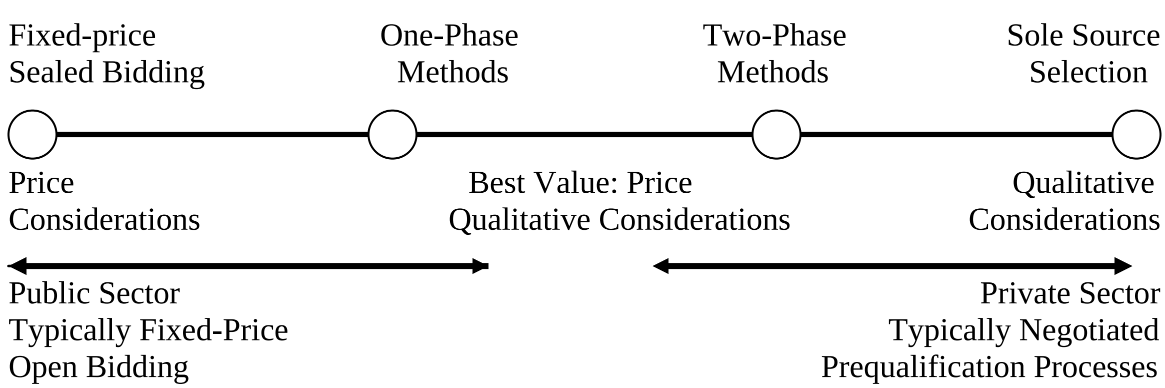


Figure 2.5. Design-Build Selection Process Continuum (Gransberg et al. 2006)

Molenaar and Gransberg (2001) and Gransberg et al. (2006) illustrated the one-step and two-step process in transportation as shown in Figure 2.6 and Figure 2.7.

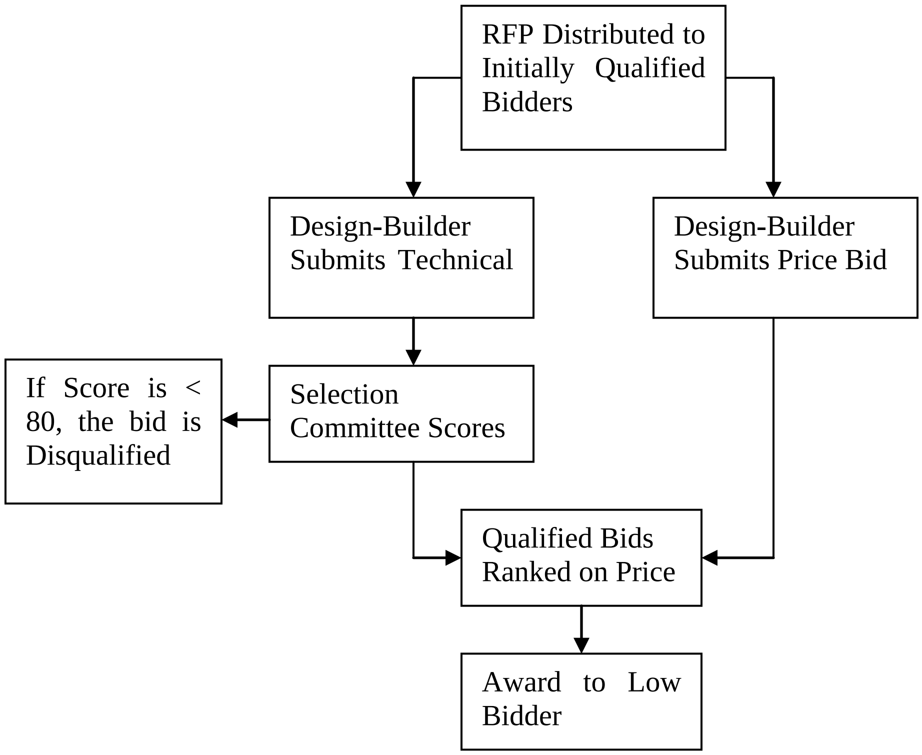


Figure 2.6 Indiana Department of Transportation's one-step selection process (Molenaar and Gransberg 2001, Gransberg et al, 2006).

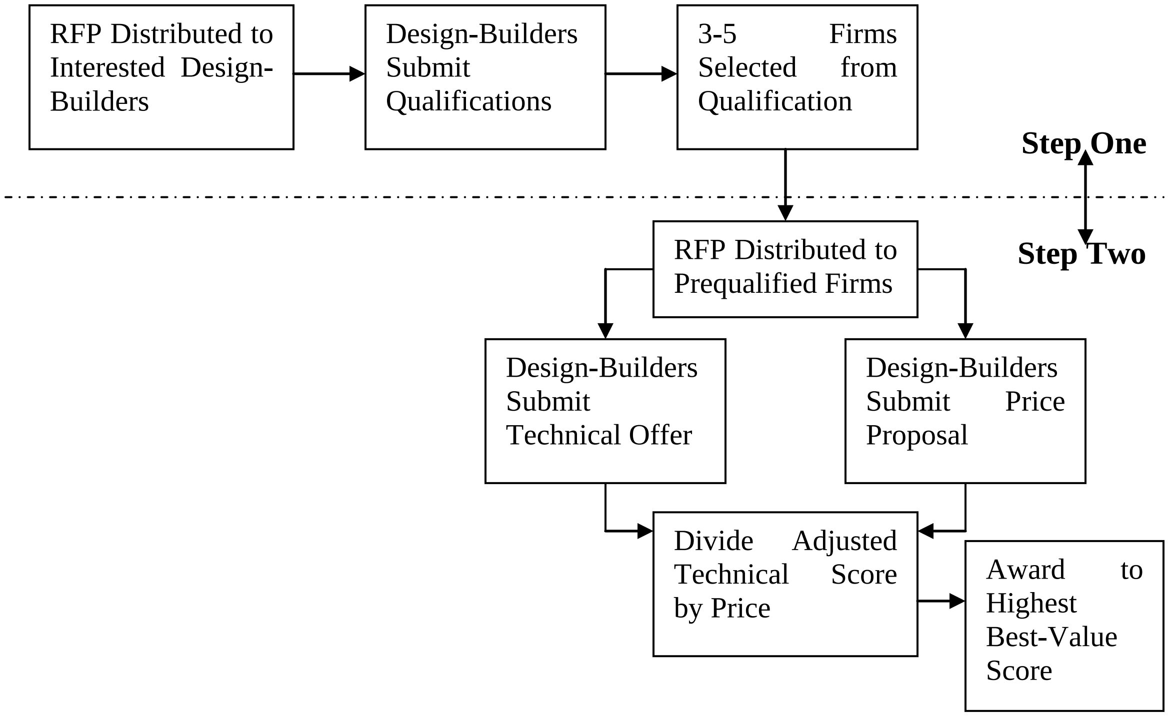


Figure 2.7. Washington State Department of Transportation's Two-Step Selection Process (Molenaar and Gransberg 2001, Gransberg et al., 2006).

Migliaccio et al. (2009) studied the procurement process of the two-phase BV in two DB highway projects in Texas and illustrated the process as shown in Figure 2.8.

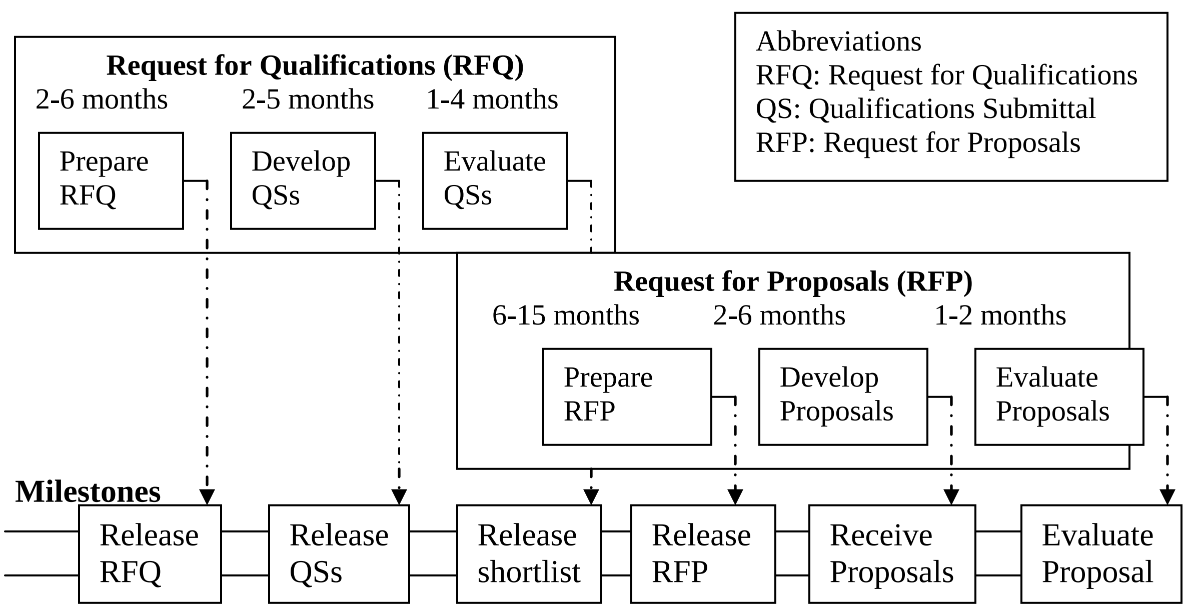


Figure 2.8. Procurement Process of Two-Step Best Value with Durations and Milestones (Source from Migliaccio et al. 2009)

2.4.3 Format of RFQs and RFPs

The RFP is a common vehicle in DB project procurement. For those projects using a RFP as the procurement vehicle, a RFQ may also be used to prequalify design-builders.

Beard et al. (2001) listed elements (Figure 2.9) and selection criteria (Figure 2.10) in typical DB RFQs and RFPs.

Elements of RFQ

• Identification of owner	Honoraria
• Description of project and scope	RFP requirements
• Building type and size	Summary of proposal selection criteria
• Estimated cost	Basis of award
• Project schedule	Identification of jurors
• Selection process	Minimum requirements of D/B team
• Type of design-build competition	Submittal requirements
• Key dates	Prequalification selection criteria
• Presubmittal conference	Submittal deadline and address
• Number of finalists	

Elements of RFP

• Identification of owner, consultants, jury, and design-build teams	Presentations
• Eligibility and honoraria	Disqualification
• Communications	Instructions to proposers
• Preproposal conference(s)	Weighted proposal selection criteria
• Competition schedule	Basis of award
• Proposal form	Information provided by owner
• Alternates	General conditions of contract
• Supplements to proposal form	Agreement and bond forms
• Program of facility requirements	Performance specifications

Figure 2.9. Elements of DB RFQ and RFP (Source from Beard, 2001).

Prequalification Selection Criteria

- Builder's financial and bonding capacity
- D/B team's building-type experience
- Record of design and technical excellence
- Staff experience
- Design-Build experience
- D/B's organization-management plan
- D/B's quality control plan
- D/B's record of on-budget performance
- D/B's record of on-schedule performance

Proposal Selection Criteria

- Architectural image and character
- Alternate for engineering project: technical innovation and environmental acceptability of engineered solution
- Functional efficiency and flexibility
- Quality of materials and systems
- Quantity of usable area
- Access
- Safety and security
- Energy conservation
- Operation and maintenance costs
- Cost/value comparison
- Completion schedule

Figure 2.10. Selection Criteria of DB Prequalification and Proposal (Source from Beard et al., 2001).

Comparing the elements and selection criteria of RFQs and RFPs, a RFP has detailed documentation (bond, proposal forms, e.g.), and the project's cost and technical approach. A RFQ is more concerned with design-builders' qualification, with some minimum requirements in design-builders' experience in DB PDS and similar types of projects, as well as DB organization and personnel. A RFQ provides the project background information, advertises projects to potential design-builders, and introduces the RFP requirements and proposal selection process to design-builders.

According to Gransberg et al (2006), a RFP usually contains three major elements:

(1) Contract boilerplate, also named general and special provisions,

(2) Technical requirements that range in specificity across the performance hierarchy,

(3) Evaluation of proposal submittal which is required to exchange sufficient information to allow the award decision to be reached.

The RFP elements listed in Figure 2.9 can be categorized into one of the three above-mentioned types. In a best value selection, the following elements of the evaluation plan should be included in a RFP (Gransberg et al, 2006): evaluation process, technical criteria, project management criteria, cost criteria and weighting.

Gransberg et al. (2006)'s description of RFP content is similar to Beard et al. (2001) in that a typical RFP includes four sections: (1) Technical requirements of proposer's service or workmanship, (2) Project scope description and quality requirements, (3) Timeline requirement, (4) Contract clauses that govern the relationship. A well-constituted RFP should also introduce the owner's evaluation criteria and selection process of design-builders (Beard et al., 2001).

In ASCE (2008)'s introduction of RFP preparation, four categories of elements were listed: selection criteria, qualification, technical consideration, and cost consideration.

Gransberg and Barton (2007) conducted an analysis of federal DB RFP evaluation criteria. In this analysis, the evaluation process was categorized as vague, semi-detailed and detailed. Five evaluation categories were identified. They were price, technical, qualification, schedule, and project management. Price was found to be the most important criteria, and qualification was the criteria that appeared most frequently in DB RFPs.

Given the amount of information that is required for developing a DB proposal, it is reasonable to infer that allowing design-builders more time to prepare the DB proposal would result in better project performance. It is this inference that forms the basis for the study detailed in Chapter 3.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Research Objectives

Before defining the methodology, the research objectives need to be identified.

Chen (2009) studied the relationship between PD and DB project performance in transportation projects. Project schedule growth was found to have a strong and negative linear relationship with PD. Cost growth was found to have a weak linear relationship to PD. Based on Chen's (2009) research, four questions are provided for this study of DB water/wastewater projects.

(1) What is the relationship between procurement duration and project performance in DB WW projects?

(2) Is the relationship between PD and DB project performance in DB WW projects similar to transportation projects?

(3) Does the relationship vary with project complexity? And is this variation similar to DB transportation projects?

(4) What are the similarities and differences of the procurement formats (e.g., RFQ, RFP) between DB WW projects and transportation projects?

3.2 Research Hypotheses

According to these four questions, four related hypotheses are provided:

(1) The longer the procurement duration, the better the project performance.

(2) The relationship between PD and DB project performance in DB WW projects is similar to that in transportation projects.

(3) Project complexity affects the relationship of procurement duration and project

performance, and the variation among WW projects with different complexities is similar to transportation projects.

(4) There are some similarities and differences in the procurement formats (e.g., RFQ, RFP) between DB WW projects and transportation projects.

3.3 Method Selection

Chen’s (2009) study methodology is data collection through email survey, reviewing published project information (e.g., State Department of Transportation reports), and previous research, followed by correlation analysis of the data. That is also the same methodology used by 13 previous studies listed in Table 2.4. Almost all of these studies used a questionnaire survey followed by data analysis to explore factors that have impacts on project success and the extent of that impact. Yin (2002) listed five research strategies catering to different types of research questions (e.g., what, how, why). The types of “what” questions in a form of “how many” or “how much” is suitable for the survey archival analysis strategy rather than experiment, history or case study. This study aims to find the relationship of procurement duration (PD) and project performance in DB water/wastewater projects. It is in the form of “what” the relationship is, or “how much” PD impacts project performance, so either survey or archival review is suitable for this study. However, archives of the related data regarding procurement duration and project performance data are unavailable in the industry, so a survey is considered to be the best method for the quantitative study of the relationship.

Vivek Bhaskaran (2009) summarized the pros and cons of four different types of surveys: in-person interview, phone survey, mail survey, and web/online survey. Compared to the other four types, the web/online survey is supposed to be inexpensive, can be selfadministered, with very low probability of data errors and saves time. Almost all of people surveyed had email accounts. Thus, an on-line questionnaire survey was selected as the research tool for data collection in this study.

Correlation analysis was used to study the linear relationship of the data.

The method of least squares was utilized to fit a straight line for the scatter plot of procurement duration (PD) data and performance measurements (PM). The function used to express the linear relationship is (Johnson, 2005):

$$\hat{y} = a + b\,x$$

where x is the PD data, ŷ is the expected PM value using a linear equation, ŷ is the actual PM value (such as cost and schedule growth), and a and b are intercept and slope of the straight respectively.

The sample correlation coefficient (r) is calculated to measure the linear relationship using the equation (Johnson, 2005):

$$r = \frac{S_{xy}}{\sqrt{S_{xx} * S_{yy}}}$$

Here, $S_{xx} = \sum (x_i - \bar{x})^2 = \sum x_i^2 - \frac{(\sum x_i)^2}{n}$

$$S_{yy} = \sum (y_i - \bar{y})^2 = \sum y_i^2 - \frac{(\sum y_i)^2}{n}$$

$$S_{xy} = \sum (x_i - \bar{x}) (y_i - \bar{y}) = \sum x_i y_i - \frac{(\sum x_i) (\sum y_i)}{n}$$

where s_e stands for the standard error of the estimate, and is calculated as:

$$s_e^2 = \frac{S_{yy} - (S_{xy})^2 / S_{xx}}{n - 2}$$

The analysis of variance was used to check if the expected performance value ŷ was consistent to the actual value y. Similar to Chen (2009)'s study of the relationship between procurement duration and DB project performance, if no linear relationship was found, then a residual plot observation and analysis would be conducted in a later phase. After the linear regression analysis, the results were compared between WW projects and previous research on transportation projects. If there were differences in the relationship types (e.g., negative or positive, strong or weak) between WW and transportation projects, procurement documents of transportation and water/wastewater projects were analyzed to find possible explanations for the differences. Content analysis (CA) was used when evaluating the procurement documents. CA is a method used to determine the presence of certain words or concepts within texts or sets of texts (Yu et al, 2006). According to Yu et al (2006), researchers quantify and analyze the presence, meanings, and relationships of such words and concepts, then make inferences about the messages within texts. CA is currently used in various fields, ranging from marketing and media studies, to literature and cultural studies, sociology and political science, psychology and cognitive science, and many other fields of inquiry <http://writing.colostate.edu/guides/research/content/com2a2.cfm> (Feb.2, 2010). CA has also been applied in the construction industry:

- Yu et al (2006) used CA to identify critical success factors (CSF) for construction project success. CSFs were collected from an open-ended questionnaire survey and categorized into 5 groups. The significance of CFPs was ranked according to their frequencies within the survey.
- Gransberg and Molenaar (2004) conducted CA to analyze owners' quality evaluation requirements (QER) and quality approach (QA) in DB projects. 78 RFPs were reviewed to define the QER and QA categories. CA was used to count

the number of QER and QA categories. Results were analyzed based on the frequency of each category.

- Gransberg and Barton (2006) used CA to rank the weighted criteria in DB project RFPs to identify owner's motivations to seek DB process. 110 RFPs were reviewed, and evaluation criteria were categorized as price, technical, qualification, schedule, and project management. Each category's weighted percentage, average point, and frequency of presence were quantified.
- Gransberg and Windel (2008) used CA to study how owners communicate design quality requirements for public DB projects. 75 RFPs were reviewed to code the quality-related RFP criteria and requirements. Detailed definitions of these criteria and requirements were provided also using CA.

All of the above four CA studies in the construction industry collected data from surveys or RFP documents, defined categories, counted the frequency of each category, and finally summarized the data to draw conclusions.

According to GAO (2006), five major factors should be considered when deciding whether to use CA:

(1) Assignment objectives: CA is applicable for answering descriptive questions which provide information about conditions or events, or comparing an outcome to a norm or standard. In this study, CA was used to describe the content of procurement documents in DB projects, and compare the content (standards) in WW DB projects to DB transportation projects.

(2) Data available to be collected: in this study, data for CA is from procurement documents (e.g., RFQ, RFP).

(3) Kinds of data required: in the early stage of this study, possible variables in CA include the content, project owner's selection process, etc.

(4) Kinds of analysis required: the CA in this study aims to count the frequencies of each variable in procurement documents, and compare the frequencies of each variable between transportation projects and water/wastewater projects.

(5) Resources needed: analysts and personnel needed for the CA.

Based on the five factors, CA is considered as the appropriate strategy to compare the procurement documents in DB transportation projects and DB WW projects.

Thus, there are two methods that make up the methodology. The first one is questionnaire survey with correlation data analysis. The second is the content analysis to compare procurement documents of DB transportation projects and DB WW projects.

3.4 Term Definition

After the objectives and methodologies have been defined for this study, the next step is to quantitatively define the measurements of PD and project performance. Based on Migliaccio, et al. (2009)'s study of the two-phase procurement process of DB highway projects, the procurement may start from an owner's viability study and extend until contract execution. The whole process is divided into as many as four steps. The whole duration may not reliably reflect the effective project PD, as there may be some delays or stoppages that occur during the process. For example, the owner's preparation may be delayed and last a long time, during which the procurement work does not move forward. In Figure 2.8, the period from the RFP issue date to proposal due date is an effective measurement of the projects' PD. This is the time that the owner gives to design-builders to prepare the proposal. The time of design-builders' preparation of a proposal can better reflect the PD than an owner's preparation of the RFQ. In Chen (2009)'s study of procurement duration in DB transportation projects, PD was also measured by the period from RFP issue date to proposal due date.

3.4.1 Raw Data Surveyed

Below are data that were collected through the on-line questionnaire survey:

RFP Issue Date: The date that the RFP was published to design-builders.

Proposal Due Date: The date that design-builders (proposers) submitted proposals to the owner.

DB Start Date: The date that the selected design-builder started the work after signing the DB contract.

Substantial Completion: The date that construction was finished.

Project Contracted Cost ($): The amount of the total DB cost in the final contract excluding RFQ and RFP development costs.

Project Actual Cost ($) (PAC): Actual final total DB cost when the construction was finished.

For all of the above dates, data were collected for "As Planned" dates and "As Built" dates in the form of (mm/dd/yyyy).

3.4.2 Durations Derived from the Raw Data

Based on these data, parameters of project procurement duration and project performance in terms of cost and schedule growth were defined as follows:

Procurement Duration (days): The duration from RFP issued to RFP due date. In Figure 2.8, this is the duration between the milestones of RFP release and owner's receiving of the proposal.

DB Duration As Planned (days): The duration from DB Start Date As Planned to Substantial Completion As Planned. It is the planned timeline for the design-builder to finish the DB contract work.

DB Duration As Built: The actual period of time from DB Start Date As Built to Substantial Completion As Built.

Planned Total Duration (days): The duration from RFP Issue Date As Planned to Substantial Completion As Planned. It is the planned time for the design-builder to finish the whole DB work, which starts from a design-builders' preparation of the proposal.

Actual Total Duration (ATD): The period from actual RFP Issue Date to actual Substantial Completion.

These durations can be illustrated in Figure 3.1.

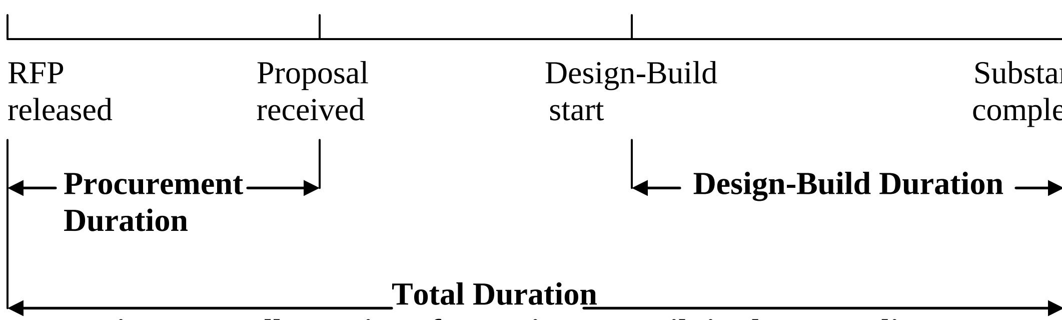


Figure 3.1. Illustration of Durations as Built in the DB Delivery Process

Figure 3.1 provides a picture of project procurement duration, DB duration and total duration. Some projects may have a two-phase selection process, as in Figure 2.8, in that case, only the duration from RFP issue date to proposal due date will be considered as the procurement duration. For DB projects with a one-step selection without a RFP format, the period from RFQ issued date to RFQ due date will be considered as the procurement duration.

3.4.3 Measurements of Project Performance

Figure 2.3 indicates that cost and schedule change are the two most frequently used project performance measurements. That is because both of these measurements are objective and can be quantitatively defined. Cost and schedule are two main performance factors that the owner emphasizes. Although quality is another significant performance factor, quality is difficult to objectively quantify. In Chen's (2009) study of DB procurement duration in transportation projects, schedule and cost growth are also used as two types of performance measurements. Similar to Chen (2009):

Schedule Growth is measured by comparing the Actual DB time or Total Project Time (total duration in Figure 3.1) to that as planned (%).

Cost Growth is measure by comparing the increase or decrease in the project price (%) between actual and as planned values.

3.5 Data Sources and Data Collection

The data sources for this study consist of two parts. The first source of data was a comparative study of DB and DBB WW projects undertaken by Bogus et al (2009). Data were collected through an on-line survey for projects completed between 2003 and 2009. Data on 31 DB projects were included in the final project sample. Data regarding project RFP Issue Date, Design Start Date, Construction Start Date, Project End Date, Project Contracted Cost and Final Cost from these 31 DB projects were used for this study. The proposal due date was unavailable in Bogus et al. (2009)'s study, so responders from these 31 projects were contacted again for the proposal due date. The second source of data is from a new on-line questionnaire (Appendix B). The questions in this new questionnaire were based on Bogus et al. (2009)'s comparative study. Questions in this on-line survey focused on the milestone dates and costs, as shown in Table 3.1.

Table 3.1. Survey Data Sample

Schedule Performance		
	Date as planned(contracted)(mm/dd/yyyy)	Date as built(actual)(mm/dd/yyyy)
RFP Issued		
Proposal Due		
Design-Build Start		
Construction Finished (Substantial Completion)		
Cost Performance		
	Total Design-Build Costs (excluding RFQ and RFP)	
Contract Award		
Final Cost		

3.5.1 Data Collected from Projects in Bogus et al (2009)'s Study

Among the 31 DB projects from Bogus et al. (2009)'s study, Proposal Due Date (PDD) data were received from 12 projects within two weeks, indicating an initial response rate of 38.7%. After two weeks, reminder emails were sent to the remaining project responders, and later phone calls were made to ask for the PDD. Ultimately, PDD data were collected for 22 projects and used for this study. The final response rate was 71%.

Figure 3.2 shows the percentage of each category of respondent for the 31 DB projects.

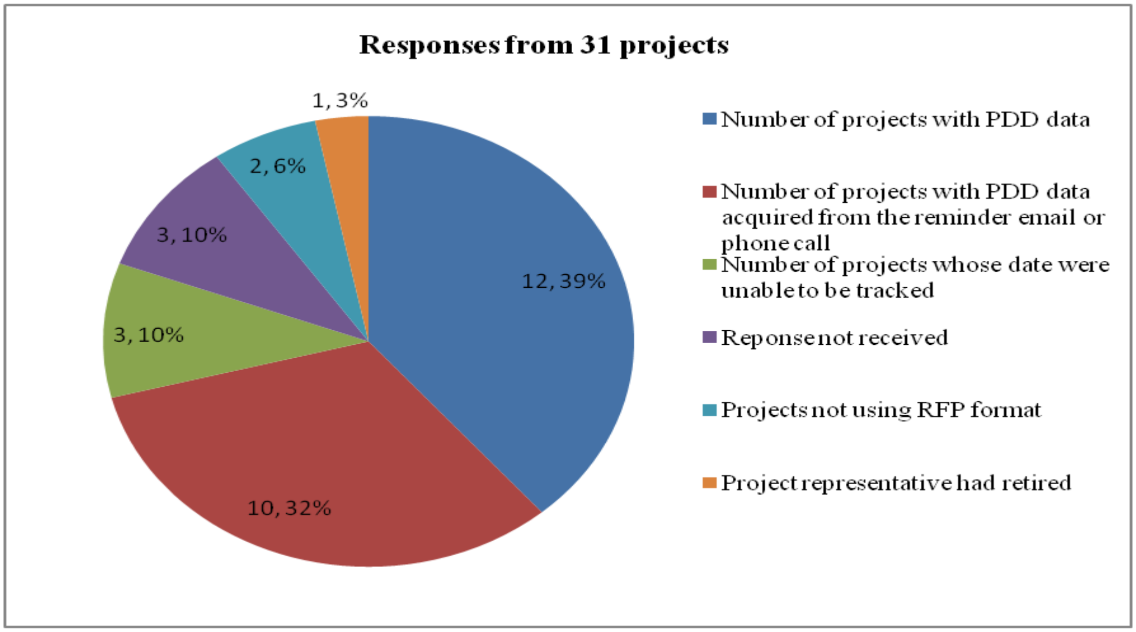


Figure 3.2. Project Number and Percentage for Each Category of Projects

3.5.2 Data Collected from the On-Line Questionnaire Survey

Water Design-Build Council (WDBC) and Design-Build Institute of America (DBIA) are two associations providing information on DB delivery application in the WW industry. A list of DB WW projects was available on the WDBC webpage. These project representatives' contact information was then searched on-line through Google. They were contacted by email and/or phone and asked to fill out the on-line survey. In WDBC's DB project lists, the information for 38 projects was searched for the owners' and design-builders' contact information. Twelve projects' owners and design-builders ultimately were contacted for the survey. If a project's representatives were unable to be identified by on-line search, either the owner's or design-builder's administrative staff were contacted about the project representatives. Contacting administrative staff was shown to be a poor strategy, as few useful responses of project representative information was received by using this strategy.

Likewise, a list of sponsors, exhibitors and owners was provided by DBIA for the 2010 WW Conference. In this list, 76 owners in the public sector were surveyed, most of them were in the city WW department, public utilities, or procurement department. Their contact information was also searched through Google, and they were contacted by email and/or phone and asked to participate in the survey. Usually more than one person was contacted in each owner entity. Project or construction managers, and procurement officers in the owner entity were contacted. If none of these people's contact information could be found on-line, the administrative staff would then be contacted to forward the on-line survey link to the people in this entity who may be the right person to be surveyed. In DBIA's WW conference participant list, the owner's list was emphasized as the project representatives to be surveyed, that is because their contact information was easier to find compared to contractors, who usually have several branch company locations and the persons to be surveyed were difficult to identify. The other reason that the owners were the main type of entity for survey is that usually the owner has better access to project data, while contractors were sometimes not allowed to release project data without owners' permission. Due to time limitation, all of these 76 owner entities were surveyed while only a few contractors were contacted.

Ultimately, 460 emails with the on-line survey link were sent for the survey. Among the 460 emails, 34 of them were sent to people related to the 12 DB projects from WDBC, and 426 were sent to the owner, and sponsors & exhibitor list from DBIA. On average, three people were emailed and/or called for each project listed in WDBC, and four people were contacted per project in the DBIA list. The survey started on 11/03/2009 and ended on 01/12/2010, lasting more than 2 months. The survey results show that 212 people viewed the on-line questionnaire, 120 of them started the survey, and 39 of them completed the survey and provided data. Table 3.2 is the summary of the survey's overall statistics.

Table 3.2. Survey Statistics Report

	Proportion / Count	Completed	Started	Viewed	Surveyed
Completed	39	**100%**	**32.50%**	**18.40%**	**8.48%**
Started	120		**100%**	**56.60%**	**26.09%**
Viewed	212			**100%**	**46.09%**
Surveyed	460				**100%**

Some of the project data were missing or incomplete, or the project provided had not been finished yet. Thus, some project data collected from the survey were incomplete. Secondary emails were sent to project representatives for the missing data as soon as the missing data was found in the raw data spreadsheet, although in most cases, the missing data (such as the RFP issue date or due date) were difficult to be tracked despite the project representative's effort. Among the 39 completed survey questionnaires, five of them responded that they did not have DB experience. In total, 34 questionnaires were completed with project data. However, some people who had worked on the same project or in a same owner entity provided data from the same project, thus making some data repetitive. These projects' data were combined into one group. One project had data provided by four people, and four other projects' data were each provided by two people. The data provided by these twelve people were combined into the five respective projects' data, and the final survey data consisted of 27 individual projects, some of them with incomplete or missing data. In this on-line survey, although project representatives who had been surveyed in Bogus et al (2009)'s study were avoided for this survey, two projects were finally found to be the same as in the Bogus et al (2009)'s study. Furthermore, these two projects' data collected in this survey were not totally consistent with the previous study. Thus, the groups of data were emailed to the project representatives to be checked for their reliability. The two projects' data from this on-line survey were tested to be accurate and thus used for the study, and the same two projects' data in the previous study were deleted.

Therefore, 20 projects from Bogus et al (2009)'s study and 27 projects from the new on-line questionnaire survey were utilized for the study.

3.6 Data Analysis

Correlation analysis was used for data analysis, to test the relationship of project procurement duration (from RFP issue date to proposal due date) and project performance in terms of cost and schedule growth. The projects in the analysis were also divided into different groups based on project complexity.

Cost and schedule growth are defined by the equations below:

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

$$\text{Design-Build Schedule Growth} = \frac{\text{Design-Build Duration As Built - DB Duration As Planned}}{\text{Design-Build Duration As Planned}} \times 100\%$$

$$\text{Total Schedule Growth} = \frac{\text{Actual Total Duration - Planned Total Duration}}{\text{Planned Total Duration}} \times 100\%$$

Cost growth (CG) is measured by the growth of actual project cost (excluding RFQ and RFP cost) compared to the originally contracted cost. Two types of schedule growth were measured: Design-build schedule growth (DBSG) and total schedule growth (TSG). The definition of the two types is to test if longer PD contributes to both less DBSG and TSG. Besides, correlation analysis will be used to test if PD has a relationship with DB duration and project total duration.

The PD is calculated in absolute calendar days. It is supposed to be related to the project ATD. The PD is expected to increase as the ATD increases. To measure the effort of the proposers in procurement, another measurement of procurement effort is defined as procurement duration factor (PDF), PDF is measured in the following equation:

$$PDF = (\text{Procurement Duration} / \text{Actual Total Duration}) \times 100\%$$

PDF is the percentage of the PD in the project total duration, higher PDF values indicated that more effort is paid in the procurement, thus better project performance is supposed to be achieved.

A scatter plot was drawn of the procurement duration and project performance in terms of schedule and cost growth. Then a linear correlation analysis was conducted.

The linear correlation analysis results of PD and CG/DBSG/TSG were compared between DB WW and transportation projects. If the results are not consistent, CA will be conducted to compare the RFPs, to explore the similarities and differences of RFPs in WW and transportation projects, and to analyze what may contribute to the different linear relationships between these two types of projects.

CHAPTER FOUR

DATA DESCRIPTION

As has been previously introduced, the data comes from Bogus et al (2009)'s study as well as an on-line questionnaire survey. People who were expected to be surveyed include owners, owners' representatives, design-builders, designers (engineer. architect, etc.), and other titles. Among the 54 individual contributors who provided the data for 47 projects, 24 of them were owners, 11 were owner representatives, 9 were design-builders, 2 of them were engineers, and 1 of them was a consultant. Figure 4.1 shows a more detailed breakdown of project representative titles.

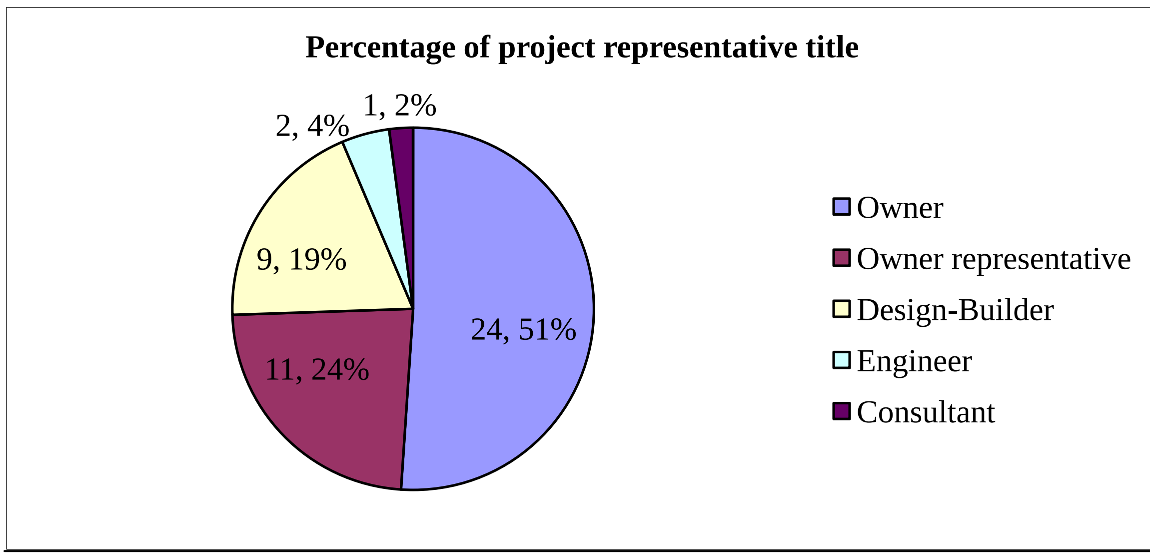


Figure 4.1. Percentage of Survey Participant Titles

Figure 4.1 shows that half of the survey participants are project owners, and 24% are owners' representatives. It is mainly because owners and their representatives tend to have better access to the project data needed for the survey, and their contact information was more easily found through use of on-line searches.

The geographic locations of 45 projects are shown in Figure 4.2.

Figure 4.2. Distribution of the 45 Water/Wastewater Projects

Two project locations in the survey were unknown, the remaining 45 project locations shown in Figure 4.2 tend to be close to the east and west coasts, with fewer projects located in the central U.S. California had 8 projects, Colorado had 5 projects, Georgia, Florida, and Nevada each had 4 projects. The unmentioned remaining states had projects numbered from 0 to 2. All of the 4 projects in Nevada were located in Las Vegas, the city that had the most projects. Among municipalities, Las Vegas, NV had 4 projects, San Diego CA had 3 projects, Colorado Springs, CO and Harrisburg, PA each had 2 projects.

4.1 Tests of the Data Consistency from Two Separate Surveys

Before conducting the overall data sample's linear correlation analysis, the consistency of project performance data between Bogus et al. (2009)'s study of DB WW projects and the other on-line questionnaire survey was analyzed in terms of PD, PDF, ATD, DBSG, TSG, PAC, and project total CG (see Appendix C for the individual project data). Because the data from the Bogus et. al (2009) study and the on-line questionnaire were not collected from random samples, there is no expectation that the two samples will necessarily be similar. The non-randomness of the data collection was due to the small number and difficulty in obtaining data for DB WW projects.

Table 4.1 provides the data of PD, DBSG, TSG, PAC, and CG in Bogus et. al (2009)'s study and the other on-line survey.

Table 4.1. Data Description of Project Performance from Two Separate Surveys

		PD	PDF	ATD	DBSG	TSG	PAC ($ M)	CG
Max	Bogus et. al	287	33 %	2406	94%	67%	96.18	17%
	On-line Survey	457	38 %	2071	54%	13%	300	9.1%
Min	Bogus et. al	25	3.7%	286	-14%	-9.6%	2.45	-11%
	On-line Survey	29	2.9%	144	-53%	-43%	0.35	-13%
Mean	Bogus et. al	103	14%	860	14%	14%	22.07	4.1%
	On-line Survey	95	12%	868	-2.3%	-7.7%	69.39	0.1%
Medi-an	Bogus et. al	74	10%	745	6.3%	7.2%	13.43	3.1%
	On-line Survey	64	8.7%	782	0.0%	-0.5%	17.48	0.0%
Stand-ard Devia-tion	Bogus et. al	75	8.6%	592	26.4%	21.5%	24.76	6.6%
	On-line Survey	95	9.9%	470	24.6%	16.3%	105.43	5.6%

It can be observed from Table 4.1 that the two groups of data have similar average values of PD, PDF, and similar standard deviations of PD, PDF, ATD, DBSG, TSG, and CG. However, the average of DBSG, TSG, PAC, and CG tend to vary. It seems that the duration factors (PD, PDF, ATD) are similar between these two groups, while the performance data and project cost seem to vary between the two groups. Inferences of means and variances are used to statistically test the consistency of the two groups of data in terms of PD, PDF, ATD, DBSG, TSG, PAC, and CG (Table 4.2 and 4.3).

Table 4.2. Inference Concerning Means between The Two Data Groups

	Null Hypothesis	Alternative Hypothesis	t Value	P Value	$t_{0.025}$	Level of Significance	Results of the null hypothesis
PD	$\mu_B = \mu_O$	$\mu_B \neq \mu_O$	0.298	0.7642	1.96	0.05	Accepted
PDF	$\mu_B = \mu_O$	$\mu_B \neq \mu_O$	0.55	0.5824	1.96	0.05	Accepted
ATD	$\mu_B = \mu_O$	$\mu_B \neq \mu_O$	-0.043	0.9656	1.96	0.05	Accepted
DBSG	$\mu_B = \mu_O$	$\mu_B \neq \mu_O$	1.97	0.0488	1.96	0.05	Rejected
TSG	$\mu_B = \mu_O$	$\mu_B \neq \mu_O$	3.45	0.0006	1.96	0.05	Rejected
PAC	$\mu_B = \mu_O$	$\mu_B \neq \mu_O$	-1.957	0.0504	1.96	0.05	Accepted
CG	$\mu_B = \mu_O$	$\mu_B \neq \mu_O$	2.11	0.0348	1.96	0.05	Rejected

μ_B: The mean value of the data group from Bogus et al (2009)'s study

μ_O: The mean value of the data group from the on-line questionnaire for this study

Table 4.3. Inference Concerning Variances between the Two Data Groups

	Null Hypothesis	Alternative Hypothesis	F Value	P Value	$F_{0.05}$	Level of Significance	Results of the null hypothesis
PD	$\sigma_B^2 = \sigma_O^2$	$\sigma_B^2 < \sigma_O^2$	1.61	0.148	2.13	0.05	Accepted
PDF	$\sigma_B^2 = \sigma_O^2$	$\sigma_B^2 < \sigma_O^2$	1.31	0.280	2.16	0.05	Accepted
ATD	$\sigma_B^2 = \sigma_O^2$	$\sigma_B^2 > \sigma_O^2$	1.58	0.180	2.28	0.05	Accepted
DBSG	$\sigma_B^2 = \sigma_O^2$	$\sigma_B^2 > \sigma_O^2$	1.15	0.389	2.23	0.05	Accepted
TSG	$\sigma_B^2 = \sigma_O^2$	$\sigma_B^2 > \sigma_O^2$	1.74	0.134	2.28	0.05	Accepted
PAC	$\sigma_B^2 = \sigma_O^2$	$\sigma_B^2 < \sigma_O^2$	18.13	1.699 E-08	2.16	0.05	Rejected
CG	$\sigma_B^2 = \sigma_O^2$	$\sigma_B^2 > \sigma_O^2$	1.42	0.217	2.10	0.05	Accepted

σ_B: The variance of the data group from Bogus et al (2009)'s study

σ_O: The variance of the data group from the on-line questionnaire for this study

The inferences concerning means and variances prove the hypothesis that the two groups of data have similar mean values of PD, PDF, and ATD, while the mean values of DBSG, TSG, and CG tended to be different. That means that project performance varied somewhat between the projects in Bogus et al (2009)'s study and the project data collected through the separate online survey. The correlation analysis of the procurement duration factors and project performance from the two groups were combined.

4.2 Overall Data Description

The descriptive measures of the project cost, duration, and performance data are provided (Table 4.4).

Table 4.4. Overall Project Data Summary

Overall Projects	Procure-ment Duration (days)	Design-Build Schedule Growth	Actual Total Duration (days)	Procure-ment Duration Factor	Total Schedule Growth	Project Actual Cost ($ M)	Total Cost Growth
Sample Number	43	37	36	40	36	42	42
Max	457	94%	2406	38%	67%	300	17%
Min	25	-53%	144	2.9%	-43%	0.35	-13%
Average	99	6.4%	848	13%	3.8%	33	2.0%
Median	67	0.0%	745	9.4%	0.0%	13.96	1.4%
Standard Deviation	86	27%	531	9.3%	22%	61.28	6.3%
Standard Error	13	4.4%	89	1.5%	3.7%	9.46	1.0%

The cost growth is calculated by comparing each project's actual and planned costs. In the PDF, four projects' actual total durations were unavailable, thus, their PDFs were calculated by dividing the PD by the planned total duration. Table 4.4 shows the range of project PD, from 25 days to 457 days, with the mean value of 99 days. The range of actual total duration (ATD) was from 144 to 2406 days, with the mean value of 848 days.

In general, procurement duration, schedule, and cost data are not expected to be normally distributed, since there is some absolute minimum value below which a project cannot perform and no absolute maximum value. For this reason, data on procurement duration, schedule, and cost tend to be skewed to the right when plotted as a density curve. A normal distribution analysis of PD, ATD, PAC, DBSG, and CG were conducted to explore the shape of the data distribution (see Appendix D). As expected, this data exhibits a skew to the right.

Table 4.5 shows the performance summaries between this study in WW projects and Chen (2009)'s transportation projects. The data from Chen (2009)'s study is used to compare with the WW data to see if different types of DB projects perform in a similar way. A statistical comparison of the two data sets can be found in Appendix E. The comparative analysis shows that there was no significant difference between WW and transportation projects PD and CG values, while the mean values of PAC and DBSG were significantly different.

Table 4.5. Project Performance Data Comparison between Design-Build Water/Wastewater and Chen (2009)'s Study in Transportation Projects

		Max	Min	Mean	Median	Standard Deviation	Sample Number
Procurement Duration (days)	WW	457	25	99	67	86	43
	transportation	139	11	88	91	27	146
Project Actual Cost ($ Million)	WW	300	0.35	33.62	13.96	61.28	42
	transportation	1840	0.15	53.72	6.98	204.56	146
Cost Growth	WW	17%	-13%	2.0%	1.4%	6.3%	42
	transportation	84%	-56%	0.4%	0.6%	16%	146
Schedule Growth	WW	94%	-53%	6.0%	0.0%	27%	37
	transportation	118%	-58%	13%	9.2%	29%	146

4.3 Project Performance Comparison based on Different Complexity Levels

Similar to Chen (2009)'s research in DB transportation projects, this study also divides the overall sample of projects into several groups based on the project complexity level and compares the project performance metrics among the different complexity groups. According to Chen (2009), there is no defined metric or method to identify the project complexity, but project contract prices can be an indication of the complexity. Chen (2009) categorized the project complexity according to the contract price. The range of contract price for different levels of project complexity was defined according to opinions and feedback from several contractors. In this water/wastewater study, the project complexity classification was not surveyed, so there is a lack of project complexity standards. However, when observing the normal score plots, it was found that the scatter plot in Figure D-3 of Appendix D can be categorized into three groups. The three subcategories are approximately prone to normal distributions, since the trendlines of all three subcategories tend to be straight (Figure 4.3, 4.4 and 4.5). Thus, the project complexity level and the range of project cost were determined based on the observation of the normal score plot (Table 4.6).

Table 4.6. Project Complexity Classification and the Range of Project Cost

Project / Complexity	Low	Medium	High	Overall
Range of Project Cost	(<$10 Million)	($10 - $50 Million)	($50 Million)	$0.35 - $300 Million)
Number of Projects	20	16	6	42

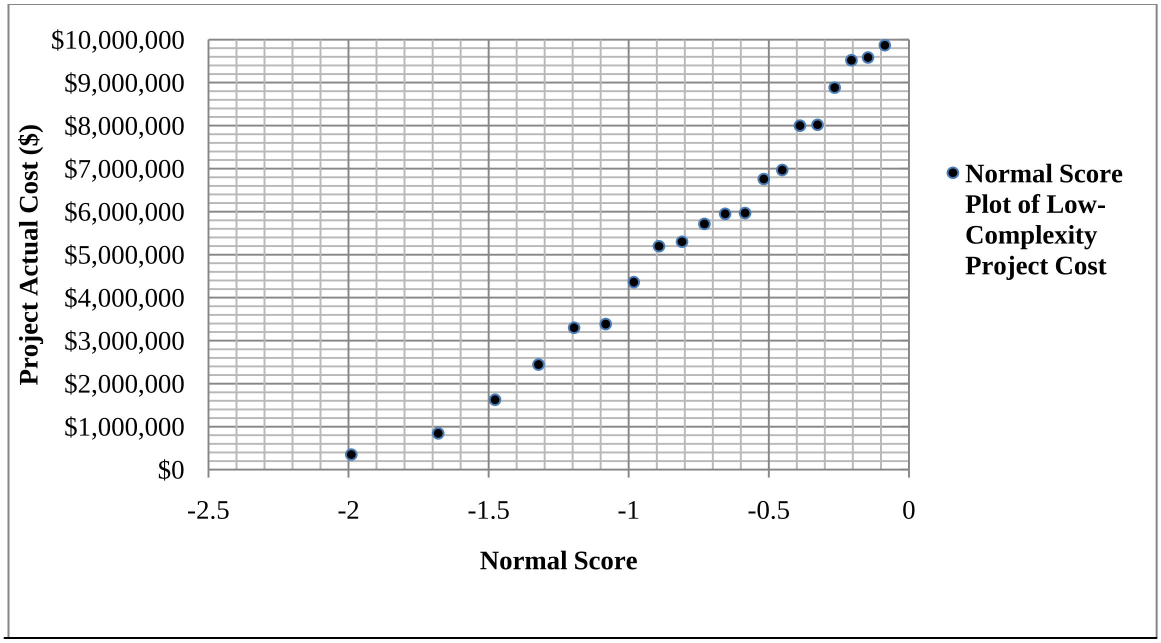


Figure 4.3. Normal Scores Plot of Low Complexity Projects' Cost ($)

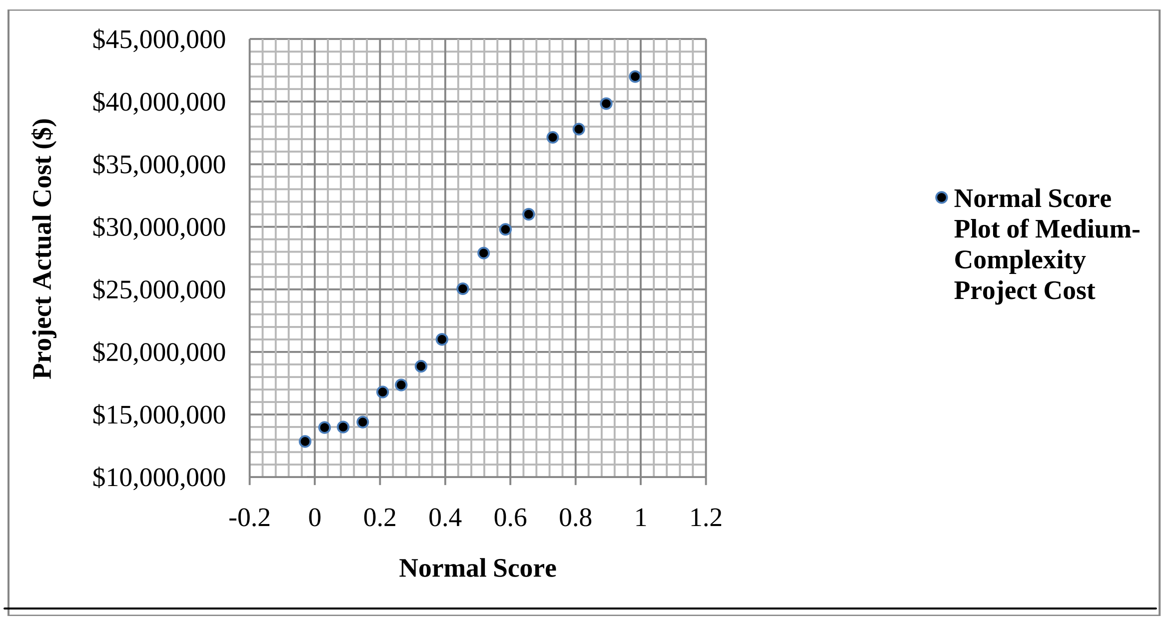


Figure 4.4. Normal Scores Plot of Medium Complexity Projects' Cost ($)

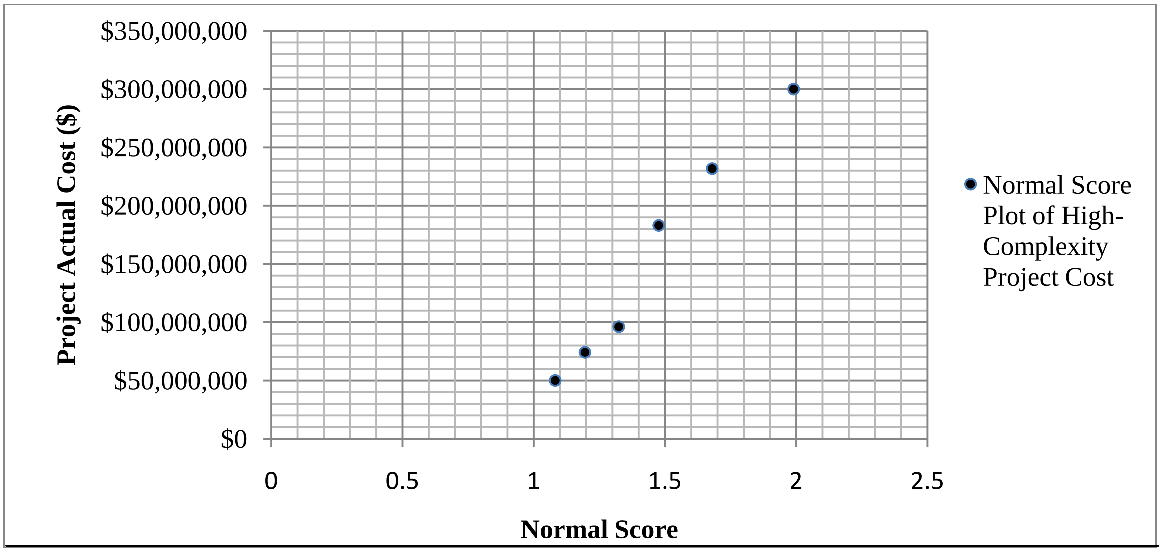


Figure 4.5. Normal Scores Plot of High Complexity Projects' Cost ($)

Interestingly, the range of project costs for complexity classification is the same as in Chen (2009)'s study of transportation projects, whose complexity was also classified as < $ 10 million (low), $10 million - $50 million (medium), and > $50 million (high).

Table 4.7, 4.8, and 4.9 show the project duration and performance for different project complexity types. Out of 47 projects, four of them did not have the actual cost data but were still included in the complexity analysis by using the contracted costs.

Table 4.7. Low Complexity Projects Data

	Procure-ment Duration (days)	Design-Build Schedule Growth	Actual Total Duration (days)	Procure-ment Duration Factor	Total Schedule Growth	Project Actual Cost ($)	Total Cost Growth
Sample Number	20	17	18	19	18	20	20
Max	117	94%	1065	38.2%	67%	9.87 M	8.9%
Min	25	-53%	144	2.9%	-43%	0.35M	-11%
Average	53	6.3%	504	12.6%	4.4%	5.60M	-0.5%
Median	51	0.0%	468	8.2%	0.0%	5.83M	0.0%
Standard Deviation	26	31.1%	217	9.5%	28%	2.93M	5.3%
Standard Error	6	7.5%	51	2.2%	6.6%	0.66M	1.2%

Table 4.8. Medium Complexity Projects Data

	Procure-ment Duration (days)	Design-Build Schedule Growth	Actual Total Duration (days)	Procure-ment Duration Factor	Total Schedule Growth	Project Actual Cost ($)	Total Cost Growth
Sample Number	18	15	14	16	14	18	16
Max	594	65%	2,040	35%	49%	42M	17%
Min	31	-48%	668	3.8%	-27%	12.85M	-13%
Average	149	3.0%	1,019	14%	3.2%	25M	3.5%
Median	117	0.0%	919	10%	0.0%	25M	3.1%
Standard Deviation	13	23%	368	10%	16.5%	9.9M	7.0%
Standard Error	32	6.0%	98	2.5%	4.4%	2.33M	1.8%

Table 4.9. High Complexity Projects Data

	Procure-ment Duration (days)	Design-Build Schedule Growth	Actual Total Duration (days)	Procure-ment Duration Factor	Total Schedule Growth	Project Actual Cost ($)	Total Cost Growth
Sample Number	6	6	5	6	5	8	6
Max	457	54%	2,406	22%	23%	300M	14%
Min	60	0.0%	974	5.9%	-6.2%	50M	1.1%
Average	180.5	15%	1,723.6	11%	5.1%	145.21 M	6.1%
Median	137	3.8%	1,796	8.9%	1.5%	96.18M	5.8%
Standard Deviation	143.54	21.9%	565.20	6.2%	11%	94.40M	4.9%
Standard Error	58.60	2.0%	252.77	2.5%	5.0%	33.37M	2.0%

Table 4.10 compares the average performance data of these 3 different complexity levels between DB WW and Chen (2009)’s study in transportation projects.

Table 4.10. Performance Data Comparison of Project Complexity Levels between DB WW and Transportation Projects

	Project Type		Procurement Duration (days)	Design-Build Schedule Growth	Project Total Cost ($ Million)	Total Cost Growth
Sample Number	WW	Low	20	17	20	20
		Medium	18	15	18	16
		High	6	6	8	6
	T	Low	23	23	23	23
		Medium	38	38	38	38
		High	85	85	85	85
Average Value	WW	Low	53	6.3%	5.60	-0.5%
		Medium	149	3.0%	25.00	3.5%
		High	181	15%	145.21	6.1%
	T	Low	88	15%	3.89	2.6%
		Medium	86	5.7%	18.35	-1.2%
		High	89	4.4%	291.21	-4.7%

Table 4.10 indicates that the data characteristics of the three complexity levels between DB WW and transportation projects are significantly different. These differences regarding project complexity levels in terms of PD, DBSG, PAC, and CG can be summarized as:

(1) The PD in DB WW projects tend to increase as the project becomes more complicated. The mean PD values in WW projects increase from 53 to 149 and finally 181 days as the project complexity changes from low, medium, to high. In contrast, the PD in transportation projects is really equal among the three different complexity levels. The PDs are 88, 86 and 89 days respectively.

Figures 4.6 and 4.7 show the linear relationship analysis of PD with PAC and ATD.

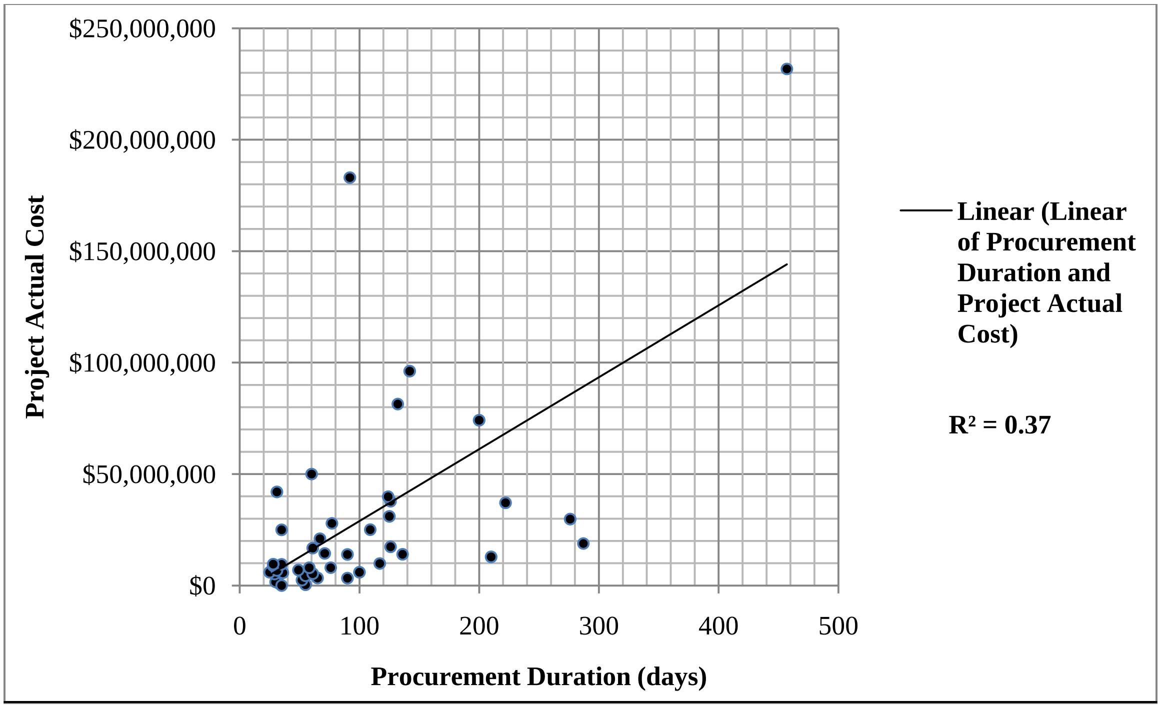


Figure 4.6. Linear Relationship of PD and PAC

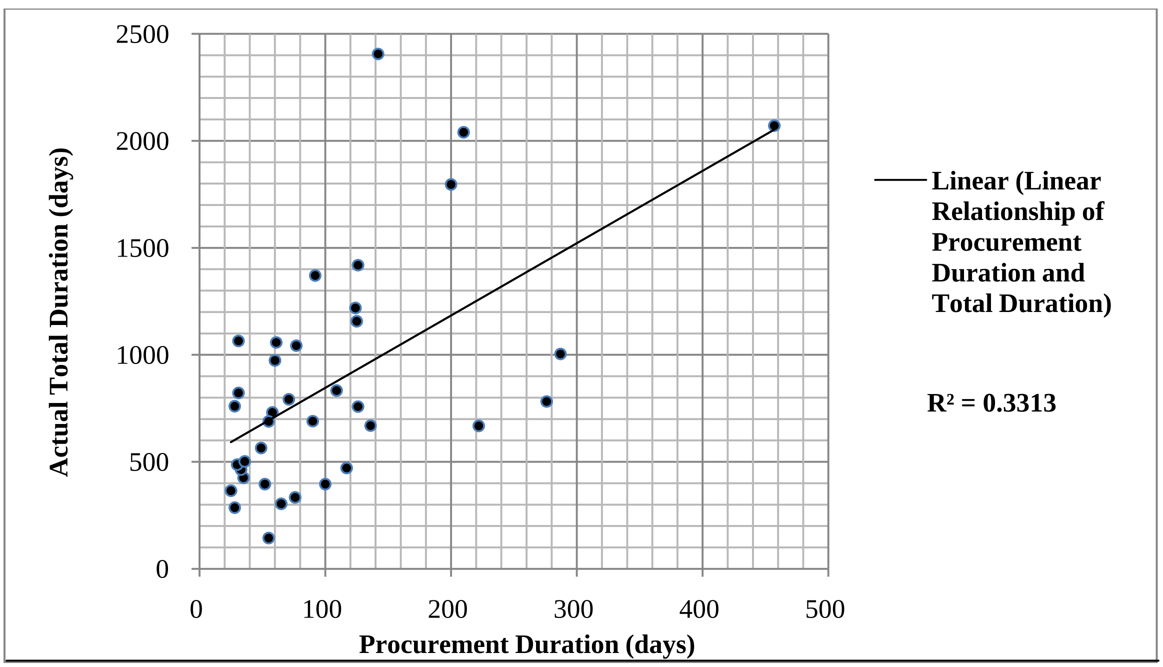


Figure 4.7. Linear Relationship of PD and ATD

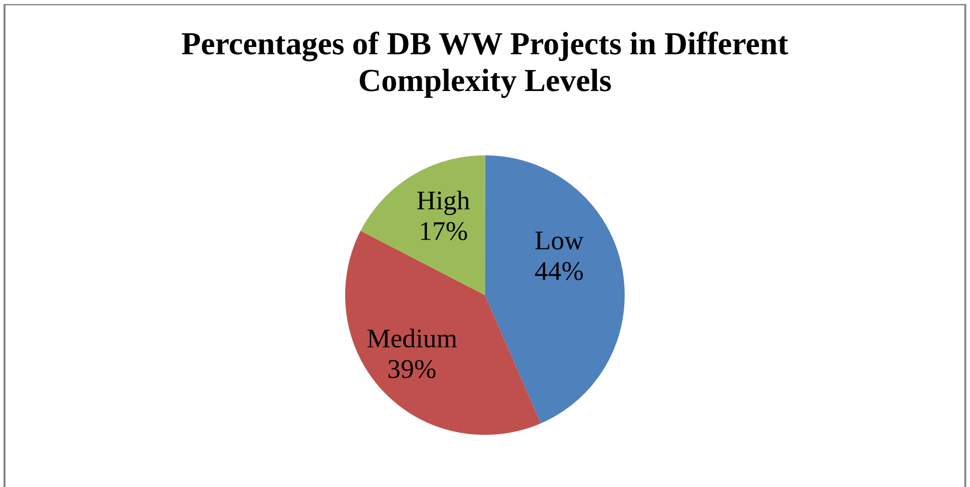
Figures 4.6 and 4.7 show there are moderate linear relationships between PD and ATD as well as PC. Procurement duration tends to increase with the project cost and duration for WW projects.

(2) The DBSG in WW projects tends to be the largest in high complexity projects (15%). That is reasonable, as it is more risky to control the schedule of projects with larger costs and higher complexities, thus the schedule is more vulnerable to changes. However, the DBSG in medium-sized WW projects (3.0%) appears to be much smaller than in low complexity projects (6.3%). The DB transportation project DBSG with different complexity levels tends to be different as well. It is found that the DBSG in transportation projects tends to decrease as project complexity increases. The DBSG decreases from 14.6%, to 5.7% and finally 4.4% as project complexity changes from low to medium to high.

(3) The PAC in WW projects tends to be much higher than in transportation projects with the low and medium complexity levels. But in the high complexity level, transportation projects' PAC is about twice that of WW projects.

(4) The CG trends of different complexity levels between WW and transportation projects flow in opposing directions. In WW projects, the CG increases from -0.5%, to 3.5% and lastly 6.1% as project complexity increases. This shows that WW projects are more vulnerable to cost changes as project cost and complexity increases. In contrast, the CG in transportation projects decreases as project complexity increases (from 2.6%, to -1.2% and finally -4.7%).

Figure 4.8 shows the percentages of projects with 3 different complexity levels between DB WW and transportation projects. It is found that the percentage of high-complexity WW projects is lower than in transportation projects.



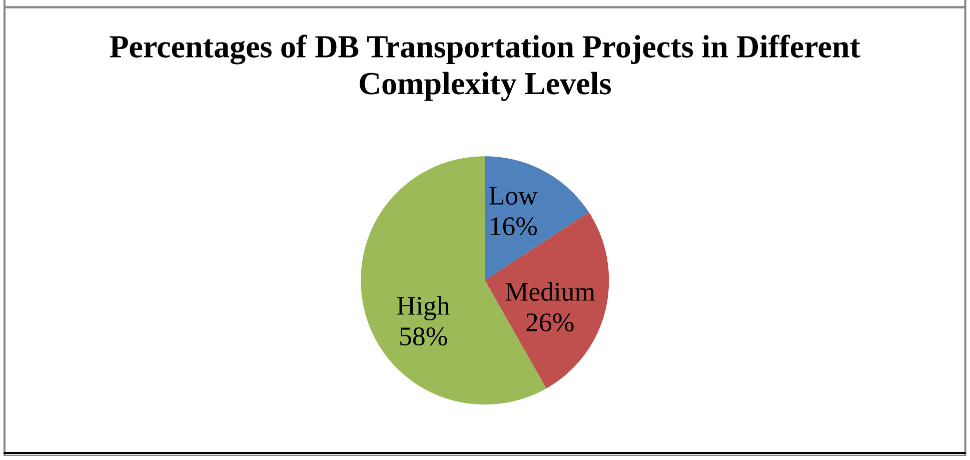


Figure 4.8 The Pencentage of Projects with Different Complexity Levels

Table 4.11 Compares the performance data of WW projects with different complexity levels.

Table 4.11. Average Value of Data for WW Projects in Different Complexity Levels

Project Complexity	Procurement Duration (days)	Design-Build Schedule Growth	Project Total Duration (days)	Procurement Duration Factor	Total Schedule Growth	Project Actual Cost ($ M)	Total Cost Growth
Low	53	6.3%	504	13%	4.4%	5.60	-0.5%
Medium	149	3.0%	1,019	14%	3.2%	25.00	3.5%
High	181	15%	1,724	11%	5.1%	145.21	6.1%

The PD, DBSG, PAC and CG have been compared in Table 4.11. The project ATD, similar to PD, PAC, and CG, increases as the project complexity level increases (from 504, 1019 to 1724 days). The PDF and TSG tend to vary little. PDF is used to measure the percentage of time for procurement (RFP issued to due date) in the total project duration (from RFP issued to substantial completion date).

In conclusion, for the WW projects in the three different complexity levels, the PD, ATD, and CG tend to grow larger as the project complexity level increases. The PDF and TSG tend to be the same, not influenced by the project complexity. The DBSG is highest in the high-complexity projects, while lowest in the medium-complexity projects. The variance of PD, TCG, and DBSG among the three complexity levels between WW and transportation projects is completely different.

4.4 Initial Conclusions and Pre-assumptions

The overall data sample and the data classification based on project complexity were analyzed for WW projects in comparison with those in transportation projects. Figure 4.9, 4.10, and 4.11 show the comparison of WW project performance data among the three complexity levels and the overall sample.

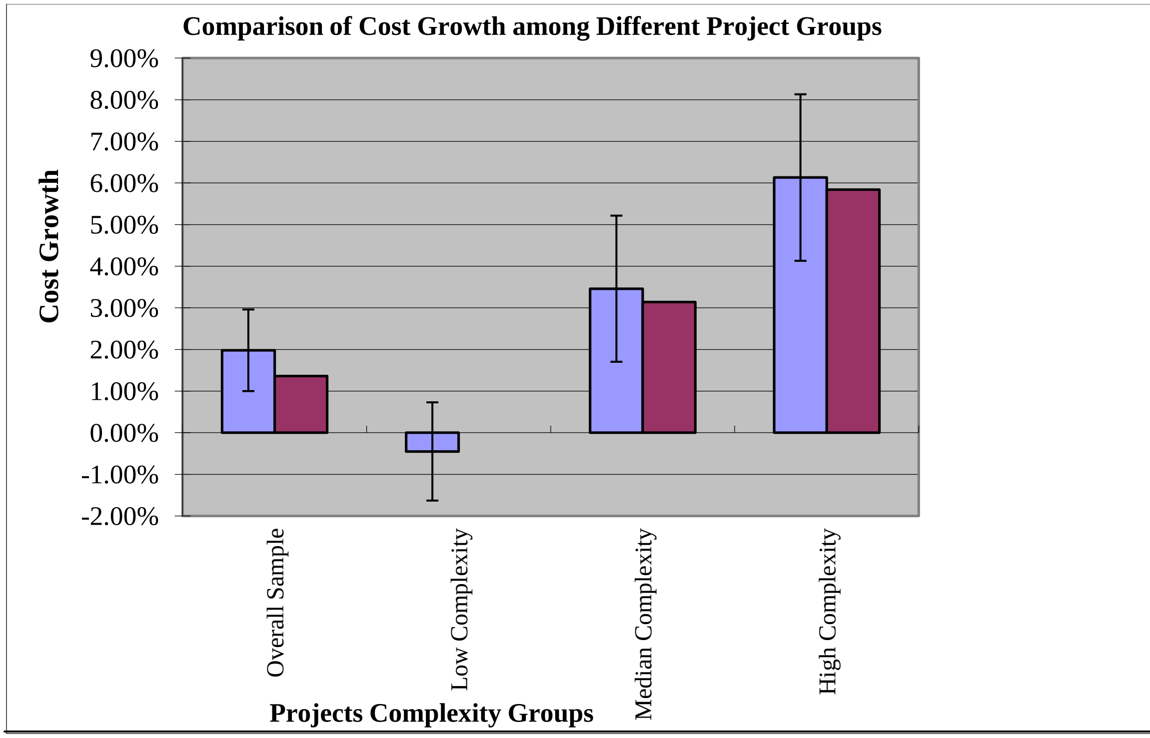


Figure 4.9. Cost Growth Performance for WW Projects in Different Complexity Groups

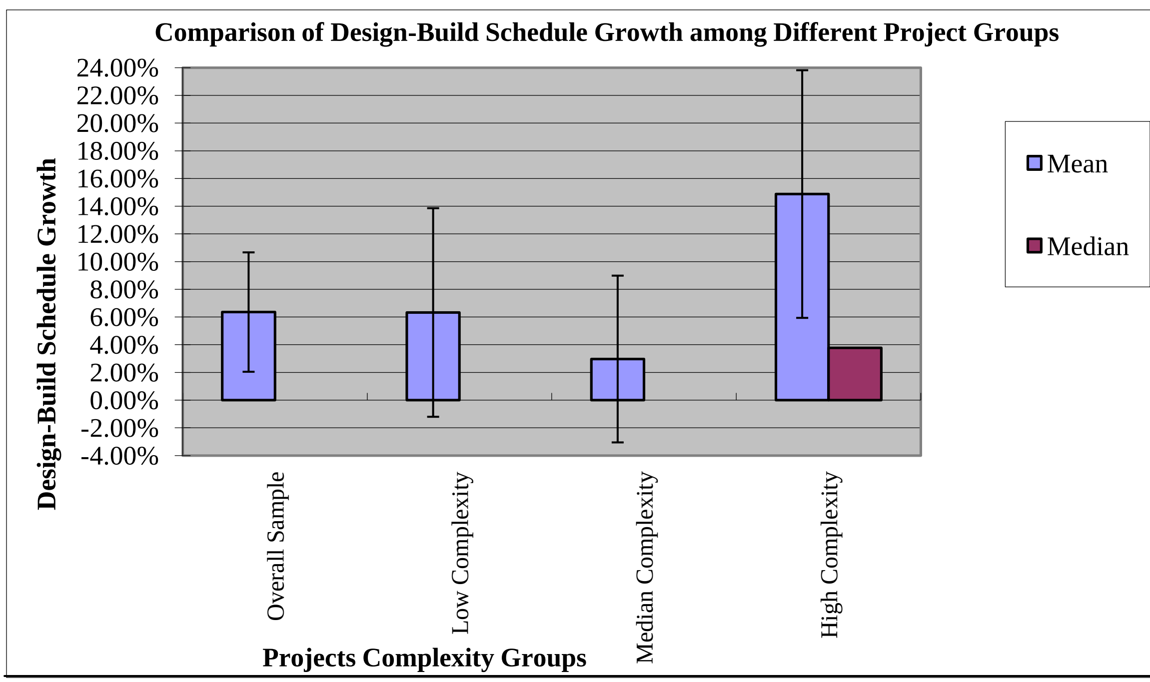


Figure 4.10. Design-Build Schedule Growth for WW projects in Different Complexity Groups

In Figure 4.9, 4.10, and 4.11, error bars with standard of means are used.

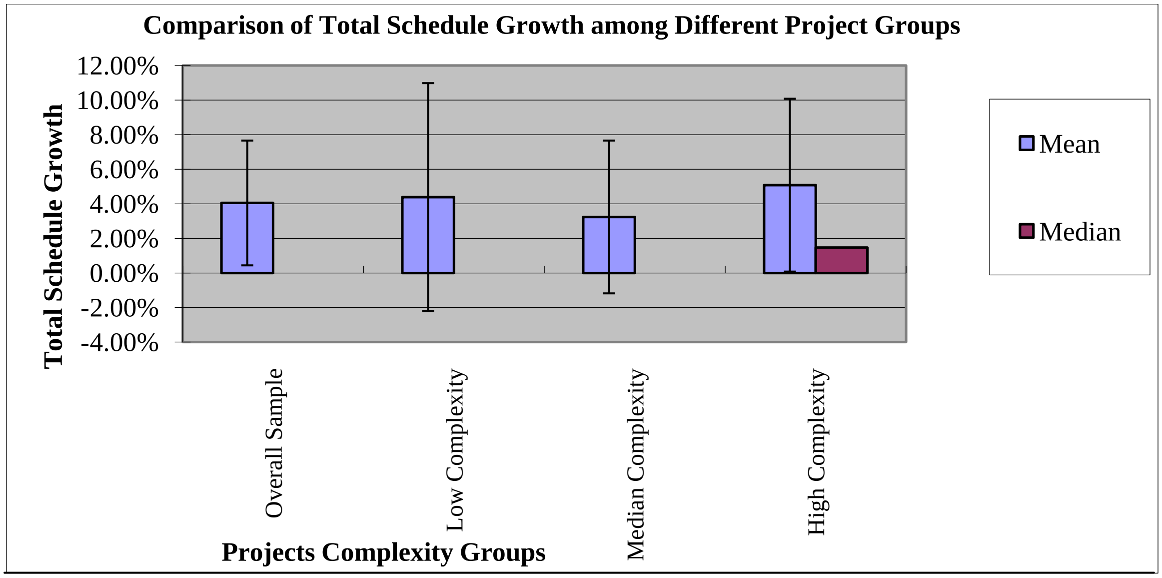


Figure 4.11. Total Growth Performance for WW Projects in Different Complexity Groups

Figure 4.9, 4.10, and 4.11 provide the data that indicates low complexity projects have the best performance in cost growth. High-complexity projects have the largest growth in all of these performance measurements – cost, design-build schedule and total schedule. Medium complexity projects have the best performance in design-build schedule and total schedule growth.

The initial description of the data sample provides some initial conclusions and assumptions:

(1) The project complexity (project actual costs) contributes to the final project performance in terms of cost growth. The low-complexity projects have the best performance in cost growth, and high-complexity projects usually have the worst results in cost growth.

(2) The project CG tends to increase when the PD increases. Thus, the PD may be in a positive linear relationship with project CG.   However, it does not mean the longer PD leads to worse project performance. It is really the project complexity or project cost that

contributes to higher project cost change, as it is assumed that projects with a higher complexity level are prone to have more risks in controlling the budget. Thus, cost change in higher complexity projects tends to be greater.

(3) The TSG is not significantly impacted by project complexity or PD. There is also little linear relationship between PD and TSG.

(4) PDF was proven by ANOVA that it did not differ significantly among different complexity projects. PD increases proportionally as the project total duration increases. It was also found from Table 4.11 that the higher the PDF is, the better project performance in DBSG and TSG. The data in Table 4.11 seems to support the conclusion that there is a negative relationship between PDF value and schedule growth. The higher percentage of project total time that the owner provides design-builders to prepare RFP, the better the achievement of DB and overall schedule performance will be.

These preliminary conclusions will be tested by successive studies of correlation analysis (Chapter Five). The following studies will highlight the correlation analysis between PD factors and performance measurements, as well as other factors (such as project complexity) which may also impact project performance. Similar to Chen (2009)'s study in transportation projects, the linear correlation analysis will be conducted first. According to Chen (2009), if the PD and project performance do not have a linear relationship, the normal distribution analysis would be conducted in the next phase, and if the second phase still did not show any relationship, the residual plot observation and analysis will be used in the final phase.

After an in-depth statistical analysis of PD factors and performance measurements, the relationship will be compared to the similar study of Chen (2009)'s. If the relationships in this study and Chen (2009)'s differ, content analysis (CA) will be utilized as explained in Chapter Three.

CHAPTER FIVE

CORRELATION ANALYSIS

Based on the preliminary hypothesis concerning the relationship between PD factors and project performance measurements, linear correlation analysis was conducted to test the hypothesis. Besides PD, the PD factor (PDF) will also be used as a procurement effort in the linear correlation analysis. Similar to Chen (2009)'s study, if there are weak linear relationships between PD factors and project performance, other statistical methods such as normal distribution analysis residual plot analysis will be conducted.

5.1 Procurement Duration Factors and Schedule Growth

PD and PD as a percentage of the total project duration (PDF) are defined as procurement duration factors and their linear relationships with schedule growth were tested. The project TSG and DBSG were used in this study as the schedule performance measurements.

5.1.1 Procurement Duration Factors and Schedule Growth for All Projects

The data distribution between PD and project TSG is illustrated in Figure 5.1. The scatter plot of TSG and procurement duration shows a weak linear relationship. The TSG has a symmetric distribution to the horizontal axis (procurement duration). It is also observed that projects with longer duration tend to have less TSG (either positive or negative). Two projects with respective PDs of 287 and 457 days have very small TSG values, which are 0% and 1.47%, respectively. Based on Figure 5.1, the longer PD is likely to reduce the project total schedule change, predict the project timeline more accurately, and cause less schedule change.

Table 5.1 provides the regression statistics (sample correlation coefficient, R square, adjusted R square and standard error of the estimates), as well as the ANOVA of predicted TSG using the equation in Figure 5.1 and the actual TSG data.

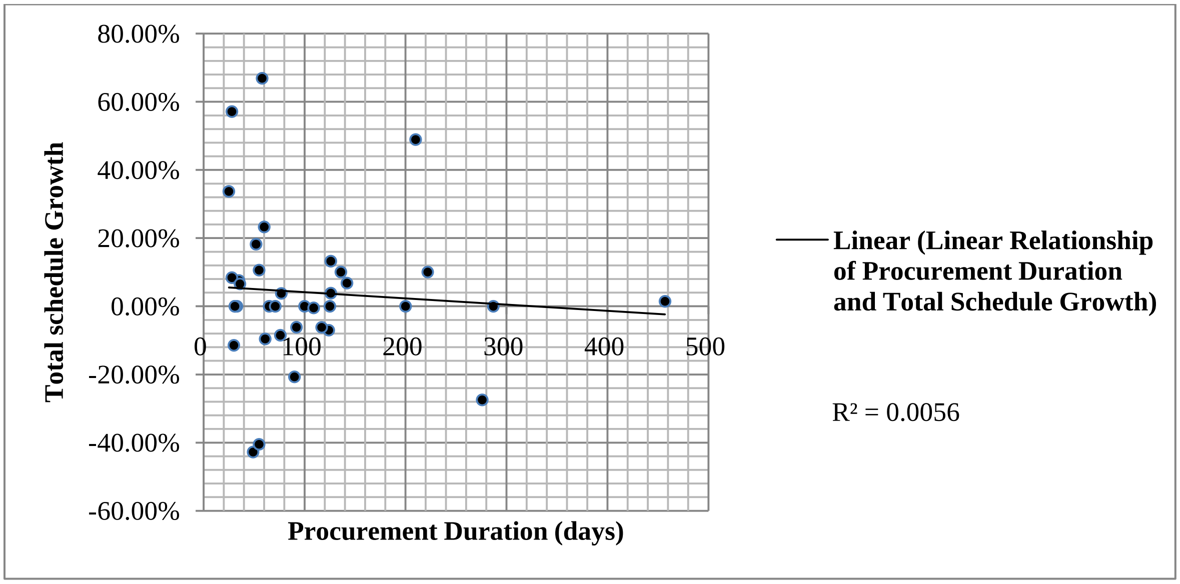


Figure 5.1. Overall Project Schedule Growth in Relation to Procurement Duration

Figure 5.1 shows little linear relationship between PD and TSG, with the correlation coefficient -0.075, R square 0.0056 and a high standard error of 0.222. A regression analysis of TSG and PD is provided in Appendix F.

The linear relationship of TSG and PDF is illustrated in Figure 5.2. It also shows a weak and negative relationship, although the linear relationship between TSG and PDF tends to be stronger than that in TSG and PD. Similar to the linear relationship between TSG and PD, a higher value of PDF also tends to decrease TSG, and most high TSGs occur in low PDF (lower than 10%).

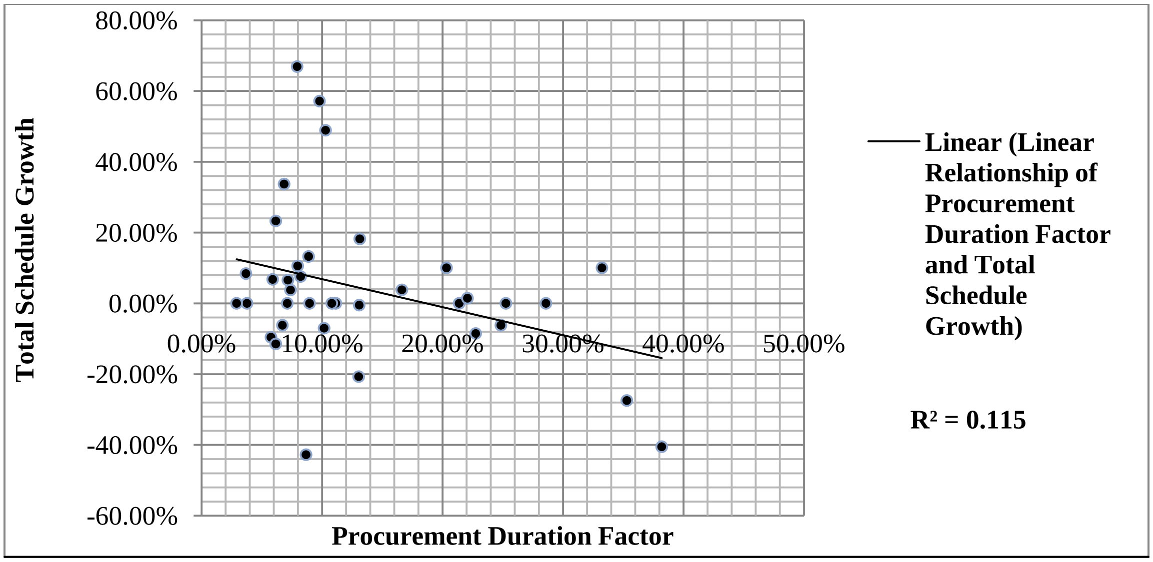


Figure 5.2. Data Distribution of TSG and PDF

The linear relationship of PD and DBSG is shown in Figure 5.3.

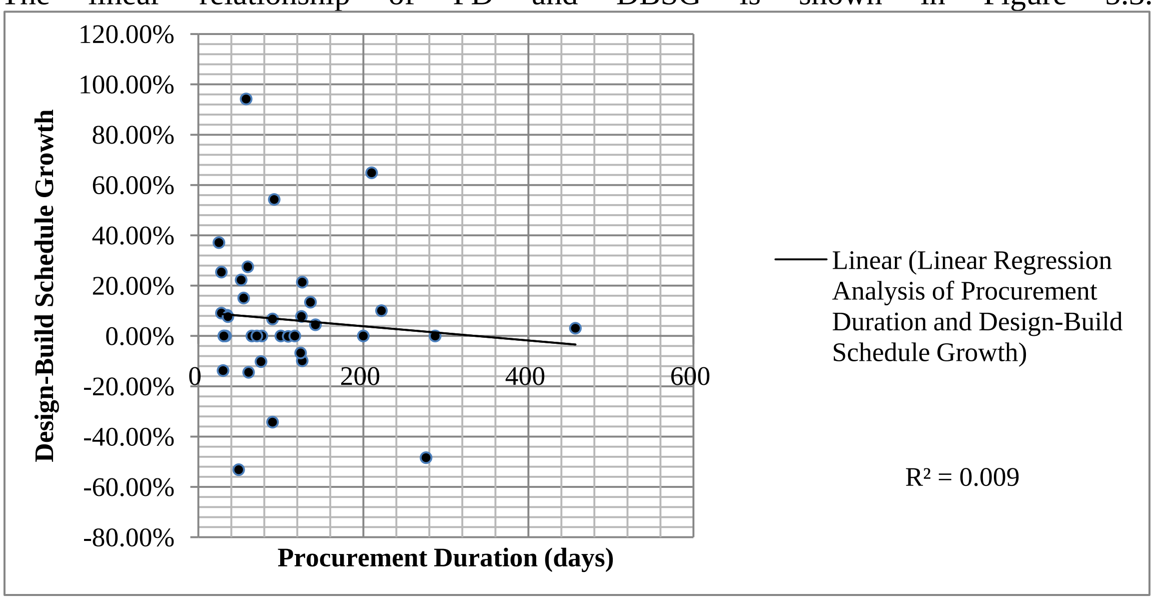


Figure 5.3. Design-Build Schedule Growth in Relation to Procurement Duration

The scatter plot of DBSG is similar to that of TSG because both have minimal linear relationship with PD, but both appear to be symmetric to the PD horizontal axis in Figure 5.1 and 5.3. There is also a trend that indicates a longer PD improves the predictability of DB schedule.

Figure 5.4 shows the linear relationship analysis of PDF and DBSG. Similar to Figure 5.2, the linear relationship between PDF and DBSG appears weak and random. A higher PDF tends to reduce DBSG, and most high DBSG occurs in low PDF (lower than 10%).

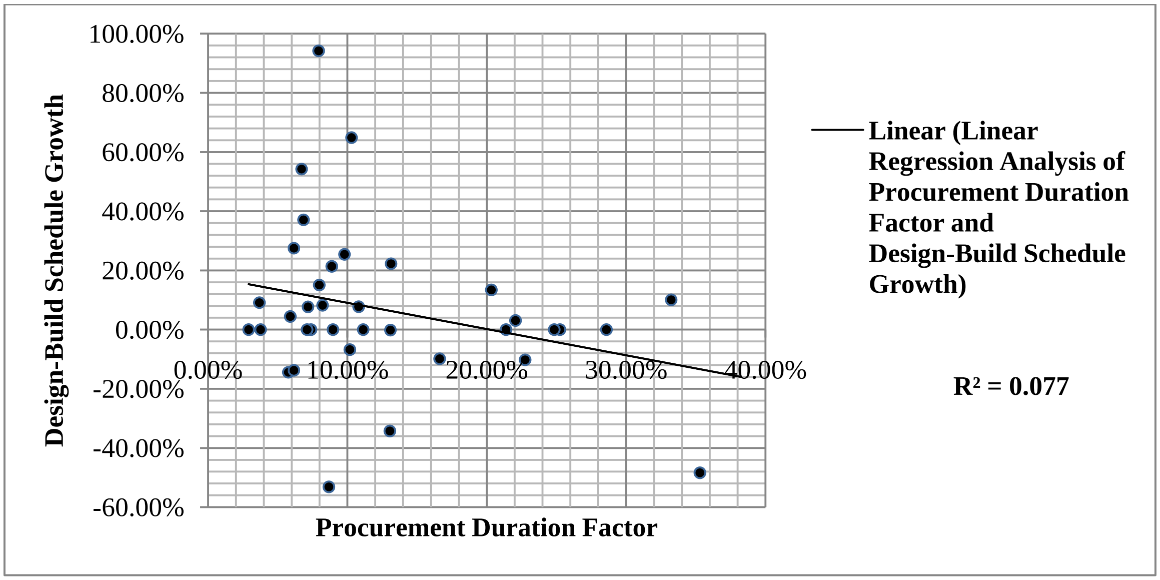


Figure 5.4. Linear Relationship Analysis of PDF and DBSG

It can be noted that the DBSG and TSG have similar linear relationship with PD and PDF, with strong and positive linear relationships.

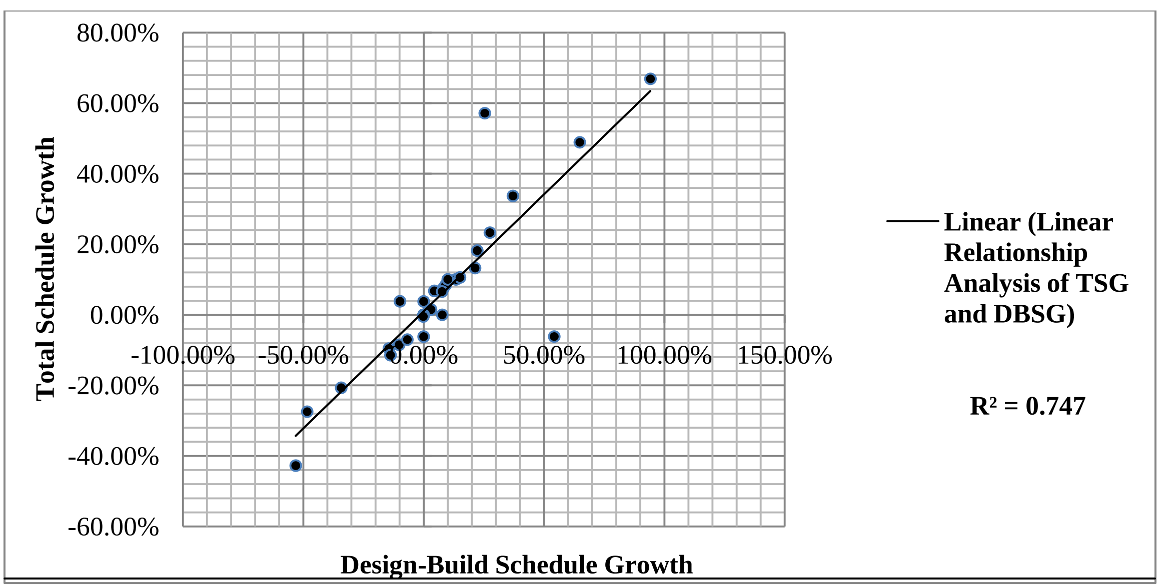


Figure 5.5. Linear Regression Analysi of DBSG and TSG

Figure 5.5 indicates that there is a strong linear relationship between DBSG and TSG. The results infer that a WW project with a higher TSG generally has a greater DBSG.

Table 5.2 summarizes the linear relationship of PD factors and schedule growth using correlation coefficient (CC), R square, adjusted R square, and standard error of estimate.

Table 5.1. Linear Data Analysis of PD Factors and Schedule Growth

Data Analysis / Relation	Correlation Coefficient	R Square	Adjusted R Square	Standard Error
PDF&TSG	-0.339	0.115	0.090	0.209
PD&DBSG	-0.095	0.009	-0.019	0.271
PDF&DBSG	-0.28	0.077	0.051	0.266
TSG & DBSG	0.865	0.748	0.740	0.107

The data for PD and TSG has been provided in Table 5.2. These four linear relationship analyses prove weak and negative relationships between PD factors and schedule performance, with a small CC, R square, and large standard error of estimates. The highest CC value is only -0.339 for PDF and TSG. The two schedule performance measurements (TSG and DBSG) have a strong and positive linear relationship with a low standard error of estimate.

5.1.2 PD Factors and Schedule Growth in Different Project Complexity Levels

Project complexity has been defined according to the project actual cost, and the ranges are defined as less than \$10 M (low), \$10M to \$50M (medium), and above \$50 M (high).

Figures 5.6 and 5.7 are the data distributions of PD and schedule performance for low complexity projects.

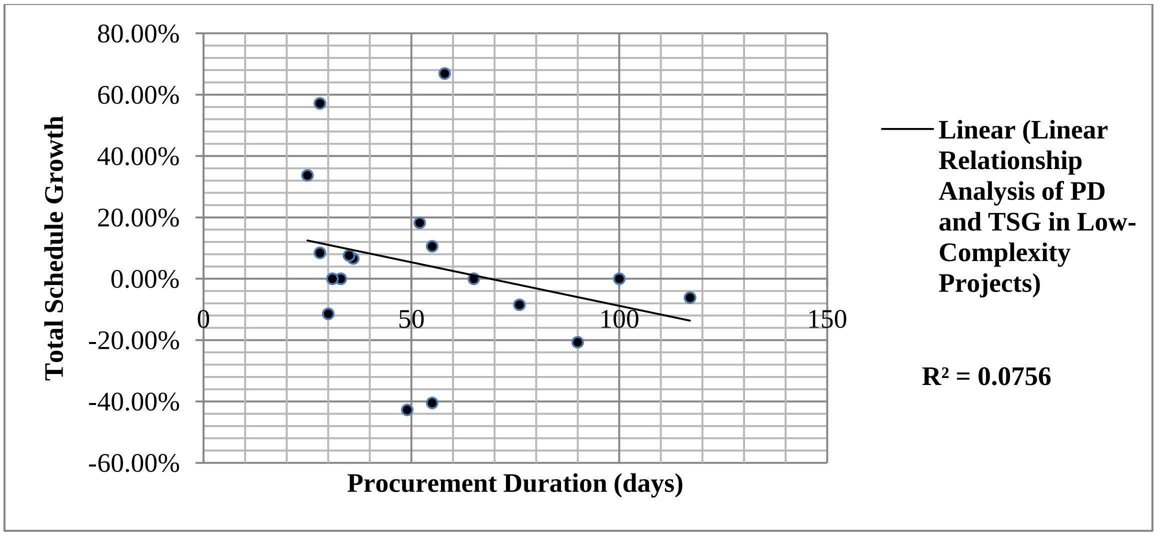


Figure 5.6. Data Distribution of PD and TSG in Low Complexity Projects

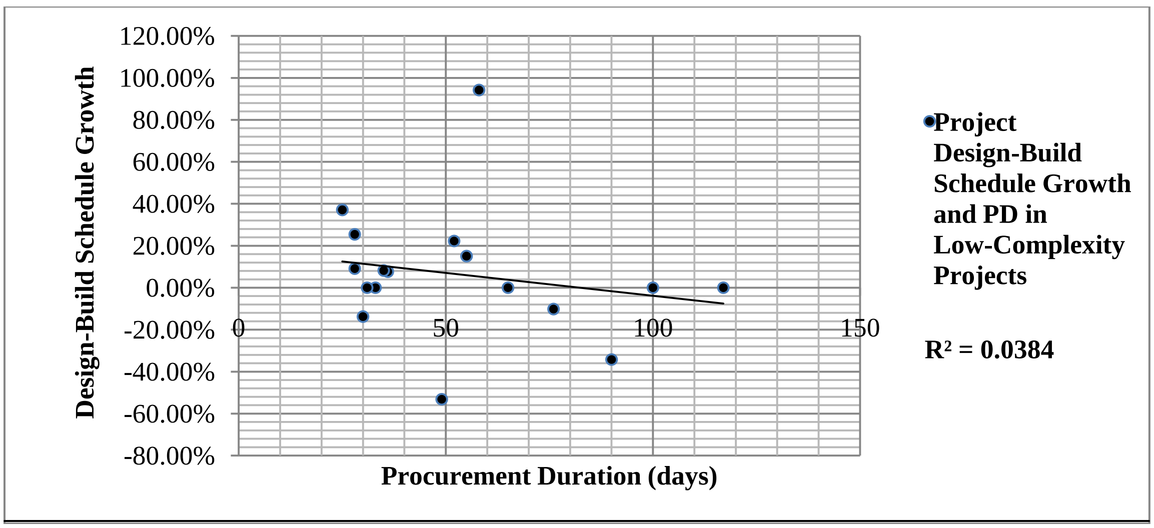


Figure 5.7. Data Distribution of PD and DBSG in Low Complexity Projects

The distributions show a weak and negative linear relationship between PD and schedule performance (TSG and DBSG) in low-complexity projects. However, PD in both TSG and DBSG can be classified in to 3 groups. PD shorter than 50 days, the schedule growth is random and irregular, higher schedule growths (higher than 20%) occur in this range. PD between 50 and 100 days, the TSG and DBSG are in a strong negative linear relationship with PD. PD longer than 100 days tends to have a stable schedule.

Figures 5.8, 5.9, 5.10 and 5.11 illustrate the linear regression analysis of PD and schedule performance in medium and high-complexity projects.

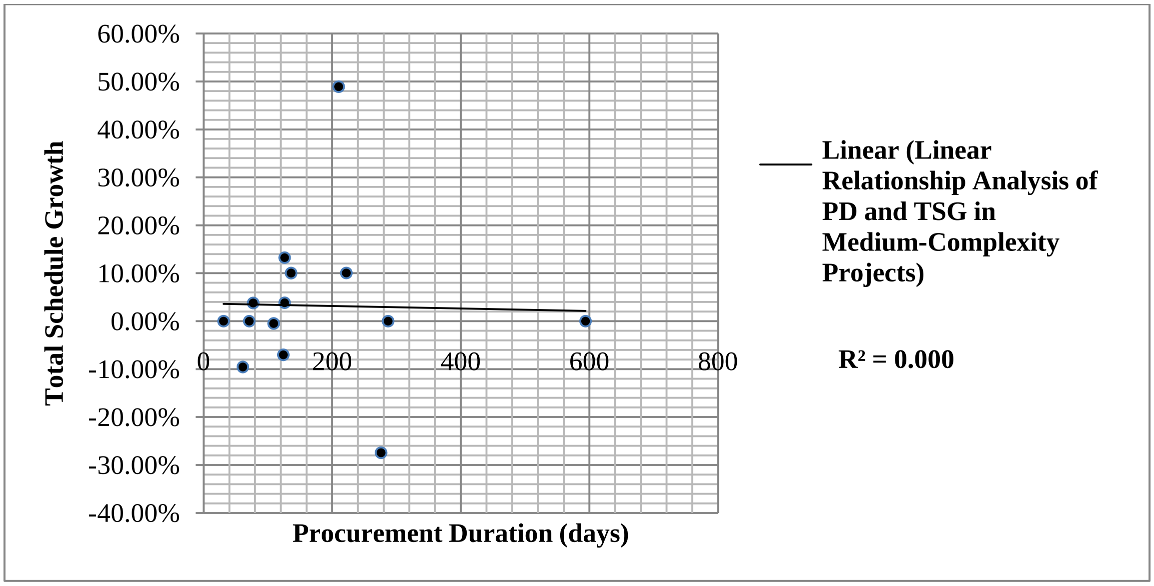


Figure 5.8. Data Distribution of PD and TSG in Medium Complexity Projects

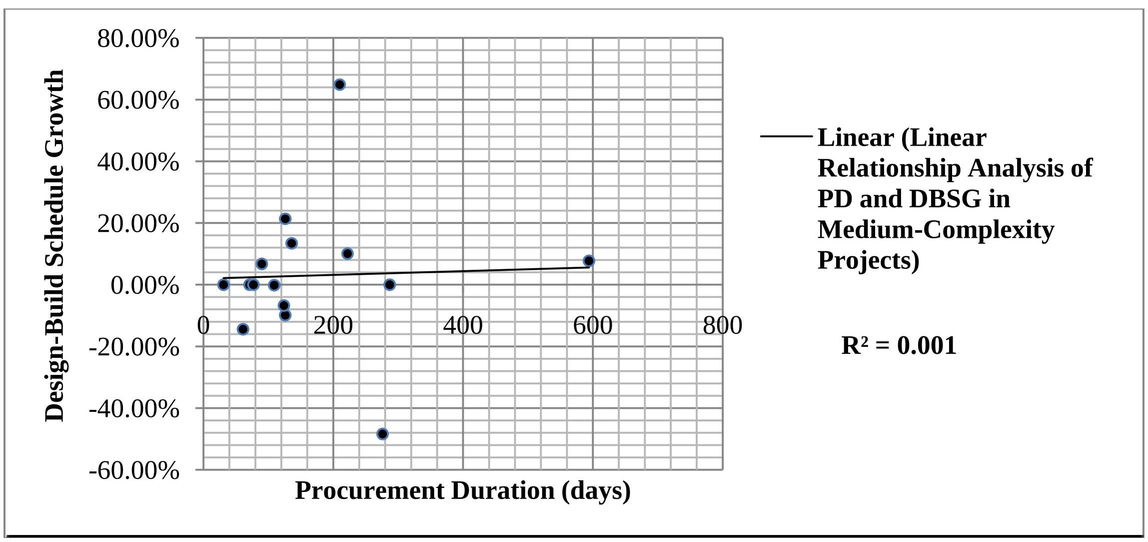


Figure 5.9. Data Distribution of PD and DBSG in Medium Complexity Projects

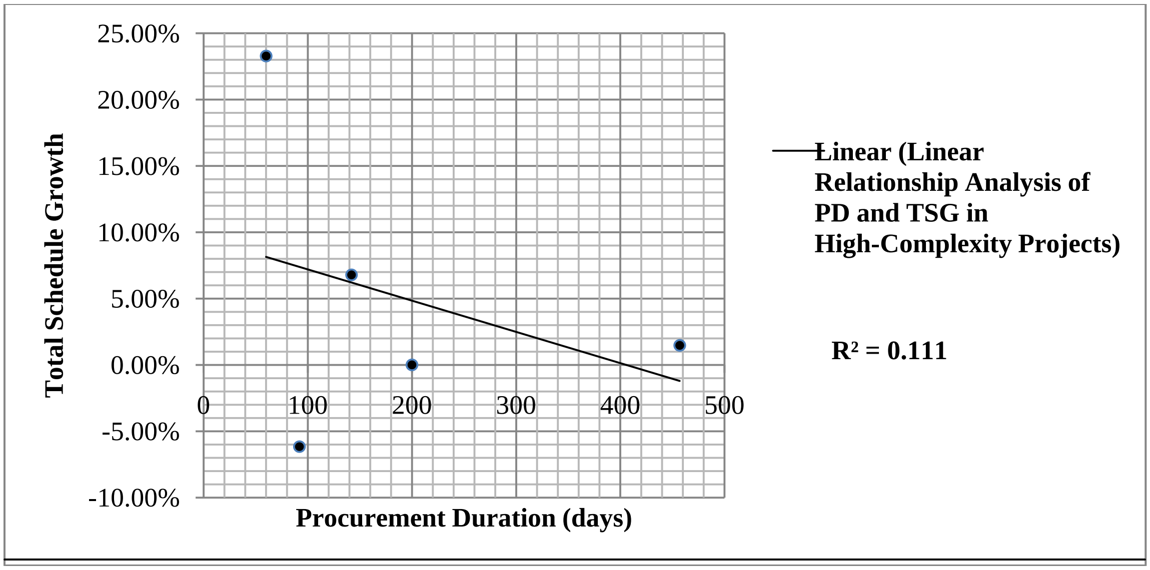


Figure 5.10. Data Distribution of PD and TSG in High Complexity Projects

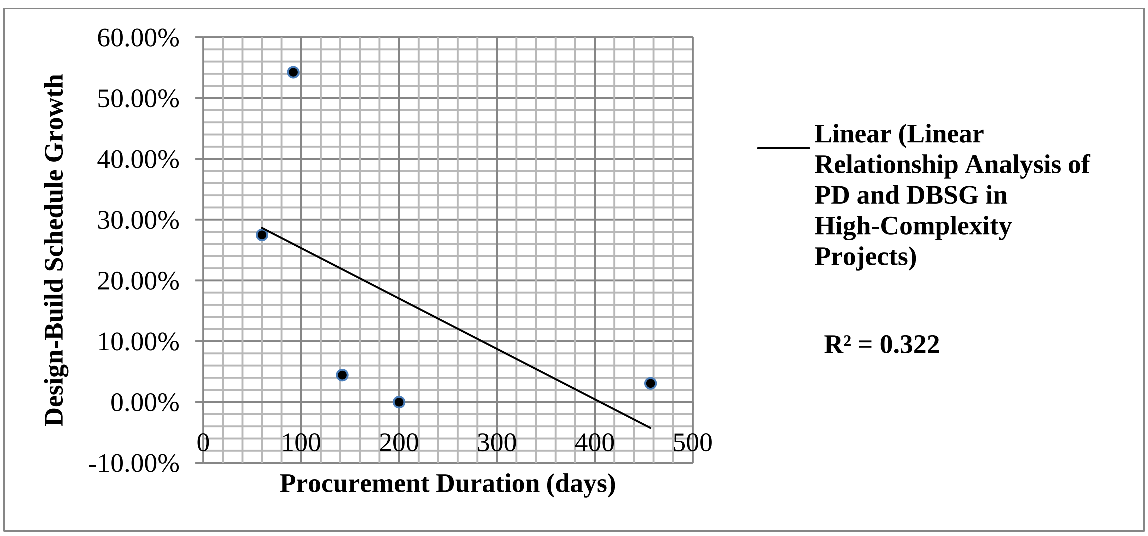


Figure 5.11. Data Distribution of PD and DBSG in High Complexity Projects

Most data distributions between PD and schedule performance seems to be random and indicate a weak and negative linear relationship. Only the scatter plot of PD and DBSG in high complexity projects indicates a moderately negative relationship (Figure 5.11). 32.22% of the reduction of DBSG can be explained by the increase of PD, although there is insufficient sample number (N=5) in the data analysis in high complexity projects.

Since the relationship of PDF tends to have a similar linear distribution as PD, the data distributions of PDF are not listed.

Table 5.2. PD Factors and Schedule Growth in Different Complexity Levels

	Data / Analysis Relation	Correlation Coefficient	R Square	Adjusted R Square	Standard Error
Low Complexity	PD&TSG	-0.275	0.0756	0.018	0.277
	PDF&TSG	-0.410	0.168	0.116	0.263
	PD&DBSG	-0.196	0.038	-0.026	0.315
	PDF&DBSG	-0.178	0.032	-0.033	0.316
	TSG & DBSG	0.932	0.869	0.860	0.099
Medium Complexity	PD&TSG	-0.023	0.0005	-0.083	0.172
	PDF&TSG	-0.246	0.060	-0.018	0.167
	PD&DBSG	0.037	0.001	-0.082	0.242
	PDF&DBSG	-0.327	0.107	0.033	0.238
	TSG & DBSG	0.972	0.945	0.940	0.040
High Complexity	PD&TSG	-0.334	0.111	-0.185	0.122
	PDF&TSG	-0.291	0.085	-0.22	0.123
	PD&DBSG	-0.568	0.322	0.096	0.220
	PDF&DBSG	-0.474	0.224	-0.035	0.235
	TSG & DBSG	-0.109	0.012	-0.317	0.128

Most of the linear relationships between PD factors and schedule performance are weak and negative, with low correlation coefficients, low R Square value, and high standard error of estimates. PDF and TSG in low complexity projects as well as PD and DBSG in high complexity projects appear to have a moderate negative and linear relationship. TSG and DBSG in low and medium projects have a strong and positive linear relationship. The linear relationship of TSG and DBSG in high complexity projects tends to be weak, but there is an insufficient sample number (N=5) in high complexity projects.

PD and PDF are found to be unrelated to TSG and DBSG. It is implied that the project size (project actual cost and total duration) is an indication of schedule performance. Figure 5.12 and 5.13 provide the linear data distribution of PD factors and DBSG.

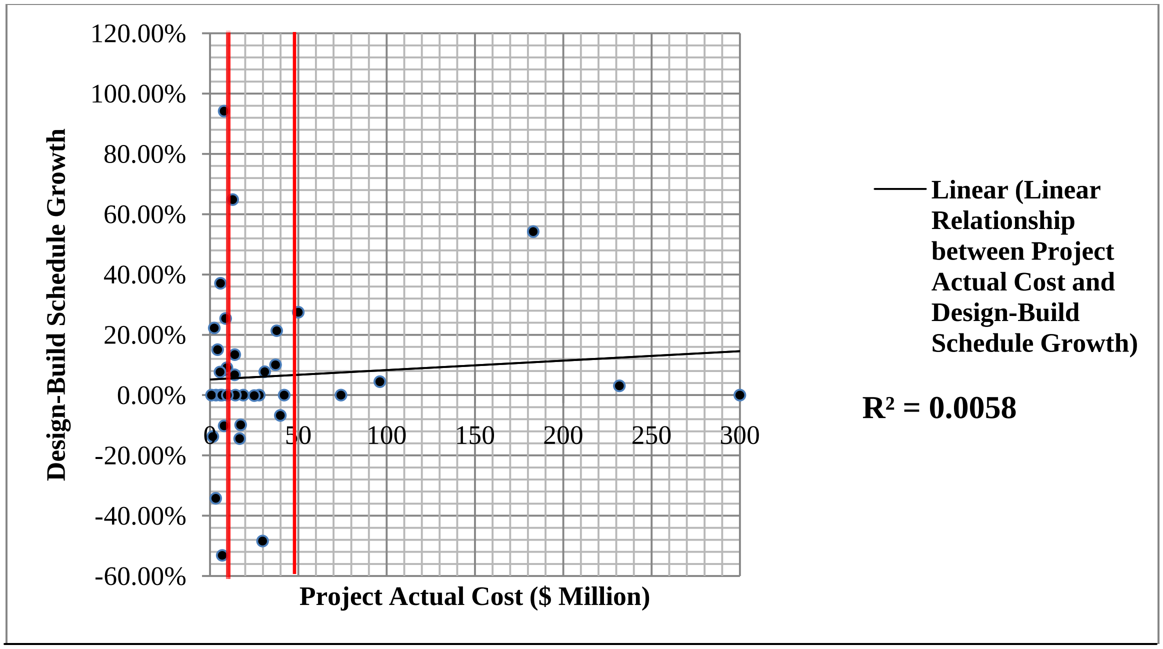


Figure 5.12. Data Distribution of Project Cost and Design-Build Schedule Growth

The two red vertical lines in Figure 5.12 divide the overall project sample into three complexity levels. Most high DBSGs occur in low-complexity projects (PAC less than \$10 M). The overall sample shows no linear relationship between PAC and DBSG (R^2 = 0.005).

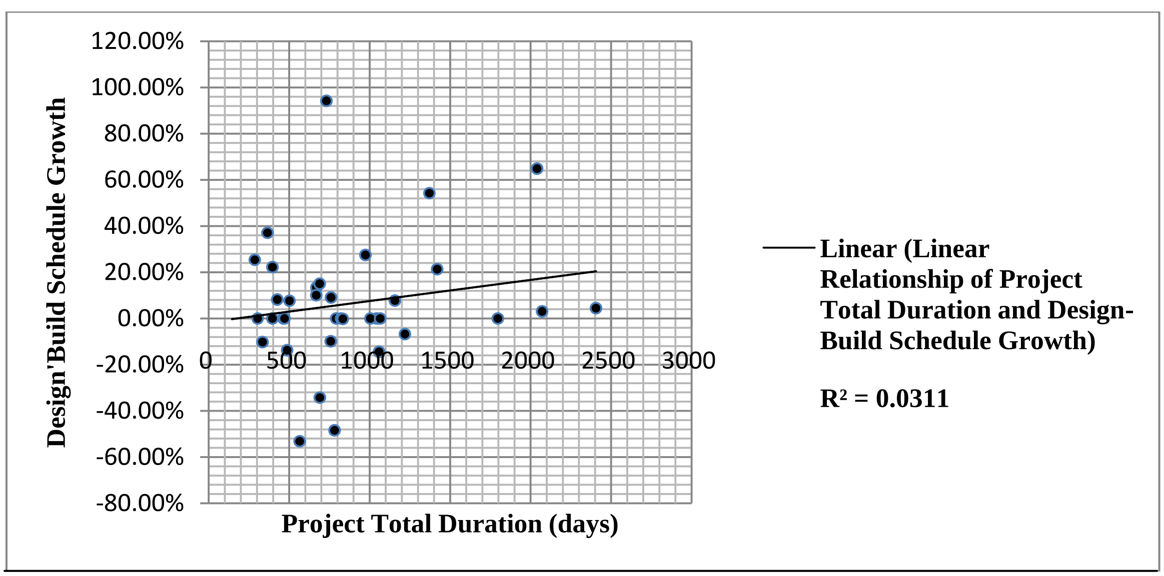


Figure 5.13. Data Distribution of Project Duration and Design-Build Schedule Growth

The weak linear relationships in Figures 5.12 and 5.13 show that project size in terms of cost and duration are still not related to project schedule performance. It is indicated that the project size does not impact project schedule performance.

5.2 Procurement Duration Factors and Cost Growth

The linear relationship analysis of PD factors (PD and PDF) and cost growth will be conducted based on the overall sample, and three different complexity levels.

5.2.1 Data Analysis of the Overall Sample

The overall sample of CG's linear relationship with PD and PDF are analyzed in Figures 5.14 and 5.15.

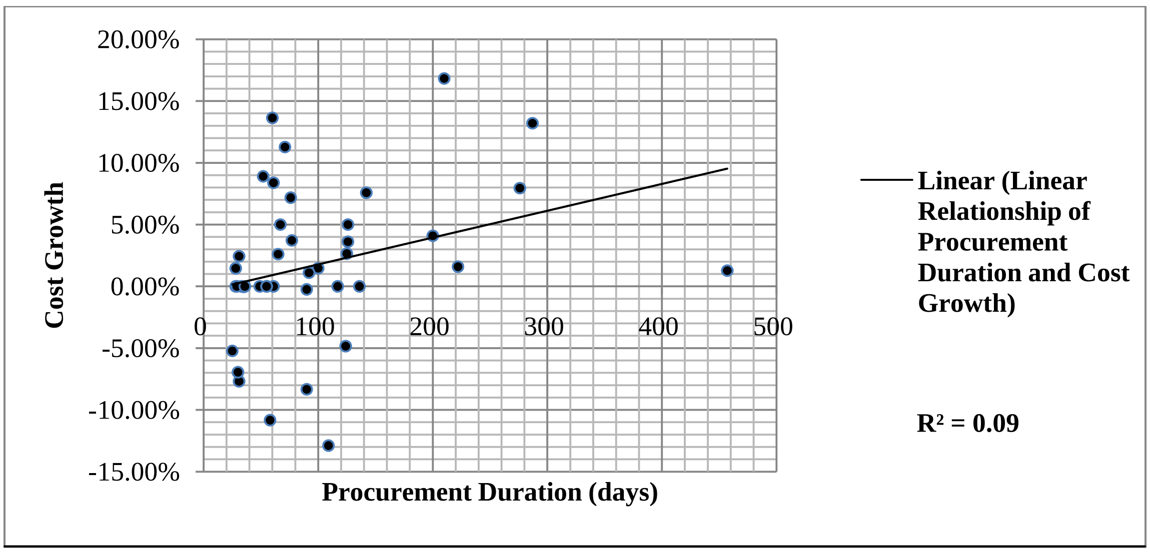


Figure 5.14. Data Distribution of PD and CG

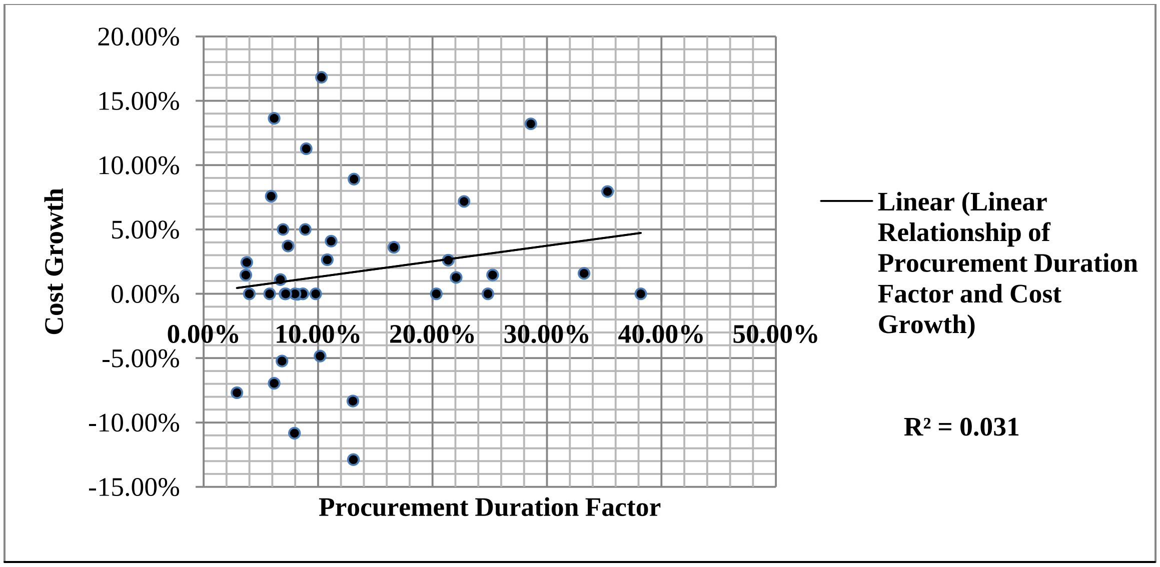


Figure 5.15. Data Distribution of PDF and CG

The above two figures show a weak but positive linear relationship between PD factors and CG. The data are summarized in Table 5.4.

Table 5.3. Linear Data Analysis of PD Factors and Cost Growth in the Overall Sample

Data / Analysis Relation	Correlation Coefficient	R Square	Adjusted R Square	Standard Error
PD&CG	0.300	0.090	0.067	0.601
PDF&CG	0.178	0.032	0.0078	0.604

It can be summarized from the overall project sample of CG that there is a weak linear relationship between PD factors and CG. The PD factors tend to have expected positive relationships with CG. PD does not necessarily increase the CG, but some other factors such as project complexity may contribute to CG increase. Thus, it is deduced that some other variables may account for CG and that CG is in positive linear relationships with project size (project actual cost and total duration). However, Figure 5.16 and 5.17 disprove this notion. The linear relationship between project size (cost and duration) and CG is weak. Thus, factors that correlate to CG remain undefined.

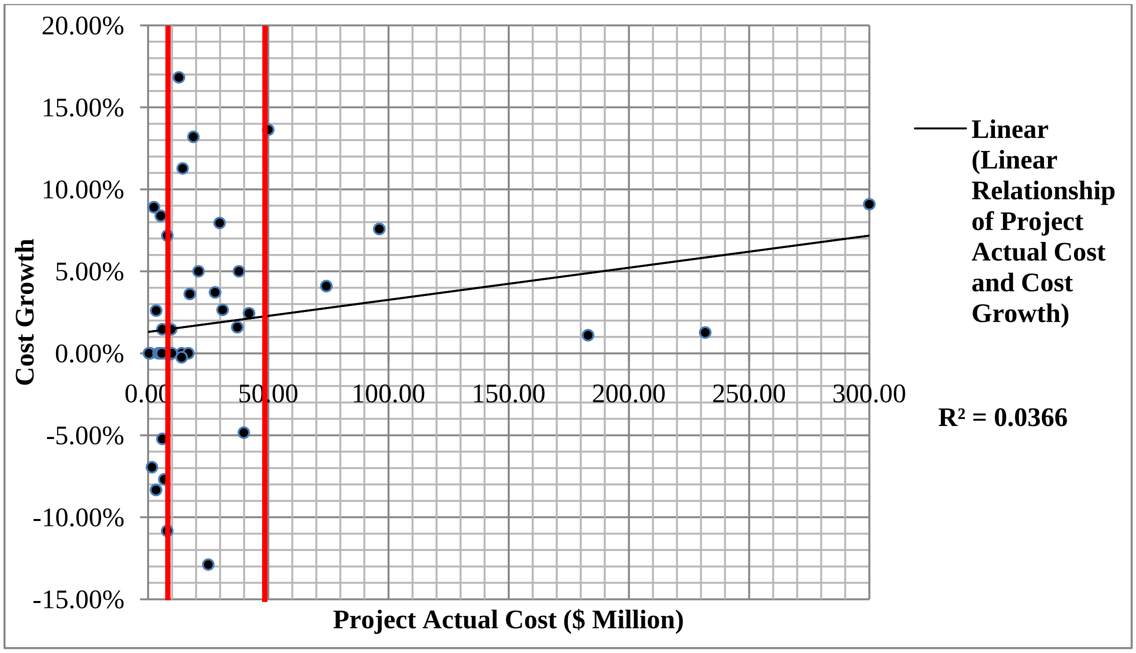


Figure 5.16. Linear Regression Analysis of PAC and CG.

The vertical red lines in Figure 5.16 divide the project complexity into three complexity levels. It is found from Figure 5.16 that the low-complexity projects (PAC less than 10 $M) have irregular cost growths. It is similar with medium-complexity projects. Most high CG occur in the low and medium complexity projects. In high complexity projects, there appears to be some positive linear relationship, which indicates that PAC is an indicator of CG. However, due to the insufficient number of the sample, the conclusion in high complexity projects cannot be drawn. But the overall sample indicates no linear relationship between PAC and CG (R^2 = 0.036).

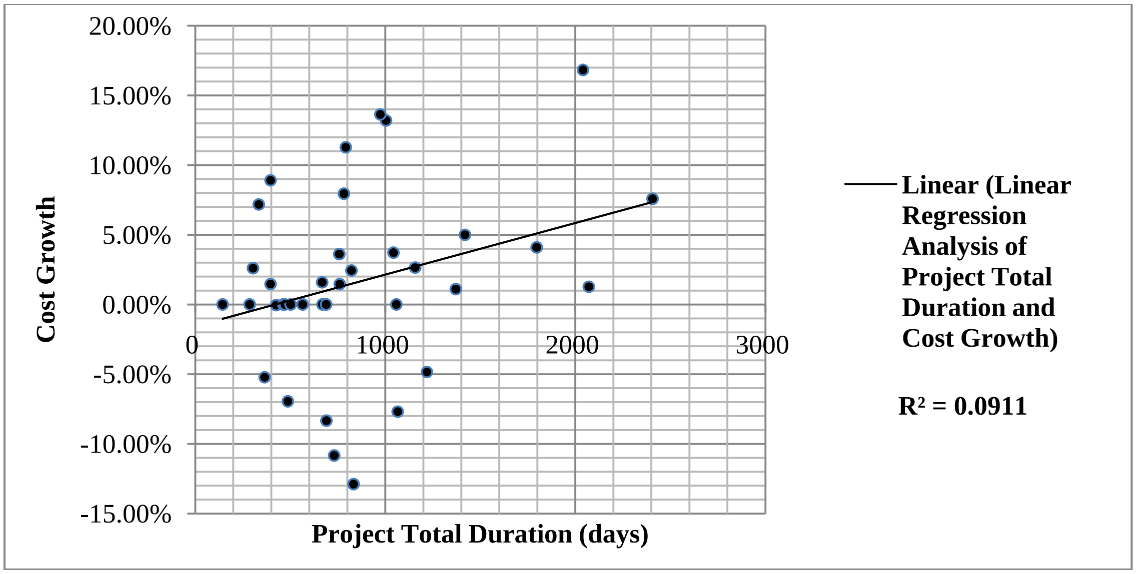


Figure 5.17. Linear Regression Analysis of ATD and CG.

5.2.2 Data Analysis of PD Factors and CG in Different Complex Levels

Table 4.10 indicates that CG is greater in higher complexity projects. The complexity level seems to have some impacts on the CG. The study of the relationship between PD factors and CG is separated into three different complexity level projects. Figures 5.18 to 5.20 show the linear distribution analysis of PD and CG.

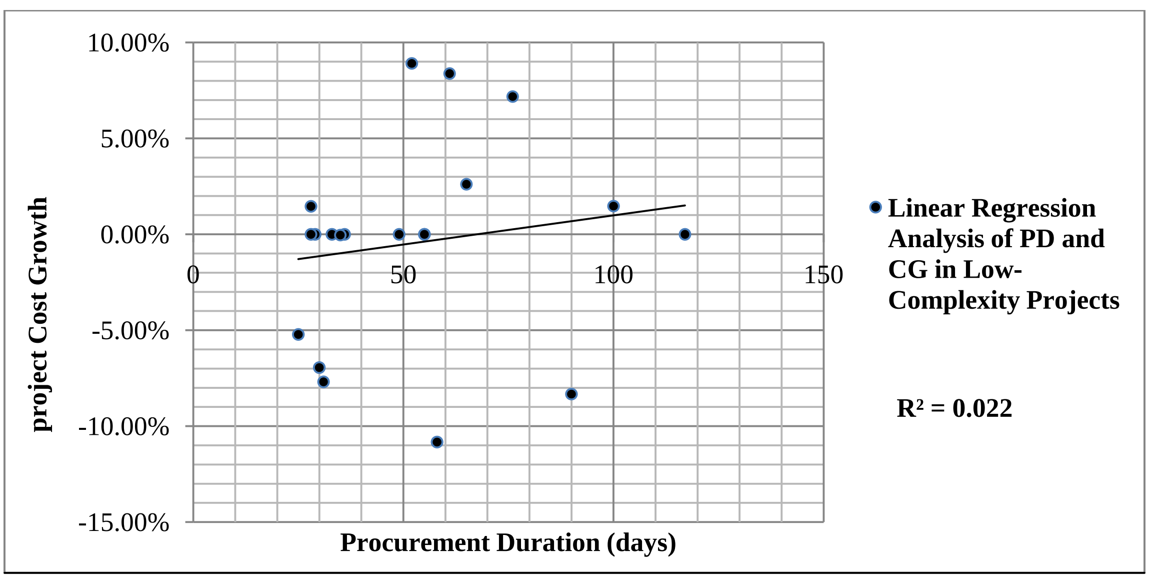


Figure 5.18. Data Distribution of PD and CG in Low-Complexity Projects

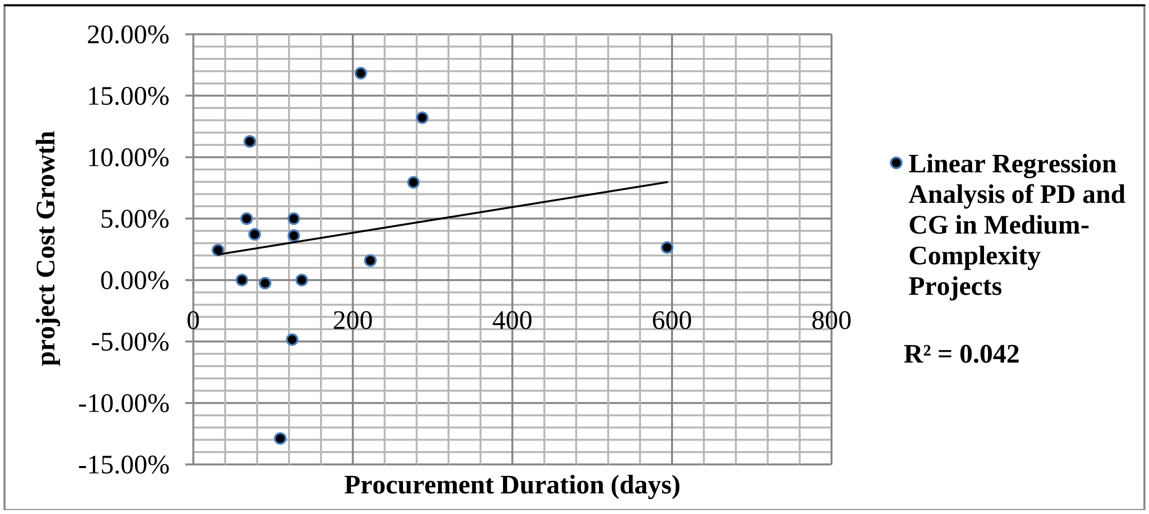


Figure 5.19. Data Distribution of PD and CG in Medium-Complexity Projects

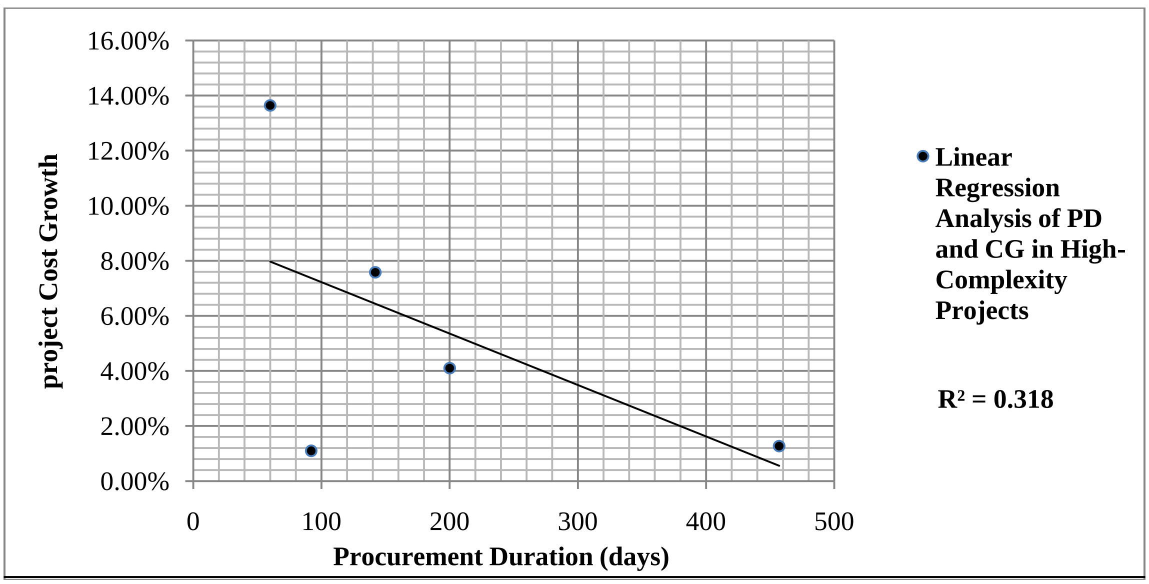


Figure 5.20. Data Distribution of PD and CG in High-Complexity Projects

Similar to the overall sample, the linear relationships of PD factors and CG in low and medium projects appear weak and positive. In high-complexity projects, these relationships are positive and moderately linear. However, considering the insufficient sample (N = 5), it is not recommended to make any conclusions regarding the relationship between PD factors and CG in high complexity projects. The data analysis of PD factors and CG are summarized in Table 5.5.

Table 5.4. Linear Data Analysis of PD Factors and Cost Growth Divided by Three Project Complexity Levels

	Data / Analysis Relation	Correlation Coefficient	R Square	Adjusted R Square	Standard Error
Low-Complexity	PD&CG	0.151	0.023	-0.026	0.054
	PDF&CG	0.356	0.127	0.076	0.048
	ATD &CG	-0.526	0.277	0.232	0.045
	PAC &CG	-0.010	9.5E-05		0.054
Medium-Complexity	PD&CG	0.206	0.042	-0.026	0.071
	PDF&CG	0.154	0.024	-0.051	0.074
	ATD &CG	0.405	0.164	0.094	0.071
	PAC &CG	-0.308	0.095	0.030	0.069
High-Complexity	PD&CG	-0.564	0.318	0.091	0.050
	PDF&CG	-0.542	0.294	0.059	0.051
	ATD &CG	-0.397	0.158	-0.123	0.056
	PAC &CG	-0.808	0.658	0.544	0.036

It is found from Table 5.5 that the linear relationships between CG and other variables vary among the three complexity levels. For example, there is a moderate and negative linear relationship between project ATD and CG in low complexity projects (r = -0.526 and adjusted R^2 = 0.232), but then this relationship turns positive in medium complexity projects (r = 0.405 and adjusted R^2 = 0.094). The linear relationship of PAC and CG in medium complexity projects is stronger than in low-complexity projects. There are some strong linear relationships in high-complexity projects, and all of the relationships are negative. The relationship of PAC and CG in high-complexity projects is relatively strong (adjusted R^2 =0.544) but negative. It is unexpected to find that higher project costs reduce the cost growth, since a higher project cost is supposed to make the project more complex and increase changes in project scopes.

5.3 Linear Regression Analysis of Cost and Schedule Growth

The linear regression analysis in this study has found weak linear relationships between PD factors (PD and PDF) and project performance measurements (cost and schedule growth). However, PD factors reflect a negative relationship with schedule growth, but a positive relationship with CG. An additional analysis is conducted to analyze the possible linear relationship between schedule growth and CG. Schedule growth has been defined previously as TSG and DBSG, and it is indicative that TSG and DBSG have a strong positive linear relationship. Either TSG or DBSG can be used as the schedule performance measurement to test their linear relationships with CG. Figure 5.36 is the data distribution of DBSG abd CG.

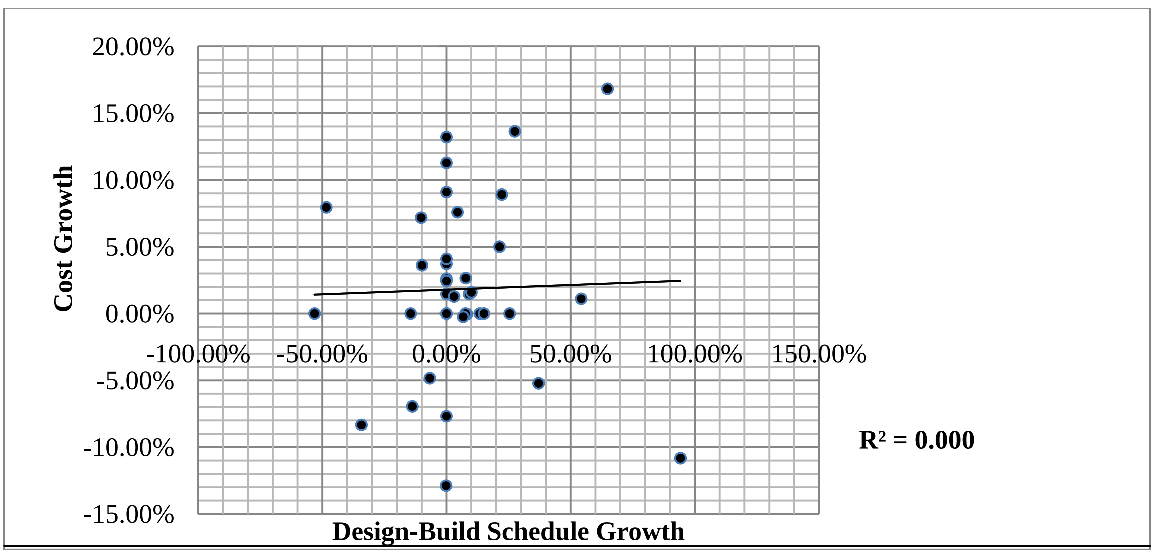


Figure 5.21. Data Distribution of DBSG and Cost Growth in the Overall Sample

Figure 5.21 shows a no linear relationship of CG and DBSG. It can be concluded that there is no relationship between project cost growth and schedule growth.

5.4 Data Analysis Summary

The correlation analysis has not identified any linear or non-linear relationship between PD factors (PD and PDF) and project performance (TSG, DBSG, CG). Most of the linear relationships appear weak, and the residual values of project performance are irregulaly distributed. Most of the performance measurements are close to normal distribution. It is found that PDF has a similar relationship with project performance as PD does. TSG and DBSG have a similar relationship with PD factors.

The overall sample was classified by three complexity levels. The definition of project complexity was also based on project price, as Chen (2009) did in the study of DB transportation projects. The three continous ranges of project costs for WW projects were found to be the same as those used in Chen (2009)'s study of transportation. Both schedule and cost growth analysis were conducted based on the overall sample and three complexity levels. Table 5.6 summarizes the data analysis of schedule and cost performance in their relations to PD factors.

Table 5.5. Data Analysis of PD Factors and Performance Measurements

Groups			Total Schedule Growth (TSG)	Design-Build Schedule Growth (DBSG)	Cost Growth (CG)
Overall Sample		PD	Extremely Weak Negative; A longer PD makes the schedule more predictable.	Extremely Weak and Negative; A longer PD makes the schedule more predictable.	Weak and Positive.
		PDF	Similar to PD	Similar to PD	Similar to PD
Three Complexity Levels	Low	PD	None	None	None
			PD in both TSG and DBSG can be classified in to 3 groups. PD shorter than 50 days, the schedule growth is random and irregular, most high schedule growth (higher than 20%) occur in this period. PD longer than 100 days tend to have a stable schedule.		
	Median	PD	Extremely weak, negative.	Extremely weak, positive.	Weak and positive.
			None.	None.	None. Most PDs are below 200 days.
	High	PD	Moderate negative linear relstionship	Moderate negative linear relstionship	Moderate negative linear relstionship.
			Random and irregular.	Random and irregular.	Insufficient sample (N=5)

Table 5.6 summarizes the data analysis between PD factors and project performance.

5.5 Comparison of Regression Analysis between PD and Project Performance in WW and Transportation Projects

The linear regression analysis of PD and project performance in WW projects was compared to a similar analysis for transportation projects. The similarities and differences in WW and transportation projects are summarized in this section.

5.5.1 Schedule Growth in WW and Transportation Projects

In WW projects, the linear relationship of PD and schedule growth (SG) is weak in the overall project sample. This linear relationship in the low and medium complexity levels also tends to be weak in general, although in high complexity projects, there seems to be some moderate negative linear relationship between PD and schedule growth. The linear relationship in medium complexity projects tends to be weakest.

In transportation projects, there is a strong and negative linear relationship between PD and schedule growth in the overall sample. However, this linear relationship is weakest in high-complexity projects, and strongest in low-complexity projects. Table 5.7 summarizes the differences in the linear relationships in WW and transportation projects.

Table 5.6. Linear Relationships between PD and Schedule Growth in WW and Transportation Projects

Project Type		**Overall Project**	**Three different complexity levels**		
			Low	**Medium**	**High**
WW	Linear Relationship	None	Weak and Negative	Weakest and Negative	Moderate Negative
	R Square	0.0091	0.0384	0.0014	0.3222
Transportation	Linear Relationship	Strong and Negative	Strongest and Negative	Relatively Strong and Negative	Weak and Negative
	R Square	0.6406	0.8535	0.569	0.0528

Table 4.10 shows the data that schedule growth increases for higher complexity WW projects. In contrast, the schedule growth is decreasing for higher complexity transportation projects.

5.5.2 Cost Growth in WW and Transportation Projects

In WW projects, the linear relationship of PD and CG is weak but positive in the overall sample. When divided by three complexity levels, the linear relationships in both low and medium complexity projects are also weak and positive, while it turns moderately negative in high-complexity projects.

In transportation projects, this linear relationship is weak and negative in the overall project sample. It is also weak in all three complexity levels. This linear relationship is weakest in high-complexity projects, and relatively strongest in low-complexity projects.

Table 5.8 summarizes the differences of linear relationships between PD and cost growth in WW and transportation projects.

Table 5.7. Linear Relationships of PD and Cost Growth in WW and Transportation Projects

Project Type		Overall Project	Three different complexity levels		
			Low	Medium	High
WW	Linear Relationship	Weak and Positive	Weak and Positive	Weak and Positive	Moderately Negative
	R Square	0.09	0.0228	0.0424	0.318
Transportation	Linear Relationship	Weak and Negative	Relatively Strongest and Negative	Weak and Negative	Extremely Weak
	R Square	0.6406	0.136	0.0121	0.0015

CG data in Table 4.10 illustrates that CG increases for higher complexity WW projects. In contrast, CG decreases for higher complexity transportation projects.

5.5.3 Linear Relationship between Schedule Growth and Cost Growth in WW and Transportation Projects

The linear relationship of SG and CG in both WW and transportation projects are weak. In WW projects, the linear relationship is positive and extremely weak, with an R Square value of 0.0008. In transportation projects, it is also weak and positive, with an R Square value of 0.0836. The different linear relationships between PD and project performance are identified that: According to Chen (2009), there is a strong linear relationship between schedule growth and PD in DB transportation projects, and a longer procurement duration helps reduce the project schedule growth. However, in WW projects, there is an extremely weak and negative linear relationship between PD and schedule growth.

The similarities of transportation and WW DB projects lie in that:

- There is little relationship between PD and cost growth. Cost growth is not affected by PD, although in transportation projects, the trend of PD and cost growth's relationship is negative, while the same trend in WW projects is positive.
- There is also little relationship between cost growth and schedule growth in both transportation and WW DB projects. The cost and schedule performance are separated and not related.

5.6 Summary of Findings

Although the relationships that have been found are very weak for WW projects, there are still some conclusions that can be drawn from the data analysis results:

(1) In the overall sample, projects with PD longer than 100 days have less change in total project and design-build duration. Thus, the project schedule is more stable. Projects with PDF higher than 10% have lower DBSG. If the time given for design-builders to prepare proposals is longer than 10% of the total project time, the design-build schedule is more stable and can be acurately predicted.

(2) Cost and schedule growth have little linear relationships. Cost growth is in a positve relationship with PD factors, while that relationship in schedule growth and PD factors tends to be negative.

(3) There may be other factors besides procurement duration that impact the project final performance. The project size is not one of these influencing factors. Table 5.9 presents the correlation coefficient between project size and project performance. PAC and actual total duration ATD are used to measure the project size. The low correlation coefficients indicate the weak relationships between project size and final performance.

Table 5.8. Correlation Coefficient between Project Size and Project Performance

	Design-Build Schedule Growth	Total Schedule Growth	Total Cost Growth
PAC	0.026	-0.105	0.177
ATD	0.176	0.124	0.302

Based on the above conclusions, the related suggestion for owners and design-builders in the DB WW industry is: To achieve the benefits of a stable project schedule with less changes, the time given for design-builders to prepare proposals is suggested to be longer than 100 days. More than 10% of the total project delivery time is suggested to be spent on design-builders' proposal preparation.

CHAPTER SIX

CONTENT ANALYSIS

The results of the data analysis presented in Chapter Five show that there were differences between this study of WW projects and Chen (2009)'s study of transportation projects. These differences were especially seen in the relationship between PD and schedule growth. Because of these differences, further analysis was done using CA to try to determine why these two types of projects behaved differently.

6.1 Background of Content Analysis Application in Water/Wastewater Study

CA is applied in the study of the relationship between PD and project performance. Based on those differences and similarities of relationships between WW and transportation projects, related hypothesis concerning the PD and project performance are provided below:

(4) There are some variables included in the procurement documents that impact the project final cost and schedule performance.

(5) In most DB transportation projects, schedule issues are of greater concern than in WW projects.

(6) The projest costs in both transportation and WW projects may not be so easily controlled by the design-builder, even though sufficient time is provided to prepare the cost proposal.

(7) Cost change and schedule change are not necessarily interrelated in both transportation and WW projects.

The RFP is a significant data source to test the hypothesis through the review of RFP content, especially content related to the selection process, weighted criteria for design-builder selection, and required items in design-builders' proposal submittal. As introduced in Chapter Three, there are a few defined steps to conduct the CA (GAO, 1996):

(1) CA objectives: The objective of the CA in this study is to explore the similarities and differences of the RFPs between DB WW and transportation projects.

(2) Definitions of variables: Variables will be defined through the review of RFPs and other procurement documents (contract clauses, RFQ, general condition, e.g.). Possible variables may include but not be limited to: proposal content, evaluation criteria, and selection process. Each variable will be categorized into different types. For example, selection process may be categorized as one-step, two-step and three-step.

(3) Selection of materials for analysis: procurement documents (mainly RFPs) from 31 Department of Transportation (DOT) and 17 WW projects will be used for CA.

(4) Development of an analysis plan: The presence and frequency of each defined variable will be documented.

(5) Text analysis: Based on the data acquired from the above step, the similarities and differences of each variable in transportation and WW procurement documents will be analyzed, especially these categories related to schedule and cost controls. These similarities and differences will be used to explain and hypothesize the relationships of PD and project performance in transportation and WW projects.

(6) Conclusion: the results of the CA in transportation and WW procurement documents will be summarized.

6.2 Variables of Procurement

After the objectives of the CA are defined, the variables of procurement in WW and transportation projects will be defined through the review of the RFP and other procurement documents. Each variable will then be categorized. There were a total of 31 DOT and 17 WW projects' procurement documents that were reviewed. The RFP is the primary format used for CA in this study. The RFPs were not traceable in all of these projects, and some other procurement formats were used instead, such as RFQ, contract, etc.

The variables in these procurement documents in transportation and WW projects were defined as below.

6.2.1 Proposal Contents

Design-builders are usually required to contain these items in their proposals in a certain order and format prescribed by the owner. Proposal contents may include but not be limited to:

Executive summary (ES): ES usually excludes price consideration, which will be submitted in a separate cost proposal. A typical ES may include these items:

- Changes in their previous submittals if it is a two-step selection process, including the change of team personnel
- Introduction of design-build team organization
- Introduction of key personnel experience (may include major subcontractors' information)
- A summary of proposal content

Proposer information and certifications: Design-builders may be required to provide evidence and forms regarding their organization and qualification:

- Proposal letter, which is a formal letter from the design-builder to the owner, and may be written in a standard form
- Safety performance: The design-builder's safety performance and record in recent years (5 years, e.g.), and safety approach
- Disadvantaged Business Enterprise (DBE) and subcontractor's selection: DBE programs are adopted by many public agencies such as DOT to provide opportunities for small business owners, who are at a disadvantage to participate in a large project. Proposers may be also required to provide the major subcontractors' information, which may include subcontractors' information on the work and technical requirements, and a list of subcontractors with whom the proposer has negotiated in good faith.
- Job training program: Design-builders' program to train workers for the specific jobs in this project
- Affidavit: a formal oath or evidence that the design-builder will perform the job according to the contract once it is awarded the contract, and it will meet each specification, code, and local ordinance.

Management proposal (MP): It is a proposal for design-builders to describe their general approach to manage the whole project, including management of personnel, finance, facilities, and equipment. A typical MP may include but not be limited to these items:

- Project Management: it may include these sub-items:
    - ➢ Control and coordinate the various subcontractors

- Interface with the owner, communication between the designer/engineer and contractor
- Control the cost and schedule of the project
- Comply with federal, state and local environmental, land-use planning and other applicable laws and requirements
- Illustrate its overall ability to provide the experienced personnel and facilities required to successfully complete the Project.
- Risk Management and Allocation: which usually includes but is not limited to control of the budget within an upset amount, substantial deadline, and unknown or differing site conditions

- Quality Assurance/Quality Control (QA/QC): the proposer may be required to describe their approach for QA/QC, which should comply with the related requirements in the RFP. The QA/QC program may include the quality requirements in both design and construction.
- Safety Program: proposers' safety program should comply with contract clauses and government regulations, and proposers' safety management procedure.

Technical proposal (TP): TP is specific to the project scope. In WW and transportation projects, the items below are usually required:

- Geotechnical and earthwork plan

- Preliminary design and construction schedule, as well as construction sequencing plan or work breakdown structure.
- Design approach to meet owner's performance requirements
- Construction approach
- The operation and maintenance, in the post-construction phase, and/or the maintenance of existing site conditions during the construction phase.

Price proposal (PP): The price proposal is usually separated from the TP in a sealed proposal package, which may cover these items below:

- A fixed dollar amount with cost breakdown form may be required, or a cost-plus-fee with a guaranteed maximum price (GMP).
- Various bonds may be required: payment, performance, proposal, safety bonds and guarantor information. The bonding agency's qualifications may be required or checked by the owner.
- The proposer and subcontractors (including DBE firms) may also be required to meet the owner's financial requirements.

Optional proposal (OP): sometimes the owner may require proposers to prepare an optional proposal, which uses an alternative technical approach for the project, and is responsive to the project requirements. The OP may be compared with the basic technical proposal, and may be applied in the project execution.

6.2.2 Procurement Approach

Besides the content requirements of design-builders' proposals, owners may also include other items in the RFP or Instructions to Bidders. One of these items is the introduction of the design-builder selection process. The procurement methods and process have been introduced in Chapter Two as:

- Sole Source Selection
- Qualification-Based Selection (QBS)
- Best Value (BV) Selection
- Low-Bid Selection

6.2.3 Selection Criteria

Owners usually release the selection criteria to design-builders in the RFP or other procurement documents. These criteria vary in different DB projects, and are related to the procurement approach that the owner uses for design-builder selection. For example, cost and non-cost criteria may be considered equally in the weighted criteria of the best value method. Non-cost criteria may be emphasized in qualification-based selection. The typical criteria frequently used in DB project RFQs and/or RFPs are listed below:

- Design-builders' responsiveness to RFQ and RFP: whether the proposals meet the owner's minimum requirements stipulated in RFQ and RFP.

- Cost: cost is one of the major factors when owners consider which design-builder best qualify for the project.

- Design-builders’ understanding of the project and specific approach for the project design/construction

- Design-build team organization, including key personnel’s experience

- The design-builder’s capability, including experience in DB, the coordination of the design and construction team, and experience with projects in similar size

- Financial Capacity: which may include the designer and contractor’s company asset, debt, financial records in recent years, and subcontractors’ financial capacity

- Maintenance and Operation: the design-builder’s plan for project maintenance

- Design Quality Program: design approach and management, as well as design constructability

- Construction Quality Program: design-builder’s quality management during construction

- Safety Program: previous safety performance and safety approach to the project

- Schedule/Work Breakdown Structure: design-builder’s schedule of key activities and milestones

- Subcontracting: design-builder’s subcontractor/sub-consultant selection, including subcontractors’ qualification and capacity.

- Warranty: design-builder’s warranty of the service within a certain period in the post-construction

- Environmental Protection: how the construction activities comply with owner agency, state and local environmental codes

- Coordination: the communication and cooperation among the designer/engineer, contractor and owner, through electronic contact, phone call, or regular meeting.

- Aesthetics: the general aesthetics of the design-builders proposed design

- Risk Management: management of uncertainty in maximum cost, project completion deadline, differing site condition, etc.

The criteria evaluation plan in this content analysis is categorized as:

- Vague: the owner does not provide specific evaluation factors.
- Semi-detailed: the evaluation criteria are listed but their relative weights are not mentioned.
- Detailed: a detailed evaluation plan provides a numerical score for each factor.
- Technically acceptable-low bid: design-builders’ non-cost criteria are evaluated as pass or fail. The price is the overriding factor in the design-builder selection.

6.2.4 Other Variables in Procurement Documents

There are some issues that may impact the owner’s procurement of design-builders and a design-builder’s decision to propose on a project. These variables may include:

- Procurement Steps: the procurement steps in DB projects can be categorized as one-step, two-step and three-step (see Chapter Two for more information).

- Stipend or honorarium: Some DB projects will pay some compensation in the form of a stipend or honorarium to unaccepted design-builders for their work in the preparation of proposals.

- Liquidated damage: The design-builder may be punished financially by the owner for late project completion.

- Pre-proposal conference: There may be a mandatory pre-proposal conference, in which design-builders can ask any questions regarding the RFP (asking for clarity, e.g.).

- Interviews or oral presentations during the post-proposal: During the procurement period, design-builders may be invited to an interview and/or oral presentation, to describe their approach to the project.

- Owner's project goal for cost: The owners may have a project-price cap.

- Owner's project goal for the completion date: The owner may have specified deadlines for start-up and closing out.

- Incentive for early completion: Some owners may have an incentive policy to encourage early project completion.

- Project life cycle cost analysis or value engineering: Some owners may require the design-builder to submit the value engineering or life cycle cost analysis plan, which may be one of the evaluation factors.

- Circumstances that proposals may be rejected: design-builders may be pre-warned about the circumstances under which their proposals may be declined (e.g., mandatory forms).

- Payment procedure: design-builders may be informed in the RFP about the payment procedures.

- Contract clauses regarding dispute resolution and change orders: the owner may specify some of the contract clauses on dispute and change orders in the RFP or other procurement documents.

- Warranty: Similar to clauses regarding dispute resolution and change orders, clauses on design-builders' warranty may also be included in procurement documents before design-builders prepare their proposals.

- Agreements on the owner and design-builders' rights and responsibilities: the owner and design-builders may need to reach some agreement on the two parties' rights and duties before design-builders prepare their proposals.
- Site visit: Design-builders are usually allowed or encouraged to visit the site before preparing the proposal.

6.3 Content Analysis of Variables in Procurement Documents

After the variables have been defined for the content analysis (CA), project procurement documents were selected as the CA source. These procurement documents are mainly RFPs. In case some projects' RFP were unavailable, the RFQ or other documents may be used as reference. Owner's response of project procurement is also a source to be the text for CA. The variables' presence and frequency will be counted and analyzed through CA in comparison of transportation and WW projects. Frequency rate is the percentage of the overall project sample that contains the variable. It is used to compare the frequency of each variable in transportation and WW projects. It is calculated using the formula below:

$$\text{Frequency Rate} = \frac{\text{Number of times Variable Present}}{\text{Number of Projects}}$$

Table 6.1 is the CA for variables associated with the proposal contents.

Table 6.1. Variables of Proposal Content in Transportation and WW Projects

	Transportation			**Water/Wastewater**		
	Number of the Variable	**Number of Projects**	**Frequency Rate**	**Number of the Variable**	**Number of Projects**	**Frequency Rate**
Executive summary	8	24	33%	6	13	46%
Proposer information and certifications	5	24	21%	1	13	7.7%
Financial Proposal	6	26	23%	4	12	33%
Management proposal	9	25	36%	3	12	25%
Technical proposal	25	26	96%	12	13	92%
Price proposal	26	27	96%	13	14	93%
Optional proposal	4	24	17%	1	12	8%

Table 6.2 provides detailed breakdowns for each of the variables Table 6.1.

Table 6.2. Variables of Proposal Content Items in Transportation and WW Projects

		Transportation			Water/Wastewater		
		Number of the Variable	**Number of Projects**	**Frequency Rate**	**Number of the Variable**	**Number of Projects**	**Frequency Rate**
Executive Summary	Changes of Organization	8	25	32%	3	12	25%
	DB Team Organization	28	29	97%	13	13	100%
	Key Personnel Experience	21	27	78%	13	13	100%
	A Summary of the Proposal Content	3	24	13%		12	0.0%
Proposer Information and Certifications	Proposal Letter	13	24	54%	8	13	62%
	Safety Performance	4	25	16%	3	13	23%
	Disadvantaged Business Enterprise (DBE) participation	18	29	62%	2	12	17%
	Job Training Program	4	24	17%	0	12	0.0%
	Affidavit	7	24	29%	2	12	17%
Management Proposal	Subcontractor Management	11	25	44%	3	12	25%
	Communication	15	26	58%	5	12	42%
	Cost and Schedule Control	14	25	56%	4	12	33%
	Compliance with environmental, land-use planning and other laws	17	26	65%	7	13	54%
	The list of Key Personnel and Facilities	21	25	84%	13	13	100%
	Risk Management	0	25	0.0%	2	12	17%
	Quality Assurance/Quality Control	25	28	89%	6	12	50%
	Safety Program	10	24	42%	6	12	50%
Technical Proposal	Geotechnical and Earthwork plan	18	26	69%	5	14	36%
	Design Approach	24	26	92%	10	14	71%

	Table 6.2 (cont.)							
			Transportation			**Water/Wastewater**		
			Number of the Variable	**Number of Projects**	**Frequenc-y Rate**	**Number of the Variable**	**Number of Projects**	**Frequency Rate**
	Construction Plan/Approach		20	25	80%	9	14	64%
	Maintenance		15	25	60%	2	12	17%
	Milestone and schedule for design and construction		25	26	96%	12	14	86%
Price Proposal	Price	Fixed-Price	26	27	96%	13	16	81%
		GMP	0	27	0.0%	2	16	13%
	Bond, guarantor and Insurance Requirements		22	27	81%	8	13	62%
	Subcontractor (including DBE firms) financial ability		10	25	40%	1	11	9.1%

Table 6.3 summarizes the frequency of different procurement approaches used in transportation and WW projects.

Table 6.3. Variables of Procurement Approach in Transportation and WW Projects

		Transportation			**Water/Wastewater**		
		Number of the Variable	**Number of Projects**	**Frequency Rate**	**Number of the Variable**	**Number of Projects**	**Frequency Rate**
Sole Source		0	25	0.0%	2	15	13%
Qualification-Based		3	25	12%	5	15	33%
Best Value	Negotiated source selection with discussions	3	25	12%	5	15	33%
	Source selection with formal review	4	25	16%		15	0.0%
	Fixed budget/best technical response or design		25	0.0%		15	0.0%

	Table 6.3 (cont.)						
		Transportation			Water/Wastewater		
		Number of the Variable	**Number of Projects**	**Frequency Rate**	**Number of the Variable**	**Number of Projects**	**Frequency Rate**
	Weighted criteria	3	25	12%	2	15	13%
Low-Bid	Adjusted low bid	10	25	40%	1	15	6.7%
	Low first cost after qualification	2	25	8.0%		15	0.0%
	Low first cost		25	0.0%		15	0.0%

The categories of the criteria evaluation plan (CEP) in transportation and WW projects are summarized in Table 6.4.

Table 6.4. Variables of CEP in Transportation and WW Projects

	Transportation			Water/Wastewater		
	Number of the Variable	**Number of Projects**	**Frequency Rate**	**Number of the Variable**	**Number of Projects**	**Frequency Rate**
Vague	3	29	10%	1	15	6.7%
Semi-detailed	5	29	17%	2	15	13%
Detailed	21	29	72%	12	15	80%
Technically Acceptable-Low Bid		29	0.0%		15	0.0%

T criteria, but does not summarize the relative weight of the criteria. These criteria may be included in the RFQ or RFP. able 6.5 is the summary of the CA for selection criteria in DB projects. These criteria may be weighted with a numerical score. Table 6.5 only counts the frequency of each

Table 6.5. Variables of Selection Criteria in Transportation and WW Projects

	Transportation			Water/Wastewater		
	Number of the Variable	**Number of Projects**	**Frequency Rate**	**Number of the Variable**	**Number of Projects**	**Frequency Rate**
Design-builders' Responsiveness	13	24	54%	6	12	50%
Cost	25	27	93%	14	16	88%
Design-builders' understanding of the project and approach	11	25	44%	10	13	77%
Design-build team organization	21	27	78%	10	13	77%
The design-builder's capability, experience	19	27	70%	12	13	92%
Financial Capacity	7	26	27%	5	12	42%
Maintenance and Operation Capacity	10	26	38%	3	12	25%
Design Quality program	18	27	67%	4	12	33%
Construction Quality program	19	25	76%	3	12	25%
Safety program	9	24	38%	2	13	15%
Schedule/work breakdown plan	14	24	58%	7	13	54%
Subcontracting	8	24	33%	3	12	25%
Warranty	2	22	9.1%		12	0.0%
Environmental Protection	4	22	18%	1	12	8.3%
Coordination	13	23	57%	3	12	25%
Aesthetics	7	24	29%		12	0.0%
Risk Management				3	11	27%

Besides these variables from Table 6.1 to 6.5, there are other relevant variables that may exist in DB project procurement documents. These variables are presented in Table 6.6.

Table 6.6. Other Variables in Transportation and WW Project Procurement Documents

		Transportation			Water/Wastewater		
		Number of the Variable	Number of Projects	Frequency Rate	Number of the Variable	Number of Projects	Frequency Rate
Procur-ement Steps	One-Step	5	27	19%	10	15	67%
	Two-Step	18	27	67%	3	15	20%
	Three-Step	4	27	15%	2	15	13%
Stipend or Honorarium		17	26	65%	1	14	7.1%
Percentage of design completion in the proposal		3	25	12%	3	12	25%
Liquidated Damage		9	26	35%	2	12	17%
Pre-Proposal Conference		14	25	56%	9	12	75%
Interviews or Oral Presentation		11	25	44%	9	12	75%
Owners' budget (price cap) for the project		5	31	16%		12	0.0%
Owner's goal of project completion date		16	27	59%	1	12	8.3%
Incentive for early completion		2	26	7.7%	1	12	8.3%
Site Visit		9	26	35%	8	13	62%
Project Life Cycle Cost Analysis		5	27	19%	3	12	25%
Circumstances that proposals may be rejected		8	26	31%	6	12	50%
Dispute resolution		4	26	15%	3	13	23%
How to deal with change orders		3	26	12%	3	13	23%
Payment Procedure		12	27	44%	3	13	23%
Warranty		11	27	41%	1	12	8.3%

Table 6.6 (cont.)							
		Transportation			**Water/Wastewater**		
		Number of the Variable	**Number of Projects**	**Frequency Rate**	**Number of the Variable**	**Number of Projects**	**Frequency Rate**
Rights and Respon-sibilities	**Design-builders provide the sub-contractor list**	7	27	26%	4	12	33%
	Design-builders' duties in personnel training	7	27	26%	0	12	0.0%
	Owner's right to use ideas from unacceptable proposals	3	26	12%	0	12	0.0%

Tables 6.1 to 6.6 count the frequency rates of each pre-defined variable within transportation and WW projects. The total numbers of projects in these tables are not constant and are usually less than the total number of projects studied for the CA. This is because some projects' RFPs were missing, with only RFQs or some other project procurement documents such as contracts and general condition available. Without a full picture of the RFP content, some variables in these tables were unable to be defined. Another concern is the items in Table 6.2. A proposal content which does not contain the variable may have some sub-items under the variable. For example, a project's proposal content does not include the executive summary, but an item within executive summary (e.g., DB team organization) may be required in the proposal. This item may be included in another variable (e.g., management proposal).

The same sub-item may belong to different variables in various projects. For example, the cost and schedule control may be included in the management proposal in one project, but may be required in the technical proposal in another project.

In data in Table 6.5 only count the frequencies of evaluation factors within transportation and WW projects. However, it does not summarize the relative weight of each factor. In fact, the same factor may be weighted differently in various projects. For example, the cost factor may be weighted 80% in a transportation project, but might be weighted only 20% in a WW project. The CA in this study does not count the relative weight of evaluation factors but frequencies in transportation and WW projects. Actually it is also difficult to accurately quantify the relative weight of each factor. A lot of transportation projects use adjusted scores to rank proposals, while some other projects use pass/fail to pre-qualify design-builders and make the cost the dominating evaluation factor. The numerical score for both cost and non-cost items are hard to be defined especially in those projects which do not use a weighted criteria procurement approach.

6.4 Content Analysis Summary

Based on Tables 6.3 to 6.8, the similarities and differences of procurement documents within transportation and WW projects are summarized as below.

Similarities:

- Technical and cost proposals are the most common contents in DB transportation and WW project proposals.
- In both transportation and WW projects, several items are often required in the proposal:

- DB team's qualification, including the DB organization, key personnel resume, experience with DB delivery system and similar projects
- Design and construction approach to the project
- Project scheduling and milestones in both design and construction
- Fixed price (lump sum) with cost break-down calculation
- Bond, guarantor and insurance requirements

- A detailed evaluation plan for proposals, using numerical scores for each non-cost criteria
- These factors are commonly used in proposal evaluation:
  - Cost
  - Design-builders' responsiveness
  - Design-build team organization
  - The design-builder's capability and experience
  - Schedule/work breakdown plan
- Pre-proposal meeting/conference and post-proposal interviews/oral presentations are usually parts of the project procurement process, although they tend to be more frequently used in WW than transportation projects.

Differences:

- Transportation projects usually require a certain participation level of DBE. In contrast, WW projects are mostly municipally-owned and DBE participation is not required in most but not all cases.

- Nearly half of transportation project owners require design-builders to have a major subcontractor management plan, and only a quarter of WW projects have similar requirements.
- More transportation projects require design-builders to have cost and schedule control plans in their proposals.
- More transportation projects require design-builders to have QA/QC plans in their proposals.
- The frequency of geotechnical and earthwork plans in transportation project proposals is almost twice as that in WW projects (69% to 36%).
- More than half of transportation projects (60%) require design-builders to have a maintenance plan, which is not required in WW projects in most cases.
- All transportation projects require design-builders to provide a fixed price proposal, while in some WW projects, a cost-plus-fee with a guaranteed maximum price is allowed.
- More transportation projects require the financial information of subcontractors and DBEs (40% for transportation and 9% for WW).
- The percentage of each selection approach in transportation and WW projects are compared in Figure 6.1 and Figure 6.2.

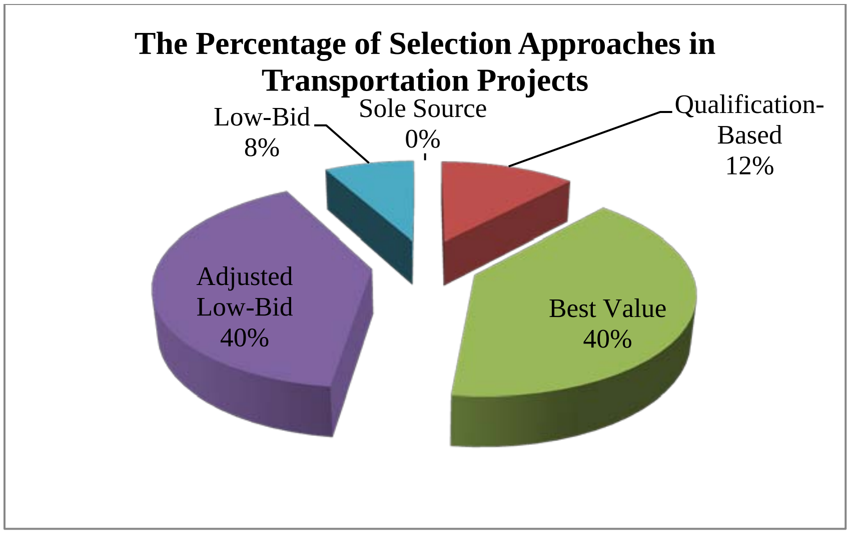


Figure 6.1. Procurement Approaches in Transportation Projects

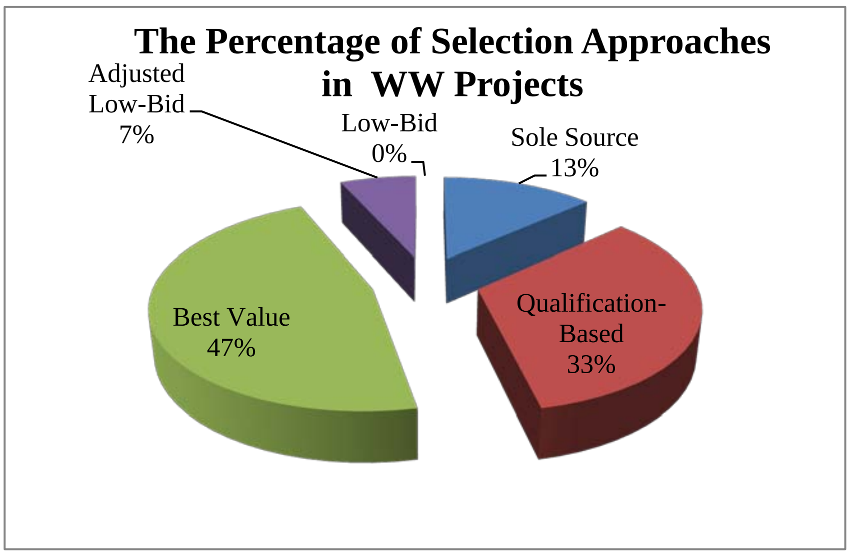


Figure 6.2. Procurement Approaches in Water/Wastewater Projects

Figure 6.1 and 6.2 shows the differences of procurement approaches in transportation and WW projects. Adjusted low bid is widely applied in transportation projects, while qualification-based selection is widely used in WW projects. The percentage of BV use is close in transportation and WW projects (40% and 47%), but most BV-based projects used source selection with formal review in transportation projects, while WW projects use mostly negotiated source selection with discussions in the BV selection.

- Figure 6.1 and 6.2 also indicate that transportation projects value cost criteria more in the procurement, while WW project owners consider more of design-builders' qualification.
- Regarding the evaluation criteria in Table 6.7, the differences between transportation and WW projects are indicated below:
    - The design-builders' understanding of the project and approach is more frequently used in WW than in transportation projects.
    - The design-builders' financial capacity is more frequently considered in WW projects.
    - The design and construction quality programs are much more commonly evaluated in transportation projects.
    - Transportation project owners evaluate safety programs more frequently than their counterparts in WW projects.
    - The coordination and communication of the designer/engineer, contractor and owner are more frequently evaluated in transportation projects.
    - The aesthetics is sometimes evaluated in transportation projects, while it is not considered in WW projects.
    - The design-builders' risk management program is sometimes evaluated in WW projects, but not in transportation projects.
- Regarding other variables listed in Table 6.8.
    - Two-step is the main process used in transportation project procurement, while one-step is widely used in WW projects.

- Most transportation projects provide stipends to responsive but unsuccessful proposers, while most WW projects do not have any stipend or honorarium for proposers.
- More than half of transportation project owners have a deadline for the project's substantial completion, while only a few WW project owners have the requirement of the project completion date.
- The site visit before proposal submission is much more frequently required or encouraged in WW than transportation projects.
- More WW project RFPs contain the circumstances under which proposals may be rejected.
- More transportation project RFPs contain the payment procedure and the requirements of design-builders' warranty.
- More than half of transportation project RFPs contain clauses of the proposers' right to protest regarding the procurement, while only a few WW project owners have the similar clauses.

6.5 Content Analysis Results

The content analysis is used to explore the reasons for the differences in the linear relationships between PD and project performance for transportation and WW projects. The hypotheses regarding these relationships within transportation and WW projects are based on the content analysis.

6.5.1 Schedule and Cost Growth in Transportation and WW Projects

Most transportation and WW projects require design-builders to prepare separated technical and cost proposals. Most owners even have two different committees to evaluate the two proposals. The DB teams' schedule and cost performance are not necessarily related. For example, a design-builder who finishes a project before the planned completion date is not necessarily also under budget. It may be due to the employment of more workers or the use of more advanced management techniques that the design-builder manages an earlier completion, but meanwhile, the cost increases.

6.5.2 Procurement Duration and Schedule Growth in Transportation and WW Projects

The duration from RFP issue to due date is the time given for design-builders to prepare proposals upon the RFPs. There is a pre-assumption that the design-builder is the main party that can influence and control the project timeline. Provided that the design-builder has good previous performance and an excellent schedule control team, the dominating factor is the time provided for the design-builders to prepare proposals. Chen (2009)'s study in transportation projects has supported the hypothesis. However, this conclusion could not be made in WW projects. The reason may be that there are other influencing factors that impact the project schedule, which could not be controlled by design-builders' time and effort spent during the proposal preparation. These factors can be found from the content analysis:

- More transportation project proposals have a subcontractor management plan (SMP). Since subcontractors are the direct executors of construction, the design-builder's management and communication with subcontractors are important to control the project timeline. The requirement of SMP in transportation projects helps design-builders control the project schedule.

- More transportation project proposals have a schedule plan, and geotechnical and earthwork plans. The preparation of these plans at earlier stages like the RFP phase may be beneficial for the design-builder to control the schedule.
- Owner's relative weighted evaluation criteria of design-builders may also impact design-builders' schedule performance. Figures 6.1 and 6.2 indicate that transportation project owners weighs more on cost criteria and WW owners weigh more on proposers' qualifications.
- Owners' procurement process may impact the performance of the design-builder. Most owners in transportation projects use a two-step selection process, while most WW project owners use one-step. The two-step may enable the owner to have a better qualified design-builder, as there is a pre-qualification process and a further evaluation of proposers.
- The stipend paid for unsuccessful proposers may motivate potential design-builders to participate in the project contract competition.
- Owner's requirements on project completion date, liquidated damages for late completion as well as an incentive policy for early completion probably impact the schedule control.

Besides the above factors of project schedule growth, there might be other factors not contained in the procurement documents of transportation and WW projects:

- One factor might be the whole procurement duration (from owners' pre-planning to contract award). The duration used in this study is a part of the whole procurement duration. It is the time for design-builders to prepare DB proposals.

The owners' effort during the procurement may also influence the project schedule growth.

- The design-builder's team effort and experience in scheduling.
- Owner and design-builder organization: the procurement duration is more a function of the organization and/or the scope of the project and would not be an indicator of project duration change (Lundt, 2009).

6.5.3 Procurement Duration and Cost Growth in Transportation and WW Projects

There are weak linear relationships between procurement duration and cost growth in both transportation and WW projects. It may also be explained by the fact that there are a series of other factors that influence cost change. Only after excluding these factors can the cost growth be controlled basically by the design-builders' efforts and time to prepare proposals. These factors might include:

- Percentage of design completion in the proposal: the more design completed in the proposal and before the construction starts, the more reliable cost estimates can be.
- Owner's budget for the project: owners' maximum amount for the project can influence the design-builders' preparation of cost proposals, as the design-builder will have to pay more attention on controlling the estimated cost.
- Life cycle cost or value engineering: the cost proposal can vary if design-builders are required to prepare price proposals in consideration of the life cycle costs.
- Maintenance, operation and warranty: the cost proposal may also vary if design-builders are responsible for the maintenance and operation, and required to provide a warranty.

- Design-builders' cost estimate and control team may have a large impact on the cost performance. The team's effort, experience, and capacity can impact both schedule and cost.
- Other factors may account for DB project cost growth, such as the whole PD, and owner's sophistication.

CHAPTER SEVEN

CONCLUSIONS

The summary, limitations and recommendations are provided in this Chapter.

7.1 Summary of the Research

This study explored the relationship of PD and project performance in the DB WW industry. The relationships in DB WW projects are compared with Chen's study (2009) in DB transportation projects. Forty-seven WW projects' data were collected from two separate studies. The initial hypotheses were provided that:

- Longer PD improves the DB project performance, as design-builders have more time to prepare proposals.
- WW and transportation projects have similar linear relationships between PD and project performance in terms of schedule and cost growth.
- Project complexity has a similar impact on the final performance of WW and transportation projects.

The mean and median test showed that the overall samples of WW and transportation project have similar mean values of PD, PAC, CG, and DBSG, as well as similar median values of PD and CG. But the median value of PAC is higher in WW projects, and the DBSG median value is higher in transportation projects.

It was found that WW and transportation projects have the same cost range for projects in the three different complexity levels. The differences between DB WW and transportation projects were:

- In WW projects, PD increases for projects at a higher complexity level. In transportation projects, PD does not change significantly for projects in different complexity levels.
- In WW projects, the schedule growth and cost growth are largest in high-complexity projects. However, the schedule and cost performance seem improved for transportation projects in higher complexity levels.

These differences showed that the complexity level had different impacts on project performances between WW and transportation projects.

In this study, PDF was defined and its relationships with project performance were also studied. PDF does not vary significantly for projects in different complexity levels. The PDF was about 13%, which means 13% of total project duration was spent for design-builders to prepare proposals. The further conclusion after the data description was that a higher complexity increases the project cost growth, while not necessarily impacting schedule growth.

The correlation analysis shows that there is no linear relationship between PD and project performance for WW projects. PDF has a similar data distribution as PD in terms of its relation to schedule growth and cost growth. A longer PD (more than 100 days) is shown to decrease the project schedule growth. Similar to transportation projects, the schedule and cost growth has no relationship in DB WW projects. Table 7.1 is a summary of relationships between project performance and its influencing factors.

Table 7.1. Relationships between Project Performance and Its Influencing Factors.

	Schedule Growth	Cost Growth
PD	Weak and negative linear relationship. A longer PD (more than 100 days) tends to minimize schedule growth	Weak and positive linear relationship
PDF	Similar to PD. A higher PDF (higher than 10%) tends to minimize schedule growth	Similar to PD
Project Actual Cost (PAC)	No linear relationship	No linear relationship
Project Actual Total Duration (ATD)	No linear relationship	No linear relationship

Although no strong linear relationships between project procurement duration and project performance in terms of schedule and cost growth have been discovered, some suggestions are provided for owners in the DB WW industry. PD longer than 100 days or the percentage of PD in the total duration (PDF) higher than 10% is recommended to reduce the projects' schedule growth.

CA is the other method adopted in this study to explore the differences of linear relationships between PD and final performance in WW and transportation projects. GAO (1996)'s CA steps were applied in this study. Through review of RFP and other procurement documents in DB WW and transportation projects, variables of procurement in terms of proposal content, procurement approach, selection criteria, and other variables were defined. Each variable's frequency rate was counted for comparison between WW and transportation projects. Based on the frequency rates of these variables, the similarities and differences of DB WW and transportation projects' procurement were analyzed. It was found that although both WW and transportation projects require design-builders to submit separate technical and cost proposals, and detailed proposal evaluation plans are provided, more DB transportation projects require design-builders' cost and schedule control plans, subcontractor management plans, quality assurance and control plans. More transportation projects use an adjusted bid procurement approach, and more WW projects use a qualification-based method. More DB transportation projects use the two-step procurement process, while more WW projects use a one-step process. There are other factors that may impact the project cost and schedule growth, such as the owner's effort in procurement, design-builder's capability and experience, and the design completion at the time of proposal submittal.

Suggestions from the data analysis and CA are provided for owners in the DB WW industry.

- A PD longer than 100 days and a PDF higher than 10% is suggested in the procurement. Some items such as the stipend are also suggested to be included in design-builder's proposal.

Based on the CA results, several suggestions for owners during the DB WW projects' procurement phase are provided as below:

- For the benefits of cost and schedule predictability, design-builders should be required to submit their cost and schedule plan, QA/QC plan, and subcontractor management plan, and earthwork and geotechnical plan.
- The stipend or honorarium should be provided for unsuccessful but responsive design-builders, even it is not required by the municipal or state law.
- Early completion incentive and liquidated damages should be included in DB contracts if the completion date is critical.

- The evaluation criteria and procurement steps may depend on owners' emphasize of the project. For example, if the project budget is the main issue, the cost-criteria should account for much in the design-builder selection, otherwise, non-cost criteria such as design-build team experience should be weighted more in the proposal evaluation. The procurement steps (one step, two-step, e.g.) may also depend on the design-builders' number. If there are more than 5 competitors involved in the procurement, a two-step may be recommended to short-list 3-5 design-builders to join the second step. A three-step may be necessary especially when there are sufficient time for procurement and when there are needs for change of proposals upon the owner's requirement.
- The time given for design-builders' to prepare proposals might impact the projects' final cost and schedule performance. Owner's effort in the project procurement phase is another influencing factor of project performance. Owners are suggested to include necessary proposal requirements in the RFP, such as the evaluation plan, stipend or honorarium policy, etc.

7.2 Limitations

There are several limitations in this study:

- When comparing the mean values of PD, project actual cost, design-build schedule growth and cost growth, it was assumed that all of these values in WW and transportation projects meet normal distribution, but actually, they are not strictly normally distributed. The skew values in WW project are positive, so the normal distributions are right-tailed for these terms in WW projects.

- Only linear regression analysis was used for data analysis. Some other statistics method such as non-linear analysis might be used for further data analysis.
- There was an insufficient number of sample projects at the high complexity level. There were moderate linear relationships between PD and schedule as well as cost growth in high complexity WW projects. However, due to the project sample (N=5), the conclusion cannot be drawn that the linear relationship in high complexity is different than the overall sample.
- The overall WW project sample consists of data from two separate surveys. These two groups of data are not completely consistent, but they are combined to study the linear relationships in the overall sample.
- The comparison of variables' frequency rates can be more accurately performed if there are more RFPs and other procurement documents of DB WW and transportation projects available.

7.3 Recommendations

Recommendations for future studies are listed:

- The project performance for WW projects using different procurement approaches (low bid, adjusted bid, best value, and qualification-based) can be studied. The study results of project performance among different procurement methods can be compared with Chen (2009) and Wardani (2004)'s studies. Related recommendations can be developed for owners to select the appropriate procurement method in the DB WW industry.
- Since PD is not the sole factor influencing project performance, various other influencing factors can be studied in their linear relation to project performance.

These factors may include but are not limited to: the whole procurement duration (from pre-planning to contract award), design-builders' experience and organization, and the RFP content. The most critical factors can be identified for DB WW owners to control the project's final performance.

- CA can cover comparisons of RFP among WW, transportation and other industries (e.g., building, industrial). The RFP content can be suggested for DB WW project owners to select the most appropriate design-builders. For example, an early completion incentive plan may be suggested for time-oriented projects. Depending on the owner's requirements of the project (timeline, budget or quality), related RFP contents will be suggested.

Appendix A. On-Line Survey Questionnaire Survey of Procurement and Performance in Design-Build Water/Wastewater Projects

Introduction: This research is to study the procurement duration and performance of Design-Build water/wastewater projects.

Survey Time: Please take 10 minutes to help us by completing this survey for at least one project you have completed in the last 5 years.

Confidentiality Note: Upon receipt of your data, the researchers will number each copy, remove company identification, and remove project identification. The information you provide will be kept in strict confidentiality.

I. Respondent Information

The information in this section will not be reported with the results. It is only for internal use.

Respondent Name

Company or Utility Name

Phone Number

Email

Check box corresponding to your relationship to the project

- Owner
- Owner's Representative
- Design (engineer. architect, etc.)
- Contractor
- Design-Builder
- Other ( )

II. Project Characteristics

Have you completed a Design-Build water/wastewater project within the last 5 years? If so, please fill out a questionnaire for the most recent completed design-build projects.

- Yes
- No

Project Name

Project Location (city/state)

Owner/Agency Name

III. Schedule Performance

Please indicate when the following activities occurred.
Note: RFP = Request for Proposals.

	As Planned (mm/dd/yyyy)	**As Built** (mm/dd/yyyy)
RFP Issued		
Proposal Due		
Design Start		
Construction Start		
Substantial Completion		

VI. Cost Performance

Please indicate the costs.

	Total Design-Build Costs (excluding RFQ and RFP)
Contract Award	
Final Cost	

Thank you for participating in the on-line survey. Please check here, if you would like a copy of the survey emailed to you (you must also provide an email address in Section I):

Appendix B. Data Spreadsheet

The Spreadsheet below contains all 47 WW projects' data used in this study. Due to the confidentiality need, respondents' name, contact information, agency name and project name are not released in the spreadsheet.

Table B-1 Raw Data Spreadsheet

No.	RFP Issue-d As Plann-ed (mm/dd/yyyy)	RFP Issue-d As Built (mm/dd/yyyy)	RFP Due Date as Planned (mm/dd/yyyy)	RFP Due Date as built (mm/dd/yyyy)	Design-Build Start Date As Planned (mm/dd/yyyy)	Desig-n Build Start Date As Built (mm/dd/yyyy)	Subst-antial Com-pletio-n Date As Planned (mm/dd/yyyy)	Subst-antial Com-pletio-n Date As Built (mm/dd/yyyy)	Project Contra-cted Cost ($)	Project Actual Cost ($)
1	8/1/1998	3/1/1999	5/25/1999	7/21/1999	2/1/ 1999	11/1/1999	10/1/2004	10/1/2005	89,400,000	96,179,125
2	08/01/04	08/01/04	12/15/04	12/15/04	01/01/05	01/01/05	04/01/06	06/01/06	14,000,000	14,000,000
3	10/01/04	10/04/04		02/07/05	10/01/05	12/07/05	10/01/06	11/01/06	16,758,900	17,365,000
4	03/01/06	03/01/06	04/05/06	04/05/06	04/01/06	04/01/06	04/01/07	05/01/07	9,525,000	9,521,053
5	07/01/01	05/24/01		08/09/01	01/01/02	01/01/02	04/01/04	04/01/04	26,900,000	27,900,000
6	01/01/04	01/01/04	8/30/2004	10/14/2004	05/01/04	05/01/04	10/01/06	10/01/06	16,660,000	18,860,000
7	01/01/00	01/01/00	07/19/00	07/19/00	01/01/01	01/01/01	12/01/04	12/01/04	71,226,566	74,143,602
8	03/01/00	03/01/00	Oct.2000	Oct.2000	02/01/01	02/01/01	12/01/03	10/01/05	11,000,000	12,850,911
9	04/18/02	04/18/02	06/18/02	06/18/02	08/06/02	09/16/02	07/01/05	03/11/05	16,800,000	16,800,000
10	10/01/06	10/01/06	10/03/06	10/03/06	10/26/06	10/26/06	07/01/07	10/01/07	6,296,075	5,967,278
11	11/01/03	11/01/03	12/23/2003	12/23/2003	01/01/04	01/01/04	10/01/04	12/01/04	2,245,000	2,445,000
12	02/01/04	02/01/04	03/30/04	03/30/04	06/07/04	06/07/04	04/14/05	02/01/06	8,972,000	8,000,000
13	01/01/04	10/20/03		11/17/03	03/01/04	03/01/04	07/01/04	08/01/04	8,885,505	8,885,505
14	07/01/06	07/03/06		07/31/06	08/01/06	08/01/06	06/01/08	08/01/08	9,445,837	9,583,553

Table B-1 Cont.

No.	RFP Issued As Planned (mm/dd/yyyy)	RFP Issued As Built (mm/dd/yyyy)	RFP Due Date as Planned (mm/dd/yyyy)	RFP Due Date as built (mm/dd/yyyy)	Design-Build Start Date As Planned (mm/dd/yyyy)	Design Build Start Date As Built (mm/dd/yyyy)	Substantial Completion Date As Planned (mm/dd/yyyy)	Substantial Completion Date As Built (mm/dd/yyyy)	Project Contracted Cost ($)	Project Actual Cost ($)
15	08/01/04	08/01/04		10/5/2004	09/01/04	09/01/04	06/01/05	06/01/05	3,300,000	3,386,000
16	07/01/04	07/01/04		9/10/2004	10/01/05	10/01/05	09/01/06	09/01/06	12,939,000	14,398,000
17	07/01/04	07/01/04		10/9/2004	08/01/04	08/01/04	08/01/05	08/01/05	5,864,000	5,950,000
18	08/01/02	08/01/02		10/16/2002	10/01/02	10/01/02	08/01/03	07/01/03	7,483,000	8,020,000
19	02/01/06	02/01/06	9/11/2006	9/11/2006	02/01/06	02/01/06	10/01/07	12/01/07	36,561,224	37,142,694
20	1/1/04	1/1/04		3/1/04	5/1/04	5/1/04	3/1/06	9/1/06	44,000,000	50,000,000
21	09/21/2008	9/21/2008	10/24/2008	10/24/2008	01/13/2009	1/13/2009	12/29/2009	12/29/2009	844158	844,158
22	12/10/2008	12/10/2008	1/14/2009	1/14/2009	03/04/2009	3/4/2009	02/12/2011		12,904,376	
23	7/1/05	7/1/2005	8/1/05	8/1/2005	10/1/05	10/1/2005	10/1/07	10/1/2007	41,000,000	42,000,000
24	05/30/2002	05/30/2002	10/01/2002	10/1/2002	01/30/2003	1/10/2003	12/31/2005	09/30/2	41,866,000	39,839,147
25	July 1, 2001	1-Jul-01	07/01/2002	10/01/2002	8/1/2004	6/1/2004	02/01/2007	03/03/2007	228,846,090	231,755,191
26	1/1/2004	1/1/2004	2/1/04	2/1/2004	4/1/2004	4/1/2004	12/1/2006	12/1/2006	7321234	6758438
27	3/01/2007	3/01/2007	11/1/2007	6/01/2007	3/1/2009	11/01/2007	3/1/2011	12/1/2010	181,000,000	183,000,000
28	1/15/2005	12/5/2008	n/a	n/a	n/a	n/a	7/31/2008	12/05/2005		
29	01/04	01/04	04/04	04/04	06/04	08/04	06/06	12/05	3,600,000	3,300,000
30	03/10/2009		05/10/2009		12/15/2009				4,890,000	5,300,000
31	12/13/2007	12/13/2007	01/17/2008	01/31/2008	06/23/2008	06/23/2008	08/26/2010	06/30/09	6968846	6968846
32	02/2009	5/28/2009	06/2009	7/22/2009	08/2009	09//2009	10/2009	10/19/2009	352,000	352,000

Table B-1 Cont.										
No.	**RFP Issue-d As Plann-ed (mm/dd/yyyy)**	**RFP Issue-d As Built (mm/dd/yyyy)**	**RFP Due Date as Planned (mm/dd/yyyy)**	**RFP Due Date as built (mm/dd/yyyy)**	**Design-Build Start Date As Planned (mm/dd/yyyy)**	**Desig-n Build Start Date As Built (mm/dd/yyyy)**	**Subst-antial Com-pletio-n Date As Planned (mm/dd/yyyy)**	**Subst-antial Com-pletio-n Date As Built (mm/dd/yyyy)**	**Project Contra-cted Cost ($)**	**Project Actual Cost ($)**
33	6/1/2002	6/1/2002	7/1/2002	7/1/2002	9/1/2002	9/1/2002	12/3/2003	10/1/2003	1746474	1625095
34	08/01/06	10/1/06	01/5/07	02/3/07	02/15/08	03/1/08	10/1/09	12/1/09	30,200,000	31,000,000
35	04/08/2008	04/08/2008	08/18/2008	08/18/2008	11/10/2008	11/10/2008	06/29/2011		81420562	
36					11/23/1998	11/23/1998	11/23/2002	11/23/2002	275000000	300,000,000
37	07/20/2007	07/23/2007	11/09/2007	11/09/2007	01/29/2008	1/29/2008	11/03/2009	11/02/2009	28,756,391	25,050,965
38	2/8/2008	2/8/2008	04/15/2008	04/15/2008	7/8/2008	09/08/2008	10/01/2010		20,000,000	21,000,000
39	10/18/2002	10/18/2002	11/27/2002	12/12/2002	04/21/2003	04/21/2003	07/02/2004	09/06/2004	4,360,000	4,360,000
40	6/30/2005	6/30/2005	11/3/2005	11/3/2005	10/19/2006	10/19/2006	12/4/2008	5/19/2009	36,000,000	37,800,000
41					01/03/2009	03/30/2011			250,000,000	
42	11/2/2006	11/2/2006	4/5/2007	8/5/2007	6/29/2007	10/17/2007	10/15/2009	12/23/2008	27599800	29793693
43	05/28/2009	05/28/2009	06/17/2009	06/26/2009	09/01/2009	10/08/2009	05/24/2011		5,196,000	5,196,000
44	03/17/2000	3/17/2000	7/12/2000	7/12/2000	8/15/2000	7/15/2000	8/1/2001	7/1/2001	9869000.00	9,869,000
45	11/15/2007	11/15/2007	12/21/2007	12/21/2007	1/21/2008	1/21/2008	2/28/2009	3/31/2009	5,715,063	5,715,063
46	06/26/09	06/26/09	7/31/09	7/31/09	12/14/09	12/14/09	12/20/13		25,000,000	
47	NA	Sep-04	12/15/2004	12/15/2004	1/25/2005	1/20/2005	5/29/2006	6/26/2006	13,991,610	13,957,104

Appendix C. Normal Distribution Analysis of Water/Wastewater Data Set

Figure C-1 to C-5 plot the ordered observations of procurement duration (PD), project total duration (PTD), project actual costs (PAC), design-build schedule growth (DBSG), and cost growth (CG) against the normal scores obtained from the standard normal distribution form. According to Johnson (2005), if the data follow a normal distribution, the pattern should be close to a straight line. Among the figures, DBSG and CG are closer to a straight line, with high R^2 values. Thus, the data for DBSG and CG in the sample projects are more normally distributed.

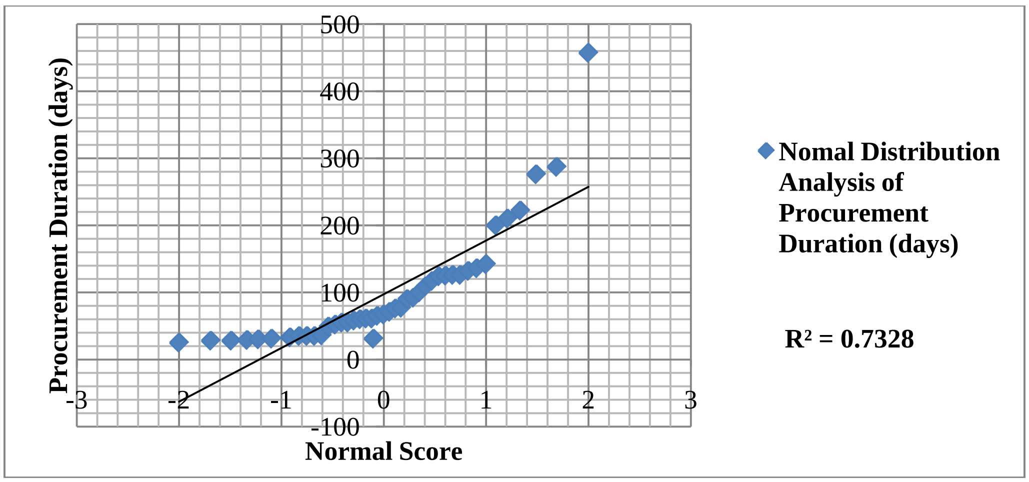


Figure C-1. Normal Scores Plot of Procurement Duration (days)

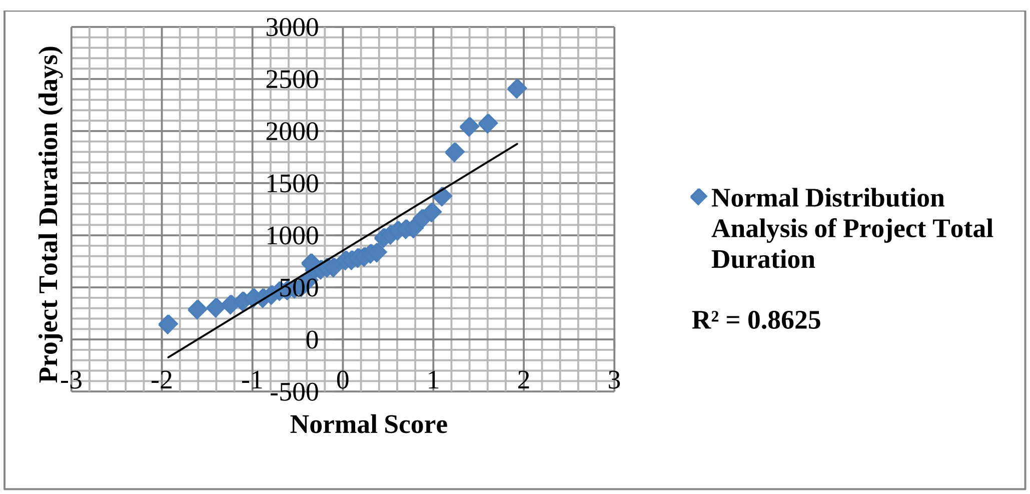


Figure C-2. Normal Scores Plot of Project Total Duration (days)

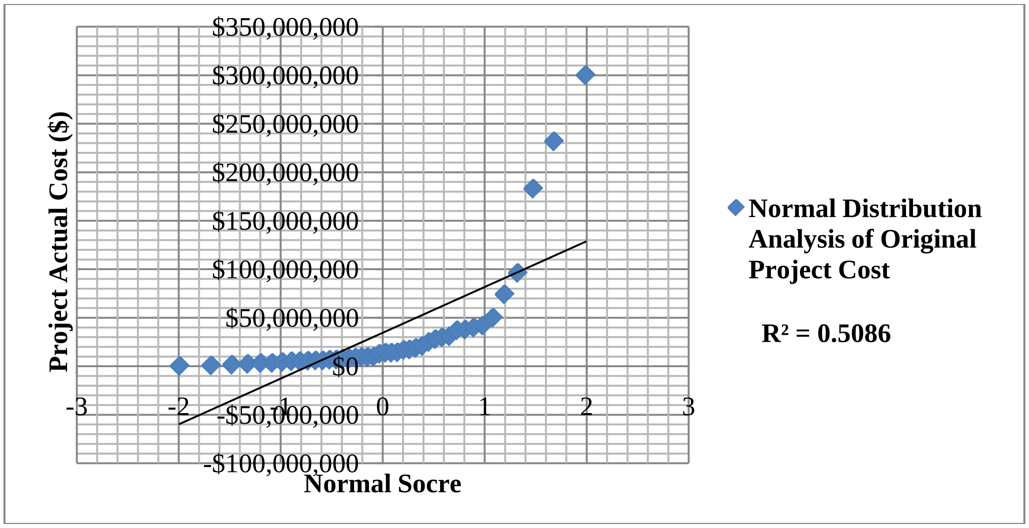


Figure C-3. Normal Scores Plot of Project Actual Cost ($)

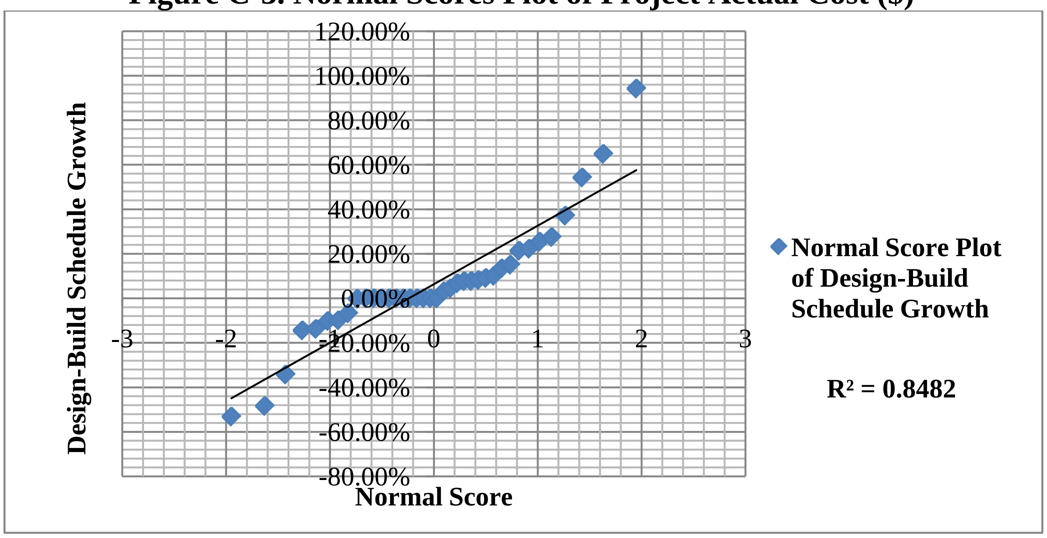


Figure C-4. The Normal Score Plot of DBSG

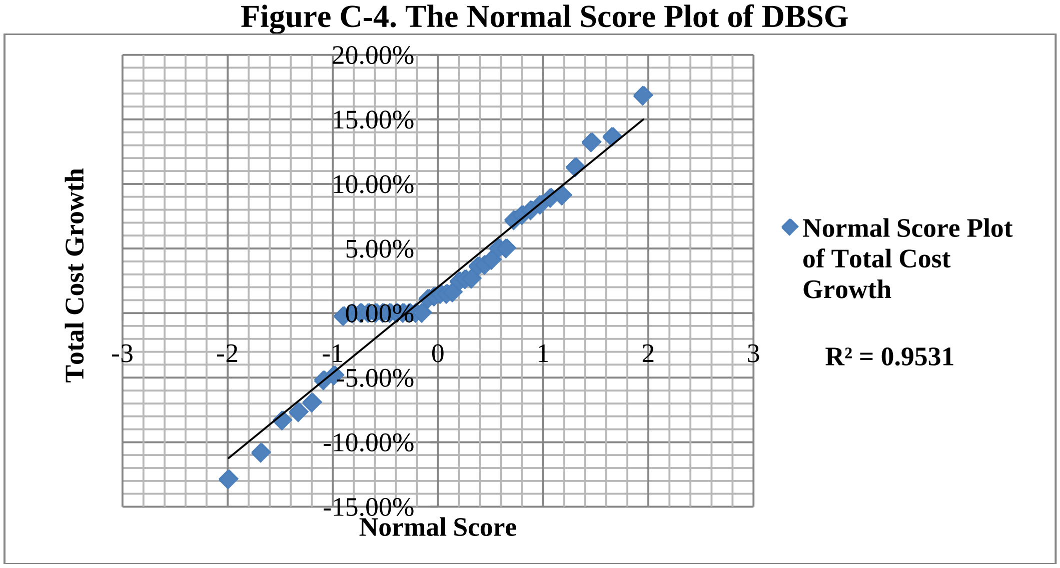


Figure C-5. Normal Socre Plot of Project Cost Growth

Table C-1 shows the skew and kurtosis of PD, PTD, PAC, DBSG, and CG.

Table C-1. Standard Normality Analysis of Project Key Terms

	Procurement Duration	Project Total Duration	Project Actual Cost	Design-Build Schedule Growth	Cost Growth
Skew	2.28	1.30	2.75	0.87	-0.02
Kurtosis	6.56	1.43	7.28	3.32	0.40

The skew values of PD, PTD, PAC, and DBSG are positive, only CG has a low negative value. That means the most key terms in Table C-1 are skewed right, with a longer right tail than the left tail in their normal distributions. Actually among all of the normal distribution analysis figures, the highest values of PD, PTD, PAC, DBSG, and CG are larger than what it would be based on the straight trendline. This is an indication that these 5 normal distributions are not strictly symmetric, and probably have large values in the right tail. The positive skews indicate that in DB water/wastewater (WW) projects, there tends to be a minimum value of PD, PTD, PAC and DBSG, but the maximum values of them could be hardly defined, as these values could be extremely large. This is especially true regarding the values of PD and PAC, which can be really large.

The standard normal distribution has a kurtosis of 0. All of the terms in Table C-1 have positive kurtosis value, which means all of them have a "peaked" distribution, with a distinct peak near the mean, declining rather rapidly, and with heavy tails. PD and PAC have higher peaks than PTD, DBSG, and CG.

Appendix D. Statistical Comparison of Water/Wastewater and Transportation Data Sets

The data in Table D-1 was compared to see if the two data sets were similar. A 5% level of significance was used to test the null hypothesis that DB water/wastewater and transportation projects have the same averages in procurement duration, project total cost, cost growth and design-build schedule growth.

Table D-1. The Mean Value of DB Water/Wastewater and Transportation Project Data

	Null Hypothesis	Alternative Hypothesis	t Value	P Value	Level of Significance	Results of Null Hypothesis
Procurement Duration (days)	$\mu_{ww} = \mu_t$	$\mu_{ww} > \mu_t$	0.818	0.207	0.05	Accepted
Project Actual Cost ($ Million)	$\mu_{ww} = \mu_t$	$\mu_{ww} < \mu_t$	-1.037	0.150	0.05	Accepted
Cost Growth	$\mu_{ww} = \mu_t$	$\mu_{ww} > \mu_t$	0.952	0.171	0.05	Accepted
DB Schedule Growth	$\mu_{ww} = \mu_t$	$\mu_{ww} < \mu_t$	-1.341	0.09	0.05	Accepted

μ_{ww}: The mean in water/wastewater projects

μ_t: The mean in transportation projects

The comparison of these mean values between DB WW and transportation projects is based on the hypothesis that all of these duration and cost factors are normally distributed. Under the assumption of normal distribution, it is found that all of these four null hypothesizes are accepted. The conclusions were reached that DB WW and transportation projects have the same mean value in terms of procurement duration, project total cost, cost growth, and schedule growth. However, Figures C-1 to C-5 show that the duration and cost data are not strictly prone to normal distribution.

Table D-2 tests the mean value of four terms. However, sometimes the mean value may not reliably reflect the average value due to some extremely large or small value in a sample with a high standard deviation, while the median can exclude the impact of unusual values in the sample. Thus the median is another measurement of the sample value. The Mood's median test is used to check if the transportation and WW projects have the similar median values in the four terms. Table D-2 summarizes the Mood's median test results.

Table D-2. The Median Value of DB Water/Wastewater and Transportation Project Data

	Null Hypothesis	Alternative Hypothesis	Chi-Square Value	P Value	Level of Significance	Results
Procurement Duration (days)	$m_{ww} = m_t$	$m_{ww} \neq m_t$	0.391	0.532	0.05	Accepted
Project Actual Cost ($ Million)	$m_{ww} = m_t$	$m_{ww} \neq m_t$	4.117	0.042	0.05	Rejected
Cost Growth	$m_{ww} = m_t$	$m_{ww} \neq m_t$	0.491	0.484	0.05	Accepted
DB Schedule Growth	$m_{ww} = m_t$	$m_{ww} \neq m_t$	4.333	0.037	0.05	Rejected

m_{ww}: The median in water/wastewater projects

m_t: The median in transportation projects

Table D-2 indicates that transportation and WW projects have similar PD and CG median values, while the values of PAC and DBSG are different. Table D-2 shows that the median value of PAC is higher in WW projects, while the DBSG value is higher in transportation projects. The median test is expected to be more reliable to reflect the sample value, because:

(1) The mean value is impacted by outliers that have extremely small or large values. The high standard deviation will make the mean less representative of the sample value.

(2) The test of mean value in Table D-1 requires the transportation and WW project sample meet normal distribution. However, Figure C-1 to C-5 and Table C-1 indicate that these samples are not strictly normally distributed. In contrast, the Mood's median test does not require the sample meet normal distribution.

Based on the tests in mean and median values, the conclusion is reached that transportation and WW projects have similar procurement duration and cost growth, but WW projects tend to have higher costs, while transportation projects have higher schedule growth.

Appendix E. Regression Analysis of TSG and PD

Table E-1. Regression Analysis of TSG and PD

Regression Statistics						
Correlation Coefficient	-0.075					
R Square	0.0056					
Adjusted R Square	-0.0228					
Standard Error of Estimates	0.222					
Sample Number	37					
ANOVA for ŷ and y						
Variation	Sum of Sq	DF	MS	F	$F_{0.05}$	p-value
Regression	0.000369	1	0.000369	0.0074	4.12	0.932
Error	1.7556	35	0.05016			
Total	1.756	36				
Inference concerning variances between ŷ and y						
Null Hypothesis	Alternative Hypothesis	F Value	P Value	$F_{0.05}$	Level of Significance	Results
$\sigma_{\hat{y}}^2 = \sigma_y^2$	$\sigma_{\hat{y}}^2 < \sigma_y^2$	82.27	1.01E-25	1.76	0.05	Rejected

The data analysis in Table 5.1 illustrates that the predicted TSG value ŷ and actual TSG value y have consistent mean values, but a large variation in standard deviation.

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