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IDENTIFYING THE IMPACT OF PRECONSTRUCTION ELEMENTS ON PROJECT BUDGET AND TIME USING BIM-GENERATED DATA: DEVELOPING A DECISION-MAKING GUIDELINE FOR PROJECT OWNERS

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IDENTIFYING THE IMPACT OF PRECONSTRUCTION ELEMENTS ON PROJECT BUDGET AND TIME USING BIM-GENERATED DATA: DEVELOPING A DECISION-MAKING GUIDELINE FOR PROJECT OWNERS

A DISSERTATION APPROVED FOR THE

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Dedication

To my supportive father and loving mother who have always stood next to me in each chapter of my life.

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Abstract

Preconstruction is the preliminary part of a project's lifecycle during which the plan for construction is established. There are many critical decisions made during this phase that may lead to variances in preconstruction budget and time. Controlling budget variances is a key objective during the preconstruction phase. Projects with low budget stability may have poor outcomes such as low project quality, inaccurate information for financial planning by owners, instabilities in project timeline, and other challenges to project success. To control for this, project owners should be familiar with critical decisions related to variances in their project budget and time during the preconstruction phase. Project owners should prioritize these decisions while holding off on decisions that are not likely to impact their budget significantly. The aim of this study was to aid project owners with identifying critical preconstruction decisions that may cause major variances in a project budget during the preconstruction phase. To develop a decision-making guideline rooted in objective data rather than subjective information, advanced preconstruction platforms (such as BIM) and other technologies were employed to measure objective data on preconstruction elements. Data were collected from 61 projects nationwide. Three statistical methods (ANOVA, T-test, and correlation) were used to identify critical preconstruction elements that impact variances in the preconstruction budget. During the data analysis, additional results related to the impact of preconstruction elements on the time needed to complete preconstruction were also obtained. Therefore, the data obtained using advanced preconstruction platforms were used to deliver information about project budget and time, two key attributes of a successful project, and to empower project owners on having a productive decision-making process during the preconstruction phase. The findings indicate that critical decisions causing significant variances in the preconstruction budget and time are

identifiable and should be prioritized over decisions that are not critical. Additionally, the findings provide the novel opportunity to inform project owners' decisions using a decision-making guideline rooted in objective data as opposed to other existing tools that utilize subjective information. Project owners will be able to use this guideline to prioritize critical decisions and reduce the risk of having budget variances during the preconstruction phase.

Chapter 1: Introduction

Background

My interest in this topic started when I worked in the construction industry as an estimator. I noticed that variations in a project's preconstruction budget, which is the estimated cost of construction, constitute a significant challenge for the owners, designers, and construction managers (CMs) during the preconstruction phase. These variations often lead to questions from project owners, who may not be aware of why the budget may change from initial estimates. The project team, including designers and CMs, typically tracks the causes of budget variations and informs the owner. While budget variations may not be completely preventable, the project team must be cognizant of elements that may significantly impact the budget. To address this need, I began thinking of a solution that would empower project owners to identify important decisions that may significantly impact their project budget.

Problem Statement

The preconstruction phase is an important part of a project's life cycle, during which the plan for construction is established. Preconstruction involves decision-making elements such as planning, programming, design, and management of a project before the buyout is completed. Elements that are included during the preconstruction phase may directly impact the project's budget, time, and quality (Craigie, 2015). These elements are not limited to estimating the budget of a building. Additional elements include evaluating the schedule, developing the scope of work (Anderson et al., 2007), value engineering (VE), requests for information (RFIs), collaborating with the design and operations team, and decision-making exercises to achieve owner expectations of being on time and within budget. The specific decisions that occur during the preconstruction phase are subject to frequent changes. For example, an owner may decide to change the type of structure or the material used for the skin, or façade, of a building. A failure to understand the potential impact of decisions made during preconstruction may lead to a decrease in quality and threaten project success (Del Purito, 2016).

As risks associated with time, quality, and budget exist for every construction project (Zou et al., 2007), the team should understand and implement good standards of practice to lower potential negative outcomes through the management of preconstruction elements. Understanding how to manage preconstruction elements helps project owners provide required personnel and technology resources. Allocating these resources during the preconstruction phase is essential to project quality and allows planners enough time and budget to solve constructability issues during preconstruction and before the project is awarded (Craigie, 2015). Throughout this document, the term "preconstruction elements" refers to variables identified such as project size, time of major changes, number of submitted RFIs, etc. The unifying term "element" will be applied consistently to refer to what has been impacted.

Information is available from previous studies on the causes of variations in budget, time, and project quality during the construction phase. However, data are limited on the causes of similar variations that may occur during the preconstruction phase. Because of this limited information, the decision-making process may be more challenging than it would be in the context of adequate data.

Construction project owners are also limited in the choice of tools that are available to guide construction teams through different phases of a project. The few available tools (reviewed in Table 1) do not rely on objective data. Rather, these tools depend on a variety of qualitative factors such as the level of communication between team members and the provider's design and reliability (Tafazzoli, 2017). In the originating studies for the tools, construction elements were neither measured nor analyzed effectively. To achieve an effective analysis, the evaluations should be rooted in numeric values (Tafazzoli, 2017).

Table1

Preconstruction related decision-making tools

Tools	Description	Data Collection	Reference
Tool #1	A Framework for Estimating Preconstruction Service Costs at the Functional Level for Highway Construction Projects	Survey	Craigie. E.K., 2015
Tool #2	Development of the Construction Environmentally Informed Decision Support System	Survey	Nadkarni, C.P., 2000
Tool #3	A Decision-Support Framework for Design of Non-Residential Net-Zero Energy Building	Interview and Survey	Tiwari, R., 2015
Tool #4	A Guide to Assessing and Managing Project Complexity	Survey	CII, 2018

Research Objectives

The objective of this study is to analyze the magnitude of the impact that preconstruction elements have on project budget variances. The findings will be used to inform project owners on the impacts of critical decisions on budget and may help them improve their decision-making process.

Of the important project attributes - budget, time, quality, and safety - quality is highly subjective and safety, while considered during preconstruction, is more applicable during the construction phase rather than the preconstruction phase. Data on subjective attributes were not collected in this study. The aim of this study is to analyze objective data related to project preconstruction budgets. Additional objective data related to the preconstruction time is also included in the analysis. Therefore, an analysis rooted in numerical data as opposed to self-reported data will be used to evaluate the impact of various elements made during the preconstruction phase.

In order to collect these quantitative data, I used Building Information Modeling (BIM) and its related software to record and analyze data related to preconstruction elements, as recommended by Tafazzoli (2017). The BIM-related software provides more information than a graphical representation of the 3D environment in a project model. Additional information available with BIM-related software includes a cost-estimating platform, material quantity take-off, material classification, system and material details, site conditions and topography, building equipment, and design changes tracking, among other features.

To achieve the goals of this study, the following research questions will be addressed:

1. What are the direct and indirect impact(s) of preconstruction decisions on project budget variances?
2. What are the most critical preconstruction elements impacting project budget variances?
3. Can the results of the data analysis be used to develop a decision-making tool for the project owner?

This study will identify ways of decreasing the risk of significant budget variances by detecting elements that impact the budget of a project. Through the outcome of this research, project owners will be aware of the budget impact of their decisions, and which preconstruction elements to focus on to reduce the risk of experiencing significant budget variances and a possible price overrun. Using the resulting decision-making tool, project owners can assess how well they identified and considered different preconstruction elements in their project and will then be better equipped to prioritize decisions and elements during the preconstruction phase.

Chapter 2: Literature Review

The goal of this chapter is to synthesize the body of knowledge and identify knowledge gaps related to the impact of preconstruction elements on budget variances. Previous studies about preconstruction elements and their impact on budget variances, BIM, and decision-making during the preconstruction phase are reviewed. The introduction is followed by an owner decision layout and the chapter ends with a summary.

Preconstruction

“Preconstruction” refers to the development of a project plan and its construction documents from the early conceptual phase through the contract award (Craige, 2015; Lopez Del Puerto, Costa Agosto, & Gransberg, 2016). For this study, preconstruction refers to the time frame that starts with the onset of the project early planning exercise (conceptual phase) and ends when the buyout is completed (review Figure 1 for information on preconstruction in the context of the project lifecycle). The buyout refers to the transition from preconstruction to construction and represents the point when the majority of contracts for labor, materials, and equipment are awarded to different subcontractor(s).

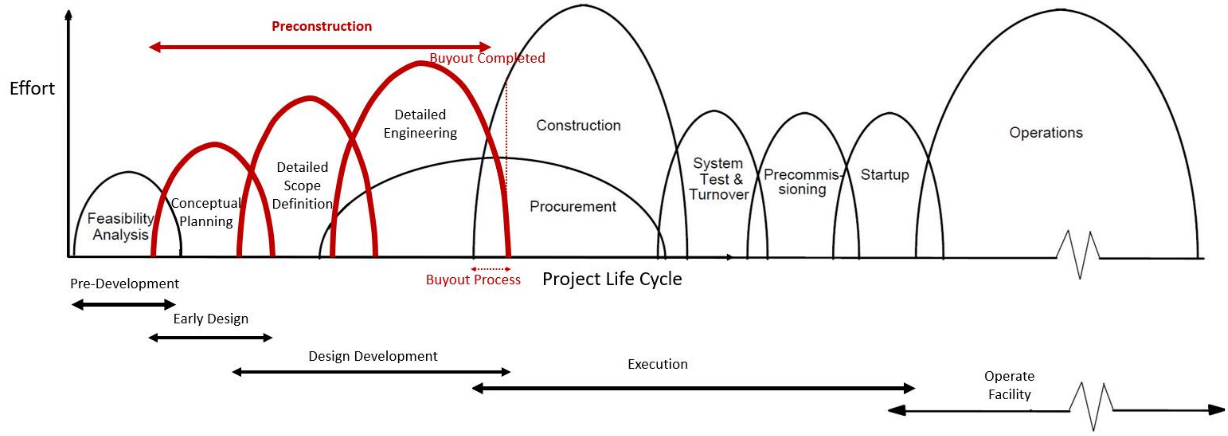

Figure 1. The preconstruction segment based on the project life cycle. The background project life cycle graph is reproduced from "Development of the Project Definition Rating Index (PDRI) for Building Projects" by Construction Industry Institute, 1999. Research Report 155-11. Authored by Chung-Suk Cho, Jeffrey Furman and Edward Gibson, Jr. Reprinted with Permission.

Preconstruction is an integral part of a project's life cycle. The level of effort that a project team puts into the preconstruction phase is a key predictor of that project's success (Construction Industry Institute, 1999) and a thorough preconstruction phase increases the chances of a smooth and successful transition for operations in the construction phase (Al-Reshaid, Kartam, Tewari, & Al-Bader, 2005). Paying attention to important details during the preconstruction phase mitigates potential construction delays and may prevent associated cost overruns that projects typically experience. (Al-Reshaid et al., 2005; Anderson, Molenaar, & Schexnayder, 2007).

Preconstruction Goals

One of the main goals of preconstruction is to develop an accurate budget for construction (Craigie, 2015). Budget development is a technical process and an attempt to predict the actual cost of construction (Carr, 1989) that requires more than a knowledge of the unit prices of labor, materials, and other elements. One of the difficulties of developing a budget is identification of the resources that should be devoted to meet a given project's contractual requirements (Akintoye & Fitzgerald, 2000).

Besides developing an accurate budget, minimizing budget variances is a prime objective during the preconstruction phase. Minimizing these variances can lead to delivering a high-quality budget estimate as well as delivering a project faster during later construction phases. Variances in a project budget are common during the preconstruction phase from when project development starts to when the buyout is completed (Cragie, 2015).

Preconstruction is not limited to just developing a budget and controlling it during this phase. Along with budgeting, avoiding variances in schedule is another primary objective during preconstruction. Developing an accurate construction schedule and proper planning and programming have been identified as important goals of preconstruction (Craigie, 2015). Another goal of preconstruction is to improve the quality of the final design by identifying design errors, omissions, and ambiguities (Craigie, 2015). Since many designers have limited experience with the means and methods of construction, constructability issues arising from design problems are common (Thabet, 2000). Such issues occur when constructability reviews (including reviews of construction knowledge, resources, technology, and experience) are not incorporated into the project planning and design (Anderson, Fisher, & Rahman, 1999). Some solutions for avoiding design deficiencies may be integrating design and construction through early involvement of construction expertise, planning based on the construction schedule requirements, learning from different approaches used in other projects (Glavinich, 1995), and standardizing design (Thabet, 2000). Making early decisions about the project scope and changes in the scope may also mitigate constructability issues (Anderson, Fisher, & Rahman, 1999).

These practices can help avoid design deficiencies indirectly benefits a project by minimizing budget and time variances during the preconstruction phase.

Budget Variances During Preconstruction

Failing to minimize variances in the budget during the preconstruction phase increases the risk of poor project outcomes such as low project quality and inaccurate financing of the project by owners (Craigie 2015, Hunter 2014). As a result, project owners may be required to cover for budget overruns and even to reallocate funds for budget decreases. Variances in a project budget also cause deficiencies in project design and may lead to a longer decision-making process in which the project team is required to fit the project design and scope of work in the available budget. A project team may also encounter modifications in the construction contract due to changes in the design and delivery timelines (Craigie, 2015). This unplanned and longer decision-making process increases the risk of instabilities in the project timeline such as the timing of project buyout and commencement of actual construction.

Minimizing budget variances is a critical goal of preconstruction (Del Puerto, Craigie, & Gransberg, 2016). Avoiding variances in a project's budget and time may facilitate faster project delivery (Del Puerto, Craigie, & Gransberg, 2016) as well as facilitating the delivery of a successful and high-quality budget estimate (Craigie, 2015). For the most part, the main causes of variances in a project budget are design-deficiencies, low quality construction documents, and a project team that is not knowledgeable about the project (Del Puerto, Craigie, & Gransberg 2016; Craigie 2015). Other causes of budget variances include the lack of "project scope definition, estimation assumption accuracy, owner requirements clarity, experience in similar projects, and experiences in similar contracts" (Liu & Zhu, 2007, p. 94). Lack of budget development experience on the part of the agency has also been cited as one of the main causes of having variances in a project budget (Hunter, 2014).

Given the importance of controlling budget variances, some studies proposed solutions to increase project owners' abilities in controlling the budget (Craigie 2015, Del Puerto et al. 2016). Budget variances during later phases may be minimized through the allocation of enough resources to the preliminary design and project site identification during preconstruction. Project owners should note that focusing on saving money during the preconstruction phase will limit the available financial resources and may decrease their chances of having a high-quality design free of deficiencies. Besides allocating sufficient resources for preconstruction, allocating enough manpower during this phase, avoiding gradual and unintentional additions to the scope of work, and a thoughtful selection of the appropriate project delivery method are other solutions that may help to minimize budget variances during later phases of preconstruction and construction. Lastly, investing in design fees is a solution that owners should consider to control for budget variances (Del Puerto, Craigie, & Gransberg, 2016). Designers need to consider the owner's limited resources when developing the project design. Likewise, the preconstruction team must manage the overall process with the same constraints in mind.

Elements Included in Preconstruction

The owner, construction managers (CMs), and designers are the main parties involved during the preconstruction phase. The CMs are mostly involved in coordinating with the owner and design team. Depending on the method adopted for delivering a project, CMs are typically responsible for managing the budget and schedule and assuring the project owner of project quality (Shane & Gransberg, 2010).

To minimize budget variances and ensure a productive decision-making process, project owners should be familiar with critical elements that cause variances in the budget and schedule during the preconstruction phase. In previous sections, a summary discussion of elements that are critical for achieving preconstruction goals was provided. These elements include providing a high-quality design, defining the scope of work, providing an accurate estimation, clarifying owner requirements, having experience in similar projects and similar contracts, and having historical data from similar jobs (Liu & Zhu, 2007, p.94). Other critical elements include practicing value engineering (VE) and communication between estimators and the rest of the project team (Eastman, Eastman, Teicholz, Sacks, & Liston, 2011; Akintoye & Fitzgerald, 2000). Knowledge about the critical elements will enable project owners to better control the budget, time, and quality (Craigie, 2015).

A plethora of research focuses on critical construction elements. These studies cover the impact of changes in construction elements on different aspects of a project, such as the budget and schedule. While many of these studies identified these elements as occurring during the construction phase, decisions related to these elements also happen during preconstruction phase. In Table 2, a summary list of these critical elements is provided. Although these studies identified a variety of elements, only those that were applicable to the preconstruction phase are listed in this table.

Table 2

Existing literature focusing on critical elements and their impact on budget and schedule

Author	Content	Investigated Impact on
Anderson, Molenaar, and Schexnayder (2007)	1. Changes in the scope of work 2. Project complexities 3. Design error 4. Local and government concerns 5. Escalation 6. Contract document conflict 7. Inconsistent application contingency	Budget
Mansfield, Ugwu, and Doran (1994)	1. Design changes 2. Lack of detail on the functional and technical requirements	Budget
Akogbe, Feng, and Zhou (2013)	1. Design changes 2. Inaccuracy of material estimate	Budget
Al-Reshaid et al. (2005)	1. Changing the location of the site	Budget
Rao (1997)	1. Time when changes happened "The sooner a change is made, the lesser will be the magnitude."	Budget
Bingham (2014)	1. Type of project delivery method	Budget
Potts, and Nii Ankrah (2014)	1. Value engineering 2. Function and performance of a project 3. Size of a project 4. Element cost analysis estimating	Budget
Han, Lee, Park, and Ji (2008)	1. Period of the cost estimating and decision-making	Budget
Craigie (2015)	1. Design fee and reimbursements 2. Design deficiencies 3. Scope of work deficiencies	Budget

Table 2 (Continued)

Author	Content	Investigated Impact on
Tafazzoli (2017)	1. Poor communication and coordination with other parties 2. Design changes 3. Design errors 4. Complexities and ambiguities of project design 5. Poor use of advanced engineering design software 6. Inadequate site assessment by the designer during phase 7. Equipment allocation problem 8. Shortage of equipment 9. Changes in government and regulation laws 10. Price fluctuations 11. Changes in material types and specifications 12. Escalation of material prices 13. Slowness in decision-making, time-consuming decision-making process of the owner 14. Inadequate contractor experience 15. Unrealistic schedule 16. Inappropriate construction methods 17. Poor site management and quality control (QC) by the contractor 18. Misunderstanding between owner and designer about the scope of work	Time

Table 2 (Continued)

Author	Content	Investigated Impact on
Hampton, Baldwin, and Holt (2012)	1. Project familiarity 2. Poor coordination 3. Poor communication	Time
Yates, and Eskander (2002)	1. Constant changes in a project requirement 2. Recommendation: making changes as quickly as possible 3. Lack of communication 4. Project funding and financing	Time
Braimah (2013)	1. Contractual related problems	Time
Gebrehiwet, and Luo (2017)	1. Inflation, price increase 2. Unclear and inadequate details and specification of design 3. Lack of quality of material 4. Late design and design documents 5. Design mistakes and errors 6. Misunderstanding of client's requirements 7. Changes in material type and specifications 8. Poor communication and coordination 9. Late in approving and receiving of complete work	Time

In most of the studies listed in Table 2, data was collected by surveying construction professionals. Thus, human judgment and academic terminology were used to develop their results. These studies have not been able to measure and analyze objective elements. Therefore, there is an opportunity to identify the impact of these elements using less-subjective data collection methods. This can be done by using measured data, such as that collected through BIM (Tafazzoli, 2017).

Building Information Modeling (BIM) in Preconstruction

BIM has been around since 1992 and has been used as a practice to model building information to identify “the real impact of approach” (Van Nederveen & Tolman, 1992, p. 223). A misconception exists that BIM is only a computer-generated, 3D model of a construction project (Cannistraro & Palange, 2008). However, BIM can be used during the project life cycle, including the preconstruction phase, for different purposes such as aiding project teams in estimating a project budget and schedule (Azhar, 2011) and allowing project stakeholders to build first (virtually), identify issues and problems, resolve the problems, and then after many virtual reviews – build the project physically (Hannon, 2007).

BIM and Developing a Project Budget

BIM provides a platform for ongoing analysis of a project as the design is developed. Contractors can simulate (or visualize) a project, compare a developing model with the previous version, and identify the appropriate means and methods for accomplishing their project. The benefit of BIM in budget estimating is realized when the preconstruction team can review the value engineering options and analyze associated expenses to provide the best budget scenario. The team can also determine the budget associated with the critical elements of a project. The team must understand the phasing plan and construction sequence, as well as its site layout, to complete an accurate project analysis (McCuen, 2015).

The most valuable benefit provided by BIM in the budget estimating process is the provision of a trustworthy source of information by automating quantity take off (QTO) and creating an exact bill of quantities. Additionally, a fast QTO increases the team’s productivity as they will spend less time and effort on quantifying and applying prices. Hence, the estimating team may utilize the saved time on other important tasks (Wijayakumar & Jayasena, 2013;

McCuen, 2015; García de Soto, Adey, & Fernando, 2017). Using BIM technology, the interconnectedness of data for material selection during the design process is a great tool for establishing the lowest budget for the life cycle of a given building. The engineer can select a material or product, and through BIM, provide a visual for key players to understand and implement those decisions. Contractors can provide value engineering services to cut budgets and generate alternative materials that are sustainable and save budgets over time within the operation phase (Jalaei & Jrade, 2015).

Using BIM for Measuring Preconstruction Elements

Many design firms and contractors have been successful in adopting BIM and been able to develop an advanced BIM related software for the benefit of their firms (Azhar, 2011). Through the advanced use of BIM, historical data based on previously completed projects can be provided to a project team. Additionally, key project information, a depiction of a construction project with its planned materials, systems, and codes, as well as detailed budget estimates can be presented from the early conceptual phase, and changes applied to the budget and model as the design develops can be provided to a project team (Hicham, 2018). With this information, it is possible to measure many of the preconstruction elements related to the design package and scope of work, budget variances, project team members involvements, project site and equipment, etc. A detailed discussion on measuring preconstruction elements through advanced BIM software is provided in Chapter 3.

Preconstruction Decision-Making

In addition to the preconstruction elements mentioned previously (refer to Table 2), the project team is tasked with gathering, reviewing, and synthesizing all available project data to compose a project budget (Phaobunjong, 2002). The project team must bring to the table prior experience that is necessary to develop the final project budget (Phaobunjong, 2002; Bley, 1990). Expertise is built over time through the development of skills, knowledge, and experience. This capability allows the project team to analyze a new project and generate experience-based assumptions when project information is yet to be made available and designs are typically conceptual. In addition to the expertise, using available decision-making guidelines or tools enables the project team to select alternatives and be more productive during the decision-making process.

The term "decision" or "decision-making" is defined as the process of selecting one alternative over other existing alternatives (Senior, 2012). Many decisions are made in the presence of existing unknowns while respecting the available information, the system's behavior, and other factors (Nik Bakht & El-Diraby, 2015). The process of "decision-making" may be different in various scenarios. Yet, its main factors are recognizable among most of the decision-making problems, namely when available knowledge or information is lacking, and when the impact of a decision is unknown (Nik Bakht & El-Diraby, 2015; Tannenbaum, 1964).

Elements of Decision-Making Tool

Some elements considered when making decisions within construction operations, as described by Ayyub and Haldar (1985), are decision elements, alternatives, consequences, risk evaluation, and decision criteria. In addition, Clemen and Reilly (2004) considered four main elements, which are a mix of objectives and values, alternatives, unknown events, and consequences under the decision analysis category. The objective here can refer to direct and indirect goals that a decision-maker attempts to achieve in addition to other beliefs and norms that they have in mind. At this point, decision-makers should use a tool based on existing information to hypothesize potential outcomes for each alternative (Nik Bakht & El-Diraby, 2015).

As mentioned earlier, many decisions are made in the presence of existing unknowns while considering the available information, the system's behavior, and other factors. A common challenge is that a design must be selected from available alternatives (through evaluation of consequences) and a decision must be made regarding which of the alternatives is most capable of solving the problem (Nik Bakht & El-Diraby, 2015). Figure 3 depicts the possible decision-making problems and their relationship with each other.

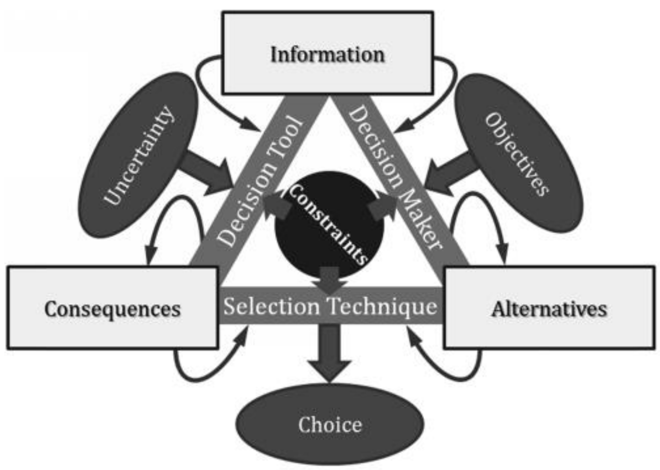

Figure 2. Decision-making problems elements and their relationship. Reproduced from "Synthesis of Decision-Making Research in Construction", by Nik Bakht, M. & El-Diraby, T. E. 2015. Journal of Construction Engineering and Management, 141(9), 04015027. Reproduced with permission.

There are differences between decision-making tools and selection techniques, and decision-makers use both. A decision-making tool refers to any means that can be used to assess the outcome of alternatives. This assumption can be made based on the existing information, some other assumptions, and the model behavior. The method of selecting one alternative and arriving at a conclusion is the selection technique (Nik Bakht & El-Diraby, 2015).

Preconstruction Decision-Making Tools

One purpose of developing a budget is to assist decisions related to funding in a timely manner while a project and its documents (particularly for planning and programming) are developing. There is a relationship between developing a budget estimate and managing it. Managing the budget involves facilitation of the preparation process, as well as making sure a project budget is aligned with the available funding (Anderson et al., 2007).

Unfortunately, decision-making and planning during a project's early phases are not typically valued as distinct phases, when compared to budget estimating, scheduling, and tracking during construction. Therefore, the possibility exists that a project with poor planning and decision-making could face more dilemmas, changes, budget and time overruns, and a lower success rate (Menches, 2006). The preconstruction team is challenged when it experiences changes that can negatively influence project budget, time, and overall quality. These challenges occur when the project team faces alternative elements affecting the budget without having enough time and good quality information about the project (McCuen, 2015). These new challenges necessitate the development of a decision-making tool that assists the team in making the most beneficial decisions for the project.

While some research has been done on decision-making during construction (Nik Bakht & El-Diraby, 2015; Ayyub & Haldar, 1985; Clemen & Reilly, 2004), few sources of information are available when decision-makers need to evaluate preconstruction and its budget- impacting elements (Hunter, 2014). Fortunately, through the aid of technology during the budget estimating and project review phases, access to historical data is efficient. The readily available historical data is critical in developing an accurate budget (Liu & Zhu, 2007) and providing a successful decision-making tool. Using technology, opportunities are available to develop a related decision-making tool based on valid historical data and to assist decision-makers in accomplishing their responsibilities while developing more productive teams and projects.

The Owner's Decisions on Preconstruction Elements

To recap, there are different preconstruction elements that may cause variances in a project budget. Reviewing all the preconstruction elements from Table 2, a list of possible decisions that owners must make during the preconstruction phase is provided in Table 3 below.

Table 3

The Layout of Owners' Decisions on Preconstruction Elements

Element	Decisions
Target budget	Should the project target budget be identified and set up or not?
Major scope & sub-scope changes	Is the project design team capable of managing changes in the project scope and sub-scope of work during the preconstruction phase? How many scopes of work will be changed during this phase?
Time of major changes	When will the majority of changes in the scope and sub-scope of work be made in the project during the preconstruction phase?
Design errors	Is the estimating team capable of identifying and mitigating design errors during the preconstruction phase?
Design changes	Will any changes in the design be made in the project?
Site assessment	Does our design team do a complete site assessment?

Table 3 (Continued)

Element	Decisions
Equipment allocation	Is the design team capable of providing a complete equipment allocation?
Awarding methods	What will be the method of awarding the project?
Function	What are the functionalities that the building is designed for? Does the project include multi-functions?
Location	Is the location of the site finalized?
Project size	Is the size of the project finalized? Will any changes to the building area be made in later phases?
Escalation, fees, and contingencies	Have the costs of escalations, fees, and contingencies been identified by the contractor? Are they considering a fixed rate for these risk-related elements, or will their rates will be changed in later phases?
Element cost analysis	Is the contractor capable of providing the element cost analysis?
Value Engineering (VEs)	Is the contractor capable of practicing VE? Are we going to specify time to review the provided VEs?
Request for Information (RFIs)	Is the contractor capable of identifying project errors and ambiguities and submitting RFIs?

Table 3 (Continued)

Element	Decisions
Contractor experiences	Does the contractor have experience in doing similar projects?
Tracking schedule	Is the contractor planning to track the schedule during the preconstruction phase?
Use of BIM	Should the project team be encouraged to use BIM for cost estimating purposes? Will the project team use BIM for communication and collaboration purposes?
Source of funding	How are we going to allocate funding for this project?
Type of construction	Do we have a new construction? Will we have some level of renovation in our project?

This list of decisions is predominantly based on the elements found from reviewing previous studies. Some additional elements added to the list were collected through reviewing the study sample in later data collection phases. Decisions related to the additional identified elements will be discussed in the discussion chapter.

Summary

Preconstruction is an important and critical part of a project's life cycle. Controlling budget variances is a critical goal that should be closely monitored during the preconstruction phase. There are different preconstruction elements that may contribute to variances in a project budget. To minimize budget variances, teams use a variety of problem-solving and decision-making skills. With the aid of technology and recent developed software (such as BIM), project teams have been able to improve their preconstruction services. These include providing more accurate budget evaluations, coordinating with project stakeholders, and comparing alternatives which improves the decision-making process.

Previous studies provided information on construction elements and their impacts on budget, delays, quality, etc. during construction. However, there is a lack of information on the impact of these elements as they individually have an impact on budget variances during the preconstruction phase. In addition, there is a lack of prior research using an agency's historical data related to the budget impact of preconstruction elements. With limited availability of these sources of information, the project owners may be less effective in minimizing their project budget variances and in making fast and accurate decisions when selecting from existing preconstruction alternatives.

The information that is available in the literature is based on subjective data such as self-reported data from surveys and numeric values were considered when analyzing these elements and their impacts on a project. Therefore, the industry appears to insufficiently address how the accuracy of their decision-making process will improve when changing from subjective to objective information. Providing a decision-making tool, developed for the preconstruction phase, and based on historical numeric values, may mitigate these challenges in the industry.

Chapter 3: Methodology

Project Overview

The goal of this study is to collect and analyze objective data regarding the impact of decisions related to preconstruction elements on budget variances during the preconstruction phase. To conduct the analysis, I used BIM-related software developed by JE Dunn Construction. The BIM-related software was developed to provide collaboration opportunities from the early design phase through completion of preconstruction. The company developed this application to serve as a reference for project teams when developing a budget range for the owner. This software features four platforms with the purpose of presenting: 1. historical data based on previous projects, 2. visual representations of a construction project with its planned materials, systems, and codes, 3. a detailed cost estimate from the early conceptual phase, while providing the opportunity to track changes in the model and project cost, as the design develops, and 4. key project information in a succinct format to stakeholders including the contractors, sub-contractors, owner, and architect (Hickam, 2018).

Using the BIM-related software, measurements of project systems and materials, cost information, and the project team's involvement may be performed. Results of the data analysis were used to develop a decision-making tool as a guide to best practices for project owners. This will be one of the first preconstruction decision-making tools rooted in numeric data rather than human judgment and opinion. Findings from this study will enable project owners to identify how their decisions on project design and scope, budget, fees, risk factors, project function, façade, construction type, and awarding methods, etc. may impact a project's budget variances and timeline during preconstruction. In this study, the following research questions were investigated:

1. What are the direct and indirect impact(s) of preconstruction decisions on project budget variances?
2. What are the most critical preconstruction elements impacting project budget variances?
3. Can the results of the data analysis be used to develop a decision-making tool for the project owners?

Research Design Overview

In contrast to other studies that relied on self-reported data, this study relies on objective data from projects assessed using BIM-related software. Measurements on material changes, their exact quantities, and associated costs were collected. Information on the degree of BIM involvement during the cost estimating process was collected. The estimating team's effort in using the software during preconstruction was also investigated. Using data collected from the BIM-related software, the objective of this study is to provide evidence on how preconstruction elements impact project budget.

Sample Selection

The target population was a group of projects developed in three different regions (South-Central, Mid-West, East) of the United States since 2017. To be included, BIM-related software had to have been used on the projects and the data had to be available through JE Dunn construction company and accessible in the database. The year 2017 was chosen because many earlier projects did not have available data. Therefore, the target population included projects from 2017-2019. This resulted in a total of 1,398 projects that were identified, 165 (approximately 12%) used BIM during the preconstruction phase and were eligible for the study. Of the 165 eligible projects, 104 were excluded due to inaccessible data (even though they were developed after 2017). The 104 non-eligible projects either had damaged or relocated cost estimating platforms, had incomplete data, or were still in the budgeting process and did not represent a complete preconstruction phase. Therefore, 61 projects were included in the final sample.

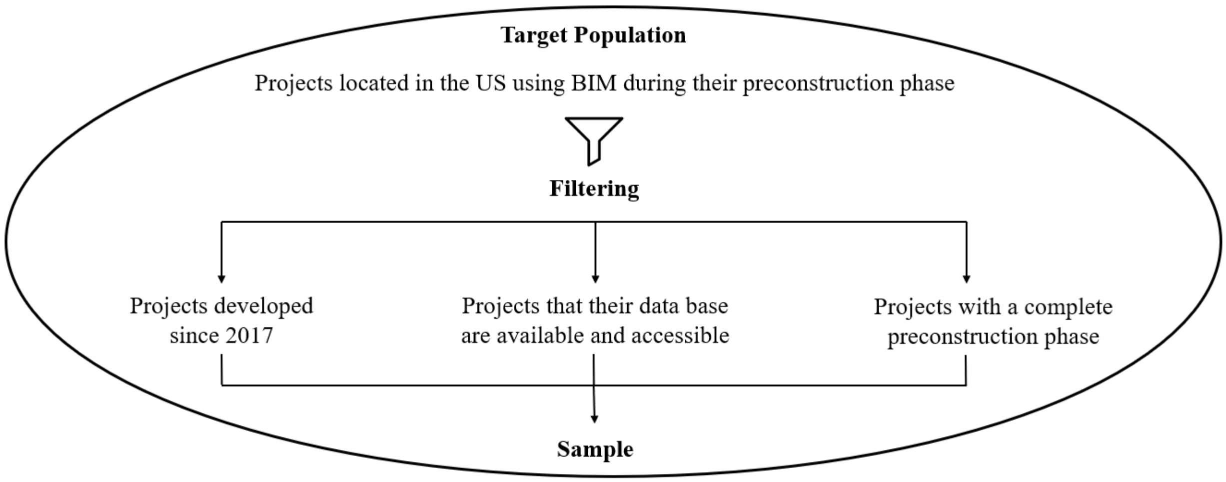

Figure 3. The Study Sampling Strategy

This study's sampling strategy was non-probability convenience sampling to select a portion of the target population that met specific criteria (Etikan, Musa & Alkassim, 2016). Characteristics of projects included in the study are summarized in Table 4.

Table 4

Descriptive categories for projects studied (N = 61)

Categories	Group	Number of Projects
Regions	South Central (SC)	44
	Mid-West	10
	East	7
Year	2017	22
	2018	21
	2019	18
Project Information	Available and Accessible	
Preconstruction Phase	Completed from early phase until buyout completed	
Type of Project	Healthcare	10
	Hotel	7
	Office & Bank	8
	Residential	11
	Higher Education	12
	Government	6
	Amusement	3
	Sport	1
	Data Center	1
	Correctional	1
	Transportation	1

Sample Size

After applying the eligibility criteria and filtering the target population, a final list of 61 projects was developed to be studied. This sample size exceeds the minimum desired sample size to achieve a valid analysis (Olejnik, 1984; Cohen, Manion, & Morrison, 2007; Delice, 2010). Correlational analyses need at least a sample size of 30 observations, while the causal-comparative and experimental methodologies need a minimum of 50 cases (Cohen et al., 2007). Additionally, each of the 61 projects includes 63 measurements, which helped achieve saturation.

Analysis Procedure and Data Selection

Most Critical Preconstruction Elements

Decisions regarding many different elements can lead to budget variances during preconstruction. Investigating all the elements and the corresponding decisions was neither insightful nor practical; therefore, a subset of critical elements was identified for analysis using two methods:

1. A comprehensive study of existing literature to identify related preconstruction elements highlighted by previous research, and
2. A review of the historical data from projects included in the sample to identify additional preconstruction elements that were not listed by previous research.

The available preconstruction elements were then reviewed. There were elements related to the project's contingencies and risk-related decisions. Examples of these elements are the cost of design fees, reimbursements, permits, contingencies, escalation, insurances, sub-default rate, general conditions, and general requirements. These are elements, whose associated cost will be identified by CMs as they set up a project budget. Throughout the preconstruction phase, the percentage cost considered for these elements may change.

There were other elements related to the design aspect of a project. Examples of these elements are design changes, design information provided in the model, and major scope and sub-scope changes applied to a project. The design change relates to changes in the configuration of a building or additions to, and deletions from, the designed building. Major scope and sub-scope are related to that main area or category of work to be performed in a project. An example of a main scope change would be adding or deleting equipment, while an example of a sub-scope change would be adding or deleting an item such as parking equipment. These design and scope changes were collected mostly by reviewing the Revit model and, to a lesser extent, the 2D drawings.

Additional elements related to the estimating team's effort were also identified. Examples of these elements are using BIM for cost estimating and overall time spent during preconstruction. The team's effort in submitting RFIs, developing the project budget, engaging in value engineering (VE) practices, and other related elements were also examined. Data on the VE elements were not collected by the BIM-related software. Therefore, other archived documents, such as a company's VE log, were used to measure these elements.

Lastly, elements related to project's general characteristics that should be decided by the project owners during the early decision-making process were reviewed. Examples of these elements include decisions on façade, structure, delivery method, awarding method, whether there was a predetermined target budget, project size, and other decisions that will be described in later sections.

By combining the information collected from the literature review and historical data obtained from projects included in the sample, a list of critical preconstruction elements was developed. Items included in this list were measured and collected on the projects in the sample. This list is provided in Table 5.

Data Collection Methodology

Data were collected using BIM-related software, measuring elements related to material changes, material classifications, scope changes, site, and mechanical information. Elements related to design review, design errors, detailed material information, and the team's capability in using the model for cost estimation were measured. The software and its linked cost estimating platform provided additional information about changes in price, materials and scope, and items related to the project team. Data on some elements were not collected through the BIM-related software and had to be obtained from archived documents. Examples are practicing VEs, providing RFIs, awarding methods, and providing early programming. Table 5 provides the list of all elements for which data was gathered using the BIM-related software and from recorded documents.

Table 5

Element Table

Preconstruction Element	Description	Value
Project size	Changes in the size of the building based on its area	Continuous (range = -78,672sf – 1,601,695sf) Mean: 38,179 sf
Budget Percentage Change	The percentage of budget changes from the first estimate to the last one	Continuous (range = -88% – 1428%) Mean: 24.3 %
Budget overrun or cut	The change between final budget at end of preconstruction and the owner's budget goals	Continuous (range = -$143,694,463 – $74,504,229) Mean: $5,521,200
Overall preconstruction budget change	Delta from the initial developed budget to the last one	Continuous (range = -$78,338,450 – $178,628,629) Mean: $7,068,225
Construction type	The type of construction i.e. a renovation, new construction, or mix of renovation with new construction	Nominal (renovation, new construction, mix of renovation with new construction)
Project function	The function and intended use of the building	Nominal (Healthcare, Educational, Office & Bank, Correctional, Amusement)
Early structural information	Whether or not information on the project structure is provided in early preconstruction phase	Dichotomous (No, Yes)
Location	Regional location of the project	Nominal (East, West, Midwest, South-Central)
Structural change	Whether or not there were changes in the project structure during the cost estimating process	Dichotomous (No, Yes)
Skin (façade) change	Whether or not there were changes in the skin and building envelope material and system	Dichotomous (No, Yes)
Location Change	Whether or not there were changes in the project location during the preconstruction phase	Dichotomous (No, Yes)

Table 5 (Continued)

Preconstruction Element	Description	Value
Early programming	Whether or not programming and planning information was provided in the early phase of the preconstruction	Dichotomous (No, Yes)
Target budget	Whether or not the budget goals were identified by the owner during preconstruction	Nominal (No, Yes)
CM initial budget timeframe	The time point at which the CM gets involved in the project and budgeting process	Nominal (Schematic, Conceptual, DD, CD, GMP)
Early location	Whether or not information about the location of a project is provided in the early preconstruction and planning phase	Dichotomous (No, Yes)
Awarding method	The method by which a project was awarded, i.e. a negotiated or hard bid	Nominal (negotiated, hard bid)
Delivery method	The method of delivery, which involves planning, design, and construction teams.	Nominal (DB, DBB, CM@R)
Project recency	The year when the preconstruction phase of a project was developed	Nominal (2017, 2018, 2019)
Design errors	Number of design errors and omissions made by the design team in the Revit model	Continuous (range = 2 – 4494)
Model site assessment	Site assessment and topography provided by the design team in the Revit model	Dichotomous (No, Yes)
Model equipment allocation	Mechanical equipment location provided by the design team in the Revit model	Dichotomous (No, Yes)
Detailed material in the model	Detail and specific information on different materials, equipment, and systems provided in the model. Examples of the detailed material would be millwork, door and hardware, mechanical and electrical equipment, interior window and storefronts, etc.	Dichotomous (No, Yes)
Structural model	Whether or not a structural model was provided for cost estimating purposes	Dichotomous (No, Yes)
Design change	Whether or not the configuration of the building (the design of the building) changed or new sections were added or deleted during preconstruction	Dichotomous (No, Yes)
Major changes	The number of major-scope and sub-scope changes (major area of work to be performed) made by the design team during preconstruction	Continuous (range = 0 – 62)

Table 5 (Continued)

Preconstruction Element	Description	Value
Time of major changes	The time point when major-scope and sub-scope changes happened during preconstruction	Nominal (Early, Middle, Late)
Average estimating time	Average time (in days) spent on budget updating during the preconstruction phase	Continuous (range = 4 – 497) Mean: 98
Model update	The number of times the Revit model was updated by an estimating team for cost estimating purposes	Continuous (range = 0 – 47)
Budget update	The number of times the budget was updated by an estimating team	Continuous (range = 1 – 8) Mean: 3
Overall preconstruction time	The overall preconstruction timeframe (in months) from when the first budget is developed until when the last one is submitted	Continuous (range = 0 – 49) Mean: 9
Using BIM for cost estimating purposes	The team's effort in using the provided Revit model for the cost estimating purposes.	Nominal (Not a BIM project, Revit model is provided and used for the estimating process, Revit model is provided but not used for the estimating process, Early Revit model is used for the estimating process, but later updated models are not used)
Tracking schedule	Project schedule is updated during the cost estimating process	Dichotomous (No, Yes)
RFIs	Number of RFIs submitted by an estimating team during preconstruction	Continuous (range = 0 – 318) Mean: 37
VEs	Value engineering was provided by the estimating team to the owner and design team during preconstruction	Dichotomous (No, Yes)
General requirement	The changes in percentage cost considered for all general requirements needed for the job to run such as trailer, cleaning, dumpster, etc.	Continuous (range = 0% – 8%) Mean: .13%
General requirement	The variation in cost considered for all general requirements such as trailer, cleaning, dumpster, etc.	Continuous (range = -$4,805,964 – $8,912,846) Mean: $413,364
General condition	The changes in percentage cost considered for all personnel requirements such as all PMs, superintendents, etc.)	Continuous (range = -1.6% – 9.4%) Mean:.01%
General condition	The variation in cost considered for all personnel requirements such as all PMs, superintendents, etc.)	Continuous (range = -$1,309,016 – $12,376,000) Mean: $975,098
Permit	The changes in percentage cost considered for permit	Continuous (range = -4% – .8%) Mean: -.001%

Table 5 (Continued)

Preconstruction Element	Description	Value
Permit	The variation in cost considered for permit	Continuous (range = -$483,628 – $1,097,262) Mean: -$23,931
BRI	The changes in the percentage cost considered for builder's risk insurance	Continuous (range = -.9% – .09%) Mean: 0%
BRI	The variation in cost considered for builder's risk insurance	Continuous (range = -$453,917 – $632,090) Mean: -$27,558.5
PBI	The changes in percentage cost considered for Permit, Bond, Insurance	Continuous (range = -3% – 8%) Mean: 0%
PBI	The variation in cost considered for Permit, Bond, Insurance	Continuous (range = -$11,074,430 – $6,542,239) Mean: $81,109
Sub-default rate	The changes in percentage cost considered for sub rate	Continuous (range = -1% – 0%) Mean: -.02%
Sub-default rate	The variation in cost considered for sub rate	Continuous (range = -$1,891,319 – $2,475,429) Mean: -$13,823.7
Fee	The changes in percentage cost considered for fees	Continuous (range = -.85% – 2.85%) Mean: 0%
Fee	The variation in cost considered for fees	Continuous (range = -$2,649,126 – $4,947,393) Mean: $246,686
Escalation	The changes in percentage cost considered for escalation	Continuous (range = -4% – 1%) Mean: -.004%
Escalation	The variation in cost considered for escalation	Continuous (range = -$13,226,844 – $1,430,333) Mean: -$377,192.5
Construction contingency	The changes in percentage cost considered for construction contingency. The considered percentage cost for this element went down in some projects and in some projects stayed the same.	Continuous (range = -1% – 0%) Mean: -.01%
Construction contingency	The variation in cost considered for construction contingency.	Continuous (range = -$8,065,149 – $20,208,116) Mean: $325,543
Owner contingency	The changes in percentage cost considered for owner contingency	Continuous (range = -.6% – 0%) Mean: 0%
Owner contingency	The variation in cost considered for owner contingency	Continuous (range = $0 – $12,375) Mean: $202.8
Design contingency	The changes in percentage cost considered for design contingency	Continuous (range = -10% – 7%) Mean: 0%

Table 5 (Continued)

Preconstruction Element	Description	Value
Design contingency	The variation in cost considered for design contingency	Continuous (range = -$9,672,565 – $2,925,212) Mean: -$81,688
DFR	The changes in percentage cost considered for design fee and reimbursement	Continuous (range = -6% – 7.5%) Mean: .008%
DFR	The variation in cost considered for design fee and reimbursement	Continuous (range = -$2,110,840 – $7,750,000) Mean: $103,480
Early Location	Information about the location of the building is provided during early programming.	Dichotomous (No, Yes)
Programming	The programming information about the building and its included areas and functions are provided.	Dichotomous (No, Yes)
Documentation of cost changes	The cost changes are documented and tracked throughout preconstruction	Dichotomous (No, Yes)
Element cost analysis	The cost analysis are provided by the estimating team for the project.	Dichotomous (No, Yes)
Poor communication and coordination	There is poor communication and coordination between different parties throughout preconstruction	Dichotomous (No, Yes)

There are clarifications regarding the way that some of the elements listed in the Table 5 above are identified. These identifications are specifically about overall preconstruction budget variances, VEs, major changes, time of major changes, poor communication between different parties, and detailed material in the model which will be discussed in detail below.

Overall Preconstruction Budget Variation

For measuring overall preconstruction budget variances, two elements should have been clearly identified, the initial and final developed budget. The initial budget refers to the first developed budget and the final budget refers to the last budget developed at the end of the preconstruction phase.

A project team may update the initial budget many times from the early preconstruction phase until the buyout is completed. There were projects with over 40 updates in their budget during the preconstruction phase. As one of the main goals of this research was to track variations in the budget during preconstruction, the research compared the initial budget with the last provided one. Thus, this study was able to have an overall view of the variations in the budget during this phase.

VEs Practices

Another clarification is about VEs. VEs that were accepted by the owner and architects were collected because they contributed some cost changes to the project; however, the owner and design team did not accept the provided VEs for many projects. These could not be ignored since these projects involved some level of the team's effort, representing the capability and productivity of an estimating team. Therefore, in the element *Provided VEs*, it is also specified that the team provided VEs, but the owner and design team did not accept them.

Time of Major Changes

The next element clarification is about *Major Changes* in scope and sub-scope (either in the Revit model or in the drawings and specs) and when the design team made these to a project design and scope. The number of scopes and sub-scopes that were changed during the preconstruction phase were counted in the study.

The study also identified the time when these changes occurred. Three main time points were considered: early, middle, and late. The whole preconstruction phase was broken down into three equal periods of time. Early changes happened in the first third, middle changes were in the second third, and late changes occurred in the last third.

As the changes during the preconstruction phase were tracked, a weighted score was used to give more weight to changes that came later in the process because those changes were more impactful. Weights have been used effectively in other studies to emphasize the impact of timing (Perrenoud, Smithwick, Hurtado, & Sullivan, 2016). For this purpose, I squared the magnitude of the time when the changes happened. An example of using this formula and identifying the time impact of changes in a project is detailed below.

Time of changes:

Early = 1, Middle = 2, Late = 3

sequentially squared the magnitude of the time multipliers:

Early = 1, Middle = 4, Late = 9

Considered Time Frame:

(≤0 = Early, 2-4 = Middle, > 4 = Late)

An example in one of the studied projects:

Total number of changes = 38

Number of early changes = 4

Number of middle changes = 12

Number of late changes = 22

Calculations:

Early changes = 4 x 1 = 4

Middle changes = 12 x 4 = 48

Late changes = 22 x 9 = 198, Total = 250

Weighted mean time of changes = (250 / 38) = 6.57, therefore the weighted mean time of changes was > 4 and trended toward late changes.

Average Time Spent on Budget Updating

The next consideration is for an element called *Average Time Spent on Budget Updating*. In the study, the overall preconstruction estimating time, from when the first budget was developed to when the last one was reported is measured. This time period (in days) is then divided by the number of times the budgets are updated and reported. The reason for analyzing this item is to understand how much time, on average, the preconstruction team spent updating the project budget and how this impacted other aspects of the project.

Detailed Material in the Model

The last element considered, *Detailed Material in the Model*, concerns reviewing material details in the BIM model. This topic was broad, and to measure it, I sorted it into eight groups, which were details related to drywall, acoustical ceilings, glass and glazing, doors and hardware, millwork, mechanical equipment, electrical equipment, and plumbing fixtures. A nominal code was specified for each group. For example, each detail related to drywall was coded as 1 if provided or as 0 if not provided. After data collection was complete, I averaged recorded nominal codes to identify if the overall material detail was provided in the model. For instance, if six out of eight details were provided and I had an average of .75, I labeled the project as having been provided with material details.

Limitations

This study is focused on collecting objective values. One limitation is that I was not able to collect critical elements highlighted by literature that did not have objective values. Examples of these elements is misunderstanding between owner and designer about the scope of the work and misunderstanding of client’s requirement. Another limitation is that I was not able to collect critical elements recommended by literature that are taking place after the buyout is completed and during the construction phase. Example of these elements include excessive change orders, poor quality of material, and lateness in approving or receiving of complete work.

Another example of a critical element that I was not able to collect is unrealistic schedule. I was able to measure the time needed to complete the preconstruction phase and whether or not the project team provided a schedule during the preconstruction phase. However, for identifying an unrealistic schedule, I had to have access to the construction final schedule and compare it with the schedule developed during the preconstruction phase to identify if the earlier schedule was realistic or not.

The last limitation is about the functionality of projects included in the analysis. After filtering the target population, projects that did not meet the filtering condition were not included and as a result, some projects' functionalities were not presented in the sample. Examples of these were retail, warehouse, religious, parking, petroleum, environment, manufacturing, and non-building projects. Since these projects were filtered out, I was not able to include them in the study analysis.

Data Review

As data collection was completed, the data were reviewed to identify the missing values. Different practices were used to manage missing data due to lack of information in the sources.

The first practice was discarding elements that were missing most of their values; thus, these data would not be used in the analysis. An example of a missing element is changes in government laws and regulations. Since I could not collect this item in almost all the projects, I discarded it for the data analysis step. Elements that had only a few missing cases were retained. In these cases, I ensured that the percentage of missing elements was less than 20% to provide a good representation of the original data (Downy & King, 1998). An example of this missing type of item is the VEs, which I could not collect in a few of the projects. Since most of its values were available, the element was left in the data set for analysis. To handle variables that were missing only few values, these values were coded in SPSS so that they were excluded from the analyses.

Analysis Strategy

After reviewing the collected measurements and identifying the missing values and outliers, SPSS was used to analyze the data. Three statistical analyses were performed to identify the elements related to project budget variances. T-tests and analysis of variance (ANOVA) were used to compare means between and within groups. Correlation analyses were used to identify how values were related to one another.

Results identified from the three mentioned analyses were used to develop a list of critical preconstruction elements impacting the budget and time. All the analyses with their significant values are listed in Appendix B.

Chapter 4: Results

This chapter presents the results related to the direct and indirect impacts of preconstruction elements on project budget. Elements that were expected to impact the budget and were not identified as being impactful are also presented. The second part of this chapter presents additional results related to the impact of preconstruction elements on the time needed to complete preconstruction. The duration of preconstruction was not the focus of the study; however, results that show the impact of preconstruction elements on the duration of preconstruction are included. This chapter ends with a summary of benefits that are derivable from using the budget-related decision-making tool.

Preconstruction Elements Impacting the Budget Variances

This section contains a discussion of results related to preconstruction elements and their direct or indirect impact on budget variances. To identify the indirect impact of preconstruction elements on budget variances, their interaction on other elements that directly impact the budget was evaluated. Before reviewing the results in detail, a description of variables used in the analysis are provided in Table 6 below. Following table 6, a summary of the direct and indirect impact of preconstruction elements on budget variances is provided in Table 7.

Table 6

Variable Table

Variable Analyzed	Project Characteristics
Project size	Range of changes: -78,672 sf to 1,601,695 sf Mean of changes: 38,179.6 sf Std. Deviation: 214,512
Target budget	Number of projects with target budget: 33 (68%) Number of projects with no target budget: 15 (31%)
Construction type	Number of renovation projects: 9 (15%) Number of new construction projects: 42 (69%) Number of mixed projects: 10 (16%)
CMs Similar Experience	Number of projects with experienced CM: 58 (95%) Number of projects with no experienced CM: 3 (5%)

Table 6 (Continued)

Variable Analyzed	Project Characteristics
Project Function	Number of healthcare projects: 10 (17.5%) Number of hotel projects: 7 (12%) Number of residential projects: 11 (19%) Number of educational projects: 12 (21%) Number of office and bank projects: 8 (14%) Number of government projects: 6 (10.5%) Number of amusement projects: 3 (5%)
Model updates	Range of updates: 0 to 47 Mean of updates: 3.57 Std. Deviation: 6.310
Budget updates	Range of updates: 1 to 8 Mean of updates: 3.11 Std. Deviation: 1.916
Providing site assessment	Number of projects with site assessment: 16 (28%) Number of projects with no site assessment: 38 (67) Number of projects with missed information: 3 (5%)
Providing equipment allocation	Number of projects with equipment allocation: 10 (18%) Number of projects with no equipment allocation: 45 (79%) Number of projects with missed information: 2 (3%)
Number of design errors	Range of errors: 0 to 4494 Mean of updates: 644 Std. Deviation: 906.8
Number of major changes	Range of changes: 0 to 62 Mean of changes: 21 Std. Deviation: 13.7
Location (regional)	Number of projects located in the south-central: 44 (72%) Number of projects located in the east: 7 (12%) Number of projects located in the mid-west: 10 (16%)
Awarding methods	Number of negotiated projects: 36 (59%) Number of hard bid projects: 25 (41%)
Publicity and Privacy	Number of public projects: 29 (47.5%) Number of private projects: 32 (52.5%)
Escalation	Range of percentage changes: -.05% to .05% Mean of percentage changes: -.0048 Std. Deviation: .016
General requirement	Range of percentage changes: 0 to 8 Mean of percentage changes: .13 Std. Deviation: 1.038
`Number of submitted RFIs	Range of numbers: 0 to 318 Mean of number: 37.37 Std. Deviation: 61.725
Provided VEs	Number of projects that practiced VEs: 24 (40%) Number of projects that did not practice VEs: 27 (44%) Number of projects that practiced VEs but not accepted by the owner: 10 (16%)
Structural changes	Number of hard bid projects that experienced structural changes: 28 (48%) Number of hard bid projects that did not experience structural changes: 7 (12%) Number of hard bid projects that information related to structure was missed in the database: 23 (39%)
DFR	Range of changes: -.08 to .48 Mean of changes: .00813 Std. Deviation: .064

Table 6 (Continued)

Variable Analyzed	Project Characteristics
Permit	Range of changes: -.041 to .009 Mean of changes: -.001 Std. Deviation: .007
Sub default rate	Range of changes: -1 to 0 Mean of changes: -.02 Std. Deviation: .139
Delivery Method	Number of CM@R projects: 29 (66%) Number of DBB projects: 3 (7%) Number of DB projects: 6 (14%) Number of projects that were not applicable: 6 (14%)
CMs initial budget time frame	Number of projects that CMs involved during conceptual phase: 44 (73%) Number of projects that CMs involved during Schematic phase: 3 (5%) Number of projects that CMs involved during design development phase: 3 (5%) Number of projects that CMs involved during construction documents: 3 (5%) Number of projects that CMs involved during hard bid process: 7 (12%)
Skin (façade) change	Number of projects with skin change: 29 (49%) Number of projects with no skin change: 7 (12%) Number of projects that were not applicable: 23 (39%)
Project recency	Number of projects developed in 2017: 22 (36%) Number of projects developed in 2018: 21 (34%) Number of projects developed in 2019: 18 (30%)
Using BIM	Number of projects used BIM for cost estimating: 44 (72%) Number of projects that did not use BIM for cost estimating: 16 (26%) Number of projects that used BIM for the estimating temporarily but not through the whole preconstruction phase: 1 (2%)
Tracking schedule	Number of projects that schedule was tracked in them: 25 (41%) Number of projects that schedule was not tracked in them: 36 (59%
Time of major changes	Range of time of major changes: 2 to 6.50 Mean of time of major changes: 4.631 Std. Deviation: 1.327
Time of major changes	Number of hard bid projects that had early changes: 2 (11.1%) Number of hard bid projects that had middle changes: 10 (55.6%) Number of hard bid projects that had early changes: 6 (33.3%)

The above variables were all gathered from reviewing existing literature as well as historical data from projects included in the sample. The impact(s) of each variable on budget variances was analyzed. A summary of the analysis is provided in Table 7.

Table 7

Overall Results of Preconstruction Elements Impacting Budget Variance

Element	Impact on	Impact is significant?	Comments
Overall estimating time	Overall preconstruction budget change	Yes	Preconstruction time increased with increasing budget variance.
Project size	Overall preconstruction budget changes	Yes	The overall budget increased as project size changed.
Construction type	Budget percentage changes	Yes	Percentage variance in the budget varied, depending on the construction type.
Model updates	Overall preconstruction budget changes	Yes	Model updates in a project were associated with major increases in the budget.
Providing site assessment	Overall preconstruction budget changes	Yes	Inclusion of site assessment in the project model was associated with major budget increases during the preconstruction phase.
Providing equipment allocation	Overall preconstruction budget changes	Yes	Inclusion of equipment allocation in the project model was associated with major budget increases during the preconstruction phase.
Number of design errors	Overall preconstruction budget change	Yes	A greater number of design errors and omissions on a project was associated with an increase in the overall budget.
Design Change	Overall preconstruction budget change	No	There were no significant differences in budget variance in projects with design changes compared to projects with no design changes.
Design change	Project size	Yes	There was a major size increase in projects with design changes compared to projects with no design changes, specifically in hard bid projects.
DFR	Overall preconstruction budget change	Yes	A greater number of increases in the budget was associated with increases in the budget considered for DFR.
General condition	Budget percentage change	Yes	Higher percentage changes in the budget were associated with deductions in the budget considered for the general condition.
Awarding methods	Overall preconstruction budget change	No	There were no differences in budget change based on different awarding methods (negotiated and hard bid projects).
Awarding methods	Overall estimating time	Yes	The overall estimating time was significantly different, comparing negotiated and hard bid projects.
Escalation	Overall preconstruction budget change	Yes	In negotiated projects, major budget increases were associated with deductions in part of the budget earmarked for escalation.
General requirement	Overall preconstruction budget change	Yes	In negotiated projects, major budget increases were associated with deductions in part of the budget earmarked for general requirement.
Number of submitted RFIs	Overall preconstruction budget change	Yes	In hard bid projects, the number of submitted RFIs on a project varied inversely with budget increase.

Table 7 (Continued)

Element	Impact on	Impact is significant?	Comments
Provided VEs	Overall preconstruction budget change	Yes	Hard bid projects where VEs were provided and accepted by the owner had major budget variances during their preconstruction phase.
Permit	Budget percentage change	Yes	In hard bid projects, overall budget increases were associated with deductions in the budget allocation for the permit.
Sub default rate	Budget percentage change	Yes	In hard bid projects, increases in the budget were associated with increases in the budget allocation for the sub default rate.
Target Budget	Overall preconstruction budget changes	No	There were no significant differences in overall budget variances, comparing projects with a target budget to projects with no target budget.
CMs Similar Experience	Overall preconstruction budget changes	No	The budget differences between projects with experienced CM and projects with no experienced CM were not significant.
Project Function	Budget percentage changes	No	The budget variances in different functionalities were not significant.
Number of major changes	Overall preconstruction budget change	No	A greater number of major changes on a project was not associated with increases in the overall budget.
Location	Overall preconstruction budget change	No	There were no significant differences in budget variance based on the regional location of the project.
Delivery methods	Overall preconstruction budget change	No	There were no differences in budget variance based on delivery methods.
CMs initial budget timeframe	Overall preconstruction budget change	No	There were no differences in budget variance based on timeframes when CMs get involved with the budgeting and preconstruction phase of a project.
Skin (façade) change	Overall preconstruction budget change	No	There were no major differences in budget variance based on whether or not the project had skin changes.
Time of major changes	Overall preconstruction budget change	No	There were no significant differences in budget variance based on different timelines when the major scope and sub-scope changes occurred.
Public/ private	Overall preconstruction budget change	No	There was no significant budget variance between public and private projects.

Analyzing the Impact of Overall Estimating Time on the Budget

The overall estimating time represents the length of the preconstruction phase from when the first budget is developed until when the last budget is developed. In this analysis, the association between the overall estimating time and overall budget variance is examined. The results indicated a significant yet weak correlation between overall estimating time and overall budget variance. The more the budget increased, the longer was the preconstruction phase, r (61) = .277, p = .031. See Table 8 below for the actual SPSS outputs.

Table 8

SPSS Outputs for Correlation Between Overall Estimating Time and the Overall Budget Variance

		Overall budget variance
Overall estimating time	Pearson Correlation	.277
	Sig. (2-tailed)	.031
	N	61

Analyzing the Impact of Project Size on the Budget

One of the preconstruction elements that directly impacts the project budget is the building area representing the project size. The purpose of this analysis was to find the impact of project size on the budget variance. The associations between project size and overall preconstruction budget variances were identified. The results indicated a strong positive correlation between changes in project size and overall preconstruction budget variance. Specifically, the more the project size increased, the more the overall budget increased, r (61) = .802, p = .000. See Table 9 below for the analysis outputs.

Table 9

SPSS Outputs for Project Size Correlated with Overall Preconstruction Budget Variance

		Overall Preconstruction Budget Variance
Project size	Pearson Correlation	.850
	Sig. (2-tailed)	.000
	N	61

Analyzing the Impact of Construction Type on the Budget

The next preconstruction element is about the type of construction. This refers to the project being a renovation, new construction, or a mix of renovation with new construction. In this analysis, different construction types were compared with each other based on the budget percentage change. New construction projects had a mean increase of 42%, renovation projects had a mean increase of 9%, and mixed projects had a mean increase of 10%. The mean difference of 33% between the new construction and renovation project categories was statistically significant, F (2,58) = 4.194, p = .020. See Table 10 below for the actual SPSS output.

Table 10

SPSS Outputs for Post Hoc Tests, Comparing Different Construction Types Based on Budget Percentage Changes

Dependent Variable	(I) Type of Project Construction	(J) Type of Project Construction	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Budget Percentage Change	New Construction	Renovation	-47.72159*	18.3271	.031	-91.8039	-3.6393
		Mix of Renovation & New Construction	13.45586	17.5562	.725	-28.7723	55.6840
	Renovation	New Construction	47.72159*	18.3271	.031	3.6393	91.8039
		Mix of Renovation & New Construction	61.17744*	22.925	.026	6.0357	116.3192
	Mix of Renovation & New Construction	New Construction	-13.45586	17.5562	.725	-55.6840	28.7723
		Renovation	-61.17744*	22.925	.026	-116.3192	-6.0357

Analyzing the Impact of Model Update on the Budget

The frequency of model update refers to the number of times that the estimating team has updated the project BIM model. The aim of this analysis was to find the association between the number of times a BIM model has been updated and the overall preconstruction budget variance. The results indicate a strong positive correlation between the model update and overall preconstruction budget variance, as the more the model is updated, the more the overall budget increases, r (61) = .720, p = .000. See Table 11 below for the actual SPSS outputs.

Table 11

SPSS Outputs for Model Update Correlated with Overall Preconstruction Budget Variance

		Overall preconstruction budget variance
Model updates	Pearson Correlation	.739
	Sig. (2-tailed)	.000
	N	61

Analyzing the Impact of Model Site Assessment on the Budget

The next preconstruction element related to the design aspect of a project is the provision of site assessment by the design team. In this analysis, projects that had site assessments provided in their model were compared to projects with no site assessments provided based on the overall preconstruction budget variance. Projects with site assessment provided had a mean budget increase of $24,833,996. Projects with no site assessment provided had a mean budget decrease of $587,395. The mean difference of $24,296,601 between the projects with site assessment and projects with no site assessment was statistically significant, t (52) = -3.142, p = .003.

Analyzing the Impact of Model Equipment Allocation on the Budget

The next preconstruction element related to the design aspect of a project is the provision of equipment allocation by the design team in the model. In this analysis, projects in which equipment allocation was provided in their model were compared to projects with no equipment allocation provided based on the overall preconstruction budget variance. Projects with equipment allocation provided had a mean budget increase of $32,941,949. Projects with no equipment allocation provided had a mean budget increase of $2,278,656. The mean difference of $30,663,293 between the project with equipment allocation provided and projects with no equipment allocation provided was statistically significant, t (53) = -3.475, p = .001.

Analyzing the Impact of Design Errors on the Budget

The next preconstruction element that directly impacts the project budget is design errors. The aim of this analysis was to find the association between the number of design errors and the overall preconstruction budget variance. The results indicated that there is a moderate positive correlation between design errors and overall preconstruction budget variance as the more design errors experienced in a model, the more the overall budget increased, r (58) = .445, p = .001. See Table 12 below for the actual SPSS outputs.

Table 12

SPSS Outputs for Number of Design Errors and Omissions Correlated with Overall Preconstruction Budget Variance

		Overall preconstruction budget variance
Number of design errors & omissions	Pearson Correlation	.445
	Sig. (2-tailed)	.000
	N	58

Analyzing the Impact of Design Changes on the Budget

Changes in the design can happen in different phases during preconstruction. The impact of design changes on the budget was addressed by previous studies (Mansfield et al 1994, Akogbe et al. 2013, Tafazzoli 2017). The direct impact of design changes on the budget was expected to be identified in this study. However, the results did not show a significant impact of design changes on the overall budget variance, t (54) = -1.214, p = .230.

Upon further analysis, the indirect impact of this element on the budget through its relationship with the project size was found. Projects with design change were compared with projects with no design change, based on the project size. Projects that experienced design changes had a mean increase of 127,375 sf in their size, and projects that did not have design changes had a mean increase of 5,039.9 sf in their project size. The mean difference of 122,335 sf between experiencing design changes and not experiencing design changes was significant, t (23) = -2.708, p = .013. The results indicate that in hard bid projects, changes in the design are likely to significantly impact the size of the project. As previously discussed, project size is a preconstruction element that directly impacts the budget. This result tells us about a possible indirect relationship between experiencing design changes and major budget change.

Analyzing the Impact of Design Fee and Reimbursements on the Budget

Another preconstruction element that was examined for impact on the budget is the amount considered for design fee and reimbursements (DFR). The amount of DFR is usually considered by CMs as they develop the estimate and project budget. The aim of this analysis was to find the association between the DFR and the budget percentage variance. The results indicated a moderate positive correlation between DFR and budget percentage variance. The more budget increased, the greater the DFR that was considered by a contractor, r (61) = .452, p = .000. See Table 13 below for the actual SPSS output.

Table 13

SPSS Outputs for Correlation Between DFR and the Budget Percentage Variance

		DFR percentage variance
Budget percentage change	Pearson Correlation	.452
	Sig. (2-tailed)	.000
	N	61

Analyzing the Impact of General Condition on the Budget

General condition is also a preconstruction element considered by CMs as they develop the budget. In this analysis, the association between the general condition and the budget percentage variance is identified. The results indicated that there is a moderate negative correlation between general condition and budget percentage variance. The more the budget increased, the less the general requirement that was considered by a contractor, r (61) = -.252, p = .050. See Table 14 below for the actual SPSS output.

Table 14

SPSS Outputs for Correlation Between General Condition and Budget Percentage Variance

		General condition percentage variance
Budget percentage change	Pearson Correlation	-.463
	Sig. (2-tailed)	.005
	N	36

Based on these results, the owner should note that if they experience a major budget increase, they can expect to have a major decrease in the percentage amount of general condition considered by the project contractor.

Analyzing the Impact of Awarding Method on the Budget

The awarding method is one of the important preconstruction elements as a project is awarded through a negotiated or hard bid process. Negotiated projects refer to those in which CMs are negotiating the price with the owner and are involved in the decision-making process from the early stages. Hard bid projects are those in which CMs bid for the project or award through a hard bidding process.

In this study, it was expected that the awarding method would be related to the overall preconstruction budget variance. The results did not indicate any significant impact of the awarding method on the overall preconstruction budget variance, t (59) = .621, p = .537. Although the awarding method does not directly impact the budget, its impact on other preconstruction elements that do directly impact the budget shows an indirect relationship between awarding method and budget.

In this analysis, the two awarding methods are compared based on the overall estimating time. Negotiated projects had a mean of 12.5 months of preconstruction time, and hard bid projects had a mean of 4 months. The difference of 8.5 months between the negotiated and hard bid projects was statistically significant, t (59) = 4.376, p = .000. The results indicated that negotiated projects are more likely to have a longer preconstruction period. Because the longer preconstruction period is associated with major budget increases (reviewed in previous sections), it can be concluded that awarding method indirectly impacts the budget variances, and negotiated projects are more likely to experience major budget increases during the preconstruction phase.

Analyzing the Budget Impact of Preconstruction Elements by the Awarding Method (Separately for Negotiated and Hard Bid Projects)

In analyses included in previous sections, the overall group of projects (n=61), whether they were hard bid or negotiated, was included. In an additional step, I was interested in studying negotiation and hard bid projects separately to find out the budget impact of their preconstruction element separately. For this goal, a new series of analyses was done within the different awarding methods. The results are presented below.

Analyzing the Impact of Escalation on the Budget in Negotiated Projects

Escalation is one of the preconstruction elements whose amount is decided by CMs as they develop the project budget. This element was identified by previous studies to impact the budget (Anderson et al. 2007). The aim of this analysis was to find the association between escalation and the overall preconstruction budget variance. The results indicated that there is a very strong negative correlation between escalation and overall preconstruction budget. The more the budget increased, the lower the amount of escalation considered by a contractor, r (35) = -.878, p = .000. See Table 15 below for the actual SPSS output.

Table 15

SPSS Outputs for Correlation Between Escalation and Overall Preconstruction Budget Variance in Negotiated Projects

		Escalation Percentage Changes
Overall preconstruction budget variance	Pearson Correlation	-.878
	Sig. (2-tailed)	.000
	N	35

Based on these results, the owner should note that if they experience a major budget increase in their negotiated projects, they can expect to have a major decrease in the percentage amount of escalation considered by the project contractor.

Analyzing the Impact of General Requirement on the Budget in Negotiated Projects

General requirement is also a preconstruction element whose amount is considered by CMs as they develop the budget. In this analysis, the association between the general requirement and the budget percentage change was identified. The results indicated that there is a moderate negative correlation between general requirement and budget percentage change. The more the budget increased, the lower the amount considered for general requirement by a contractor, $r(36) = -.463$, $p = .005$. See Table 16 below for the actual SPSS output.

Table 16

SPSS Outputs for Correlation Between General Requirement and Budget Percentage Change in Negotiated Projects

		General condition percentage change
Budget percentage change	Pearson Correlation	-.463
	Sig. (2-tailed)	.005
	N	36

Based on these results, the owner should note that if they experience a major budget increase in their negotiated projects, they can expect to have a major decrease in the percentage amount of general requirement considered by the project contractor.

Analyzing the Impact of Number of Submitted RFIs on the Budget in Hard Bid Projects

Hard bid projects experienced more preconstruction elements that impacted the budget. The first of these is the number of submitted RFIs during the preconstruction phase. The aim of this analysis was to find the association between the number of submitted RFIs and the overall preconstruction budget variance. The results indicated a moderate negative correlation between the number of submitted RFIs and the overall preconstruction budget variance. The fewer the RFIs submitted by an estimating team, the greater the budget increase experienced in a project, $r(25) = -.401$, $p = .047$. See Table 17 below for the actual SPSS output.

Table 17

SPSS Outputs for Number of Submitted RFIs Correlated With Overall Preconstruction Budget Variance in Hard Bid Projects

		Overall preconstruction budget variance
Number of Submitted RFIs	Pearson Correlation	-.401
	Sig. (2-tailed)	.047
	N	25

Analyzing the Impact of Providing VEs on the Budget in Hard Bid Projects

The next preconstruction element is whether or not the estimating team submitted VEs to the owner and design team. The aim of this analysis was to compare projects that provided VEs based on the overall budget variance. For this element in hard bid projects, for some projects, the estimating team provided VEs that the owner and design team did not accept. As I was grouping this item, I grouped projects that provided VEs and were accepted, projects that provided VEs and were not accepted, and projects that did not provide VEs. In this analysis, the three different groups were compared based on the overall budget variance. Projects that had VEs provided and accepted had a mean budget decrease of $8,938,478, projects that had no VEs provided had a mean budget increase of $4,907,272, and projects that had VEs provided but not accepted had a mean budget increase of $23,309,659. The difference of $32,248,137 between the projects that provided VEs that were accepted and projects that provided VEs that were not accepted was statistically significant, F (2,22) = 3.560, p = .046. See Table 18 below for the actual SPSS output.

Table 18

SPSS Outputs for Post Hoc Tests, Comparing Providing VEs Based on Overall Budget Variance

Dependent Variable: Overall budget variance

Tukey HSD

(I) Provided VEs	(J) Provided VEs	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
No	Yes	-16757978.25	8118410.36	.124	-37382394.6	3866438.09
	VEs Are Provided but not Accepted	10569559.92	9374332.81	.509	-13245464.7	34384584.6
Yes	No	16757978.25	8118410.36	.124	-3866438.09	37382394.6
	VEs Are Provided but not Accepted	27327538.17*	10480822.7	.044	701531.16	53953545.2
VEs Are Provided but not Accepted	No	-10569559.92	9374332.81	.509	-34384584.6	13245464.7
	Yes	-27327538.17*	10480822.7	.044	-53953545.2	-701531.2

Analyzing the Impact of Building Permits on the Budget in Hard Bid Projects

Building permits are another preconstruction element whose amount is considered by CMs as they develop a project budget. In this analysis, the association between the permit and the budget percentage change was assessed. The results indicated a moderate negative correlation between permit and budget percentage change as the more the budget increased, the lower the amount considered for permits by a contractor, r (25) = -.460, p = .021. See Table 19 below for the actual SPSS output.

Table 19

SPSS Outputs for Correlation Between Permit and the Budget Percentage Change in Hard Bid Projects

		Permit percentage change
Budget percentage change	Pearson Correlation	-.460
	Sig. (2-tailed)	.021
	N	25

Analyzing the Impact of Sub-Default Rate on the Budget in Hard Bid Projects

Sub-default rate is the last preconstruction element whose amount is considered by CMs as they develop a project budget. In this analysis, the association between the sub default rate and the budget percentage change was examined. The results indicated a moderate positive correlation between sub-default rate and budget percentage change. The more the budget increased, the lower the amount considered for the sub-default rate by a contractor, r (25) = .471, p = .017. See Table 20 below for the actual SPSS output.

Table 20

SPSS Outputs for Correlation Between Sub-Default Rate and the Budget Percentage Variance in Hard Bid Projects

		Sub default rate percentage change
Budget percentage variance	Pearson Correlation	.471
	Sig. (2-tailed)	.017
	N	25

The owner should note based on these results that if they experience a major budget increase in their hard bid projects, they should expect to have a major increase in the percentage of sub-default rate considered by the project contractor.

Analyzing the Impact of Setting Up a Target Budget on the Budget

One of the early decisions during the preconstruction phase is the project budget goal or the owner's predetermined target budget. In this analysis, projects that had provided a target budget were compared to projects that did not have a target budget based on the budget's overall variance. Projects that had a target budget had a mean of $5,102,126 budget change, and projects that did not have a target budget had a mean of $10,855,878 budget change. However, the mean difference of $5,753,752 between the two group of projects was not statistically significant, t (46) = -.623, p = .536.

Analyzing the Impact of CM's Previous Experience on the Budget Variances

Signing a contract with a CM with previous experience on similar projects is one of the considerations during the early programming phase. As suggested by previous studies (Tafazzoli, 2017), this element was expected to be related to the budget. However, the results indicated that projects that did not have an experienced contractor on similar projects had a mean budget increase of $1,284,112, and projects that had an experienced contractor on similar projects had a mean budget increase of $7,367,404. The difference of $6,083,292 between the two projects was not significant, t (59) = -.385, p = .701.

Analyzing the Impact of Project Function on the Budget

Project function refers to the functionality of a building, such as healthcare, education, offices and banks, hotel, government, or even a mix of different functions. This preconstruction element was expected to impact the budget. Previous studies also suggested considering functionality as an element impacting the budget (Akogbe et al., 2013, Potts et al., 2014). In this analysis, different functions were compared based on the budget percentage changes. Healthcare projects had a mean increase of 52%, hotel projects had a mean decrease of .2%, residential projects had a mean increase of 44.7%, educational projects had a mean increase of 11.5%, office and bank projects had a mean increase of 2.2%, government projects had a mean increase of 17%, and amusement projects had a mean increase of 46%. The mean differences between project functions were not statistically significant, F (6,51) = 1.601, p = .166. This result was not in support of the study expectation and previous studies. See Table 21 below for the actual SPSS output.

Table 21

SPSS Outputs for Post Hoc Tests, Comparing Different Functions Based on Budget Percentage Changes

Multiple Comparisons							
Tukey HSD							
Dependent Variable	(I) Function of the Project	(J) Function of the Project	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Budget Percentage Changes	Healthcare	Hotel	52.45843	25.63773	.400	-26.2237	131.1405
		Residential	7.47609	22.73094	1.000	-62.2851	77.2373
		Educational	40.67200	22.27537	.537	-27.6910	109.0350
		Office & Bank	54.49825	24.67717	.309	-21.2359	130.2324
		Government	34.75557	25.63773	.822	-43.9265	113.4377
		Amusement	5.77700	34.24642	1.000	-99.3252	110.8792
	Hotel	Healthcare	-52.45843	25.63773	.400	-131.1405	26.2237
		Residential	-44.98234	25.15330	.562	-122.1777	32.2131
		Educational	-11.78643	24.74237	.999	-87.7207	64.1478
		Office & Bank	2.03982	26.92500	1.000	-80.5929	84.6726
		Government	-17.70286	27.80802	.995	-103.0456	67.6399
		Amusement	-46.68143	35.90000	.849	-156.8584	63.4956
	Residential	Healthcare	-7.47609	22.73094	1.000	-77.2373	62.2851
		Hotel	44.98234	25.15330	.562	-32.2131	122.1777
		Educational	33.19591	21.71606	.727	-33.4506	99.8424
		Office & Bank	47.02216	24.17350	.461	-27.1662	121.2106
		Government	27.27948	25.15330	.930	-49.9159	104.4749
		Amusement	-1.69909	33.88529	1.000	-105.6929	102.2948
	Educational	Healthcare	-40.67200	22.27537	.537	-109.0350	27.6910
		Hotel	11.78643	24.74237	.999	-64.1478	87.7207
		Residential	-33.19591	21.71606	.727	-99.8424	33.4506
		Office & Bank	13.82625	23.74562	.997	-59.0490	86.7015
		Government	-5.91643	24.74237	1.000	-81.8507	70.0178
		Amusement	-34.89500	33.58138	.942	-137.9561	68.1661
	Office & Bank	Healthcare	-54.49825	24.67717	.309	-130.2324	21.2359
		Hotel	-2.03982	26.92500	1.000	-84.6726	80.5929
		Residential	-47.02216	24.17350	.461	-121.2106	27.1662
		Educational	-13.82625	23.74562	.997	-86.7015	59.0490
		Government	-19.74268	26.92500	.990	-102.3754	62.8901
		Amusement	-48.72125	35.22045	.808	-156.8127	59.3702
	Government	Healthcare	-34.75557	25.63773	.822	-113.4377	43.9265
		Hotel	17.70286	27.80802	.995	-67.6399	103.0456
		Residential	-27.27948	25.15330	.930	-104.4749	49.9159
		Educational	5.91643	24.74237	1.000	-70.0178	81.8507
		Office & Bank	19.74268	26.92500	.990	-62.8901	102.3754

Table 21(Continued)

Tukey HSD							
Dependent Variable	(I) Function of the Project	(J) Function of the Project	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
		Amusement	-28.97857	35.90000	.983	-139.1556	81.1984
	Amusement	Healthcare	-5.77700	34.24642	1.000	-110.8792	99.3252
		Hotel	46.68143	35.90000	.849	-63.4956	156.8584
		Residential	1.69909	33.88529	1.000	-102.2948	105.6929
		Educational	34.89500	33.58138	.942	-68.1661	137.9561
		Office & Bank	48.72125	35.22045	.808	-59.3702	156.8127
		Government	28.97857	35.90000	.983	-81.1984	139.1556

Analyzing the Impact of Major Changes on the Budget

The next preconstruction element related to the design aspect of a project is the number of major changes a design team makes during the preconstruction phase. This represents the major scope and sub-scope changes that a design team makes to a project. The aim of this analysis was to find the association between major changes and the overall preconstruction budget change. However, the results indicate that there is no correlation between major changes and overall preconstruction budget, r (60) = .207, p = .113. See Table 22 below for the actual SPSS output.

Table 22

SPSS Outputs for Number of Major Changes Correlated with Overall Preconstruction Budget Change

		Overall preconstruction budget variance
Number of Major Changes	Pearson Correlation	.207
	Sig. (2-tailed)	.113
	N	60

Analyzing the Impact of Project Location on the Budget

The regional location of a project is another preconstruction element that impacts the budget. This element was expected to impact a project budget. Of the 64 projects analyzed, only seven (11%) were from the Eastern Region, 44 (68%) were from the South-Central region, and ten (16%) were from the Mid-Western region. The results indicate that Eastern-region projects had a mean budget increase of $10,748,513. Projects located in the South-Central Region had a mean budget increase of $7,683,034, and projects located in the Midwestern Region had a mean budget increase of $1,786,867. The results indicated that the difference of $5,896,166 between the two of the three group of projects was not statistically significant, F (2,58) = .272, p = .763. See Table 23 below for the actual SPSS output.

Table 23

SPSS Outputs for Post Hoc Tests, Comparing Project Location Based on Overall Budget Variance

Dependent Variable: Overall Budget Variance						
Tukey HSD						
(I) Equipment Allocation	(J) Equipment Allocation	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
South-Central	Midwest	5896166.291	9385762.05	.805	-16679532.09	28471864.67
	East	-3065479.766	10902064.0	.957	-29288359.44	23157399.91
Midwest	South-Central	-5896166.291	9385762.05	.805	-28471864.67	16679532.09
	East	-8961646.057	13203055.2	.777	-40719130.43	22795838.32
East	South-Central	3065479.766	10902064.0	.957	-23157399.91	29288359.44
	Midwest	8961646.057	13203055.1	.777	-22795838.32	40719130.43

Analyzing the Impact of Delivery Method on the Budget

One important preconstruction element is the project delivery method, which is grouped under Construction Manager at Risk (CM@R), Design Build (DB), and Design Bid Build (DBB). In this study, the finding of a significant impact of this decision on the budget was expected. However, the results did not show any significant impact from different delivery methods on the overall budget change, F (3,37) = .637, p = .596.

Analyzing the Impact of CM's Initial Budget Timeframe on the Budget

The initial CM budget timeframe refers to when a CM gets involved in the project and develops a project budget. These involvements are happening more in negotiated projects. The owners are deciding if the CM's involvement is happening at the conceptual phase, schematic phase, design development phase, or later during the construction document phase when the designer has completed the majority of design-related decisions. In this analysis, the four different groups were compared based on the overall budget variance.

Projects that had their CM involved during the conceptual phase had a mean budget increase of $8,566,714. Similarly, the mean budget increase was $6,717,866 for projects that had their CM involved during the schematic phase, and $2,877,673 for projects that had their CM involved during the construction document phase. The mean budget decrease was $5,086,721 for projects that had their CM involved during the design development phase. The difference of $13,653,435 between changes during conceptual phase and changes during design development phase was not statistically significant, $F(4,55) = .200$, $p = .937$.

Analyzing the Impact of Skin (Façade) Changes on the Budget

Changes in the skin (façade) are related to any changes in the material and system designed as the envelope for a building. In the early programming stages, project owners usually discuss the percentage of materials and systems that will be used as the skin of the project. In this study, skin changes were expected to impact the budget. However, the results indicated no significant impact from skin change on the overall budget, $t(51) = 1.334$, $p = .188$.

Analyzing the Impact of Time of Major Changes on the Budget

The time of major changes represents the timeframe when major scope and sub-scope changes are made to a project (early, middle, or late during the preconstruction phase). The aim of this analysis was to compare the three timeframes when changes are made to a project based on the overall budget variance. Projects that had major changes during early phases had a mean budget decrease of $2,116,911 Dollars, projects that had major changes during middle phases had a mean budget increase of $10,021,517, and projects that had major changes during later phases had a mean budget increase of $9,001,288. The results indicate that the difference of $12,138,428 between changes in early phase and changes in middle phase was not statistically significant. The difference of $11,118,199 between changes in early phase and changes in the late preconstruction phase was also not statistically significant, $F(2,50) = .468$, $p = .629$.

Analyzing the Impact of Private v. Public Projects with Regard to Budget

Whether a project is public or private was expected to impact the budget. In this analysis, public projects were compared to private projects based on the overall budget variance. Public projects had a mean budget increase of $4,800,355, and private projects had a mean budget increase of $9,123,483. The difference of $4,323,128 between public and private projects was not significant, $t(59) = -.634$, $p = .529$.

Preconstruction Elements Impacting Preconstruction Time

Preconstruction time refers to the time needed to complete the preconstruction phase from when the first budget is developed to when the last budget is submitted and the buyout is completed. Identifying the impact of preconstruction elements on the time was not the main focus of this study. However, there are some indications that some of the preconstruction elements also impact how long a preconstruction takes. The length of the preconstruction is important to the owner for several reasons. Some of these reasons might be securing project financing and interest rate, having final drawings and required documents to start the hard bid, coordinating and permitting with the municipality, and identifying a realistic time for the initiations of hard bid, buyout, and actual construction will be started.

There are some indications that some of the preconstruction elements not only impact the budget, but also impact how long a preconstruction takes. These preconstruction variables are the awarding method, model updates, project size, and VEs. There are additional elements that are indicated to only impact the preconstruction time. The importance of the preconstruction time in relation to budget variances was discussed in previous sections (Table 8). The significant impact of preconstruction elements on the preconstruction time shows that these elements are indirectly impacting the budget variances. Findings related to these elements are provided in Table 24 below.

Table 24

Overall Results Table of Preconstruction Elements Impacting Preconstruction Time

Element	Impact on	Impact is significant?	Comments
Target Budget	Overall estimating time	Yes	There were longer estimating times in projects that had a predetermined target budget set.
Location	Average time spent on budget updating	Yes	There was a difference in average time spent on budget updating based on project location. Projects located in the Eastern Region were more likely to experience longer estimating time.
Budget update	Overall estimating time	Yes	A higher number of budget updates on a project was associated with longer estimating time.
Number of major changes	Overall estimating time	Yes	A higher number of major changes was associated with a longer preconstruction phase.
Project recency	Average time spent on budget updating	Yes	There was a difference in average estimating time based on the year in which a project was developed. Recent projects experienced a shorter estimating time.

Analyzing the Impact of Target Budget on Time

Target budget refers to the owner's predetermined budget goal set at the beginning of the early planning and decision-making process. Setting up a target budget impacts the timing of a preconstruction. In this analysis, projects with a target budget were compared to projects with no target budget based on the overall preconstruction estimating time. Projects with a target budget had a mean time increase of 4.25 months, and projects with no target budget had a mean time increase of 11.57 months. The mean difference of 7.34 months between the two groups was significant, t (46) = -2.884, p = .006.

Analyzing the Impact of Model Update on Time in Negotiated Projects

Model update and its impact on the budget was discussed in previous sections. In separate analyses completed in negotiated and hard bid projects, a correlation was identified between the number of times a BIM model is updated and preconstruction time. The analysis indicates that there is a medium correlation between the number of model updates and the average time spent during the preconstruction phase, r (36) = -.341, p = .048. Longer preconstruction periods are associated with more model updates and shorter periods are associated with fewer updates to the model. See Table 25 below for the actual SPSS output.

Table 25

SPSS Outputs for Model Update Correlated with Average Time Spent on Budget Updating in Negotiated Projects

		Average time spent on budget update
Model updates	Pearson Correlation	-.341
	Sig. (2-tailed)	.048
	N	36

Analyzing the Impact of Project Size on Time in Hard Bid Projects

Additional analysis in hard bid projects shows the correlation between project size and timing of a project. In the previous section, it was discussed that the project size is one of the preconstruction elements that directly impacts budget variances. In a separate analysis, the impact of this element on the preconstruction time was also identified. The goal of this analysis was to find the association between project size, first on overall estimating time, and second on the average time spent on budget updating. The results indicate a moderate positive correlation between changes in project size and overall estimating time in hard bid projects. The more the changes in project size, the greater the time increase that occurred, r (25) = .442, p = .027.

The next correlation is between changes in project size and average time spent on budget updating. The results indicate a strong positive correlation between average time and project size. According to the results, the more the changes in project size, the greater the average time increase, r (25) = .707, p = .000. See Table 26 below for the actual SPSS output.

Table 26

SPSS Outputs for Correlation of Project Size with the Overall Estimating Time and Average Time Spent on Budget Updating in Hard Bid Projects

		Overall Estimating Time	Average time spent on budget update
Project Size	Pearson Correlation	.442	.707
	Sig. (2-tailed)	.027	.000
	N	25	25

Analyzing the Impact of Project Location on Time

Project location is a preconstruction element that is usually discussed in the early programming and decision-making process. During the data analysis, an impact of this element on the preconstruction time was not expected. However, the results showed the importance of this element in relation to the preconstruction time. In this analysis, projects with different locations (South-Central, East, and Mid-west) were compared based on the average time spent on budget updating. Projects located in the South-Central Region had a mean increase in time of 91 days. Projects located in the Mid-Western Region had a mean increase in time of 46.4 days, and projects located in the Eastern Region had a mean increase in time of 236.5 days. The difference of 190 days between projects located in the Eastern and Mid-Western regions was statistically significant, F (2,56) = 7.575, p = .001. See Table 27 below for the actual SPSS output.

Table 27

SPSS Outputs for Post Hoc Tests, Comparing Projects in Different Regional Locations Based on Average Estimating Time

Dependent Variable: Average Time Spent on Budget Updating from When the model Released (days)

Tukey HSD

(I) Location Regional	(J) Location Regional	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
South-Central	Mid-West	45.459	34.145	.384	-36.75	127.66
	East	-144.641*	42.385	.003	-246.69	-42.60
Mid-West	South-Central	-45.459	34.145	.384	-127.66	36.75
	East	-190.100*	50.223	.001	-311.02	-69.18
East	South-Central	144.641*	42.385	.003	42.60	246.69
	Mid-West	190.100*	50.223	.001	69.18	311.02

Analyzing the Impact of Budget Update on Time

The overall estimating time represents the length of the preconstruction phase. The length of the preconstruction phase can be identified by both project owners, decided during the early decision-making processes, and the estimating team. The estimating team's effort in developing and budgeting a project impacts how long this phase can last. In this analysis, the goal was to find the association between the number of times the budget is updated and the overall estimating time. The results indicated a strong positive correlation between the budget update and estimating time. More budget updates result in a longer estimating time, r (61) = .802, p = .000. See Table 28 below for the actual SPSS output.

Table 28

SPSS Outputs for Correlation of Overall Estimating Time with the Number of Times a Project Budget is Updated

		Number of times a project budget is updated
Overall estimating time	Pearson Correlation	.395
	Sig. (2-tailed)	.002
	N	61

Analyzing the Impact of VEs on Time

The next preconstruction element impacting preconstruction time is providing VEs. In the previous section, it was discussed that provision of VEs is one of the preconstruction elements that directly impact budget variances. In a separate analysis, the impact of this element on preconstruction time was also identified. This analysis compared projects that had VEs provided based on the overall estimating time. Three groups of projects were collected: projects with VEs provided and accepted, projects with VEs provided but not accepted, and projects with VEs not provided. These three groups were compared based on the overall estimating time. Projects with VEs provided and accepted had a mean increase in time of 12.9 months. Projects with VEs provided but not accepted had a mean increase in time of 7.37 months, and projects that had no VEs provided had a mean increase in time of 6.53 months. The difference of 6.378 months between the projects that provided and accepted VEs and projects that did not provide VEs was statistically significant, $F(2,58) = 4.452$, $p = .016$. See Table 29 below for the actual SPSS output.

Table 29

SPSS Outputs for Post Hoc Tests, Comparing Three Groups of Projects with Different VEs Provided Based on the Overall Estimating Time

Dependent Variable: Overall Estimating Time

Tukey HSD

(I) Provided VEs	(J) Provided VEs	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
No VEs are provided	VEs are provided and accepted	-6.378*	2.217	.015	-11.71	-1.05
	VEs are provided and not accepted	-.842	2.925	.955	-7.88	6.19
VEs are provided and accepted	No VEs are provided	6.378*	2.217	.015	1.05	11.71
	VEs are provided and not accepted	5.536	2.974	.159	-1.62	12.69
VEs are provided and not accepted	No VEs are provided	.842	2.925	.955	-6.19	7.88
	VEs are provided and accepted	-5.536	2.974	.159	-12.69	1.62

Analyzing the Impact of Major Changes on Time

The next preconstruction element impacting preconstruction time and related to the design aspect of a project is the number of major changes. The number of major changes is related to the scope and sub-scope changes experienced in a project during the preconstruction phase. In this analysis, the goal was to find the association between major changes and overall estimating time. The result indicated a correlation between the number of major changes and estimating time, although the correlation is fairly weak. The more major changes were made, the longer was the estimating time, r (60) = .271, p = .036. See Table 30 below for the actual SPSS output.

Table 30

SPSS Outputs for Correlation of Number of Major Changes with Overall Estimating Time

		Number of major changes
Overall estimating time	Pearson Correlation	.271
	Sig. (2-tailed)	.036
	N	60

Analyzing the Impact of Design Errors on Time

The number of design errors in the model is another preconstruction element that impacts the timing of a preconstruction. In the previous section, it was discussed that design errors is one of the preconstruction elements that directly impacts budget variances. In a separate analysis, the impact of this element on preconstruction time was also identified. In this analysis, the goal was to find the association between the number of design errors and the average time spent on budget updating. The results indicated a significant, yet weak positive correlation between design errors and average time. More design errors in the project model meant more estimating time, r (59) = .288, p = .030. See Table 31 below for the actual SPSS output.

Table 31

SPSS Outputs for Correlation of Number of Design Errors with Average Estimating Time

		Average time spent on budget updating
Number of design errors	Pearson Correlation	.288
	Sig. (2-tailed)	.030
	N	59

The same result was found in relation to the overall estimating time, which indicated a moderate positive correlation between design errors and overall estimating time. The more design errors that occurred in a project, the more likely there would be a longer preconstruction phase, r (61) = .405, p = .002. See Table 32 below for the analysis output.

Table 32

SPSS Outputs for Correlation of Number of Design Errors with Overall Estimating Time

		Overall estimating time
Number of design errors	Pearson Correlation	.405
	Sig. (2-tailed)	.002
	N	61

Analyzing the Impact of Project Recency on Time

Project recency refers to the year the preconstruction phase is developed. Although this decision does not seem to be an actual preconstruction variable, there were interesting findings in relation to project timing and BIM. An important point to note is that projects studied in this research were developed between 2017 and the end of 2019. In this analysis, three project years (2017, 2018, and 2019) were compared based on average preconstruction time. Projects developed in 2017 had a mean increase in time of 151.5 days, projects developed in 2018 had a mean increase in time of 71.95 days, and projects developed in 2019 had a mean increase in time of 67.33 days. The mean difference of 79.57 days between projects developed in 2017 and those developed in 2018 was statistically significant. The mean difference of 84.187 days between projects developed in 2017 and projects developed in 2019 was also statistically significant, $F(2,56) = 4.356$, $p = .017$. See Table 33 below for the actual SPSS output.

Table 33

SPSS Outputs for Post Hoc Tests, Comparing Projects Developed in 2017, 2018, and 2019 Based on Average Time Spent on Budget Updating

Dependent Variable: Average Time Spent on Budget Updating from When the model Released (days)

Tukey HSD

(I) Year of the Project	(J) Year of the Project	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
2017	2018	79.570*	31.863	.040	2.86	156.28
	2019	84.187*	32.757	.034	5.32	163.05
2018	2017	-79.570*	31.863	.040	-156.28	-2.86
	2019	4.617	33.133	.989	-75.15	84.39
2019	2017	-84.187*	32.757	.034	-163.05	-5.32
	2018	-4.617	33.133	.989	-84.39	75.15

The results indicated that on average, earlier projects (2017) spent more time on budget updating, and more recent projects spent less time on budget updating. In the next analysis, the importance of recent projects in relation to using BIM will be discussed.

Analyzing the Impact of Project Recency on BIM in Hard Bid Projects

Following the impact of project recency on time, an additional analysis was completed to identify if the year a project was developed is related to using BIM. As I was studying this variable, I had two different groups of BIM projects: projects that did not use BIM for cost estimating purposes although they had the opportunity to use it, and projects that used BIM for cost estimating. The two different groups were compared based on the year they were developed. Significant results were found only in hard bid projects as projects that did not use BIM, on average, were mostly developed in 2017. Projects that used BIM for cost estimating purposes were mostly developed in 2018. The difference of one year between the two groups was statistically significant, $t\ (22) = 2.644$, $p = .015$. This finding supported the assumption that properly using BIM during preconstruction will shorten the preconstruction phase.

Summary of Results

One of the main goals of this study was to determine the critical preconstruction elements causing budget variances during the preconstruction phase. The project size, project timeline, construction type, awarding methods, and whether BIM was used during the preconstruction phase are examples of critical elements that will impact a project's budget variance or the preconstruction timeframe. The project owners should prioritize these decisions early on and possibly during the feasibility and schematic phases.

Many of the identified critical elements are related to the design and estimating team's capability, effort, and dynamics. Examples of these critical elements are the number of submitted RFIs, providing VEs, model update frequency, design changes, design errors, site assessment, and equipment allocation. Project owners should be aware of the importance of assessing their estimating and design team, making sure they have the same culture and boundaries, understand the project requirements, take the responsibilities while committing to the project set timeline, and consider the goals and objectives of the owner. There are many findings related to elements that are generally believed to be critical, but the study results show that they are not impactful. Examples of these results are setting up a target budget, project function, delivery methods, time of major changes, and building skin (facade). These are examples of elements that the project owners can wait to decide upon as they are prioritizing other critical decisions.

These results can be used to develop the budget-related decision-making tool. The results will enable project owners to be aware of important preconstruction elements impacting their projects' budget and how long the preconstruction phase may take. The results may also help project owners to prioritize their decisions, to avoid unwanted changes in their project budget and preconstruction time and not waste their time on decisions that are not critical. The detailed description of the analyses and how they will be used to meet the study purposes will be explained in detail in later chapters.

Chapter 5: Discussion

In the previous chapter, the statistical analyses related to the direct and indirect impacts of preconstruction elements on the budget variances and preconstruction time were reviewed. In this chapter, a discussion of the results is provided. The results are grouped under four major categories. These categories represent the overall characteristic of their included elements and are named as follows: early and critical project decisions, team action-related decisions, design-related decisions, and project-specific decisions. The results of this study will be explained under each of the four major categories.

Category 1: Early and Critical Project Decisions - The Owner's, CM's, and Designer's Involvement

Many of the elements identified to impact the budget variances and preconstruction time were critical and decisions related to these elements should be discussed during the early planning and programming phase of a project. These elements are the basis of decisions and are discussed under the first group: Early and Critical Project Decisions.

This group includes elements such as the purpose of the project, where the financing is coming from, the skin (façade) type, delivery methods, the use of BIM, etc. This group additionally includes elements that represent a general characteristic of a project such as its size, construction type, location, and other elements that are usually considered by owners as important decisions to review during the early decision-making process.

Project owners should pay attention to these critical elements and prioritize them, especially if they have limited time. Below, detailed discussions about each early and critical element and its impact on budget variation and time needed to complete preconstruction are provided.

Project Size

Project size, typically expressed as building area, is one of the preconstruction elements under the design-related category. However, decisions related to the overall characteristics of this element should be made during the early phases. The results indicate that project owners should discuss with the design team whether or not their project size will change during the later phases. If there is a chance that the project size will change, the owners should be prepared for major variations in their budget.

Changes in a project size not only impact the budget, but also impact the timing of preconstruction. This result is specifically true for hard bid projects. The results indicate that project owners experienced a longer estimating time when they had changes in their project size. The project owners should note that if they have a hard bid project, any changes to the size of a project, specifically after the project is awarded to the contractor, will significantly increase the length of the preconstruction phase.

To control for this, owners should collaborate with the design team and make decisions related to their project size upfront. Ignoring decisions related to the project size may cause unwanted budget and preconstruction time increases in a project.

Target Budget

The second preconstruction element is the owner's target budget which is sometimes called a budget goal or project budget. Anecdotally, having a target budget is considered critical to control a budget during the preconstruction phase. However, the results showed that this element does not have a major impact on actual budget variances. This means that setting up a target budget upfront does not help prevent major budget increases or even save money on the specific project. Project owners can delay decisions related to this element while prioritizing other important decisions impacting the budget.

Interestingly, additional results showed that setting up a target budget upfront will impact the timing of preconstruction. The results indicate that the overall estimating time is longer for projects with a set target budget compared to projects with no target budget. This result also tells us that setting up a target budget increases the length of the preconstruction phase. There might be different reasons behind these results. It is possible that when a project team has a target budget to meet, they need more time to work around the design within the estimate in order to not surpass the target budget set by the owner. Future researchers may probe the reasons and logic behind why having a target budget leads to longer preconstruction time.

These findings suggest that the project owners can wait and not rush into making decisions about the target budget, as this decision will not impact the actual budget variances, but it will negatively impact the length of the preconstruction period.

Construction Type

The project may be a renovation, new construction, or a mix of both. Anecdotally, project owners usually discuss this element when they are not sure if their project will include some degree of renovation, or in the opposite case, where they have a renovation project, and they are not sure if they will have an addition or new construction added to their project. The result shows that this element impacts the budget variations and renovation projects had an average increase of 47% in their budget compared to new construction.

Project owners should note that if they have a renovation project, they most likely should expect major budget variances over the course of the preconstruction phase compared to when they have a new construction or a mix of new construction with renovation. There might be many unknown factors that are causing major budget variances in renovation projects. Finding these unknowns are not the focus of this study. What is important to note is that prioritization of budget-related decisions should be emphasized and carefully watched if project owners are working on an existing building.

Construction Manager's Similar Experience

Signing a contract with a CM that knows the project and has previous experiences on similar projects is another element that is usually discussed during the early programming. The importance of signing a contract with a CM that is familiar with a project is usually emphasized by the project team (Hampton, Baldwin, Holt 2012, Tafazzoli 2017). However, project owners should note that this element will not impact their project budget variances and even the length of preconstruction. Owners should not prioritize this element during the decision-making process. The results indicate that for projects whose CMs had no similar experience, the budget variances and preconstruction time were not significantly different compared to projects in which CMs had previous similar experiences. To prevent unwanted budget variances, project owners can hold on making decisions about this element, specifically when it comes to the selection between two contractors. This is because their previous experiences in similar projects will not significantly impact the project budget variances and even the length of the preconstruction phase.

Something to not get confused about is that a CM lacking similar experience does not indicate that they have no experience on any project. There can be CMs with a high reputation and years of experience on different projects but with limited experience on specific projects that they are going to bid on. Project owners should not ignore these CMs since their limited experience on that specific project will not override their overall expertise.

Project Function

Project function refers to the purpose for which the project is being developed, e.g. for healthcare, residential, or educational functions. The importance of this element lies in projects that may have different uses and are called multi-functional projects. Project owners sometimes are not sure if their project will provide different uses, such as a mix of commercial and residential, or a mix of hotel and conference buildings. Decisions related to what their building is going to provide sometimes specify a significant amount of discussion time during the decision-making process.

The results indicate that the functionality of a project does not cause major variations in the budget. The implication of this finding is that owners should prioritize discussions of other important decisions rather than spending a lot of time deciding on the exact use of their buildings. Specifically, if the amount of time available for the decision-making process is limited, owners should postpone decisions about the function until after other critical elements have been discussed.

Project Location

Project location refers to the region in which a project will be developed (East, West, Midwest, and South Central). Owners may expect the location of their project to affect their budget (Anderson, Molenaar, & Schexnayder 2007, Al-Reshaid et al. 2005). However, the result shows that this element does not impact the budget variances significantly. This means that the location, where a project will be based, is not a reason for major budget variances. Project owners can delay discussions about the location of their project while prioritizing other important decisions impacting the budget.

Interestingly, additional results indicate that the regional location of a project impact the preconstruction time. Preconstruction time was longer in projects located in the eastern region by an average of 190 days compared to projects developed in the Midwest and 144 days compared to projects developed in the south-central region. Therefore, developing a project in the eastern region increases the possibility of having a longer preconstruction phase. Taken together, these findings indicate that the project location will not impact budget variances; however, owners may prioritize decisions regarding the location if the duration of the preconstruction phase is important to them or they have a limited budget.

Because of the fewer number of eastern region projects in the sample based on the selection criteria, there may be some skewness in the results. Future researchers may assess more data from projects in different regions to further investigate the impact of project location.

Project Awarding Methods

The awarding method indicates whether a project will be awarded to a contractor through a hard bid or a negotiating process and is decided very early in the project. Negotiated and hard bid projects are not significantly different as far as experiencing major variations in the budget. However, the preconstruction timing is significantly different in a negotiated project. The results indicate that the overall preconstruction time is longer in negotiated projects by an average of 8.3 months compared to hard bid projects. This result was expected since the project team, specifically CMs, are typically involved from the early conceptual phases, in the decision-making process for negotiated projects. Therefore, the overall duration of the preconstruction phase would be longer compared to hard bid projects, whose CMs are awarded the project later during the preconstruction phase. Project owners should be prepared for a longer preconstruction period and, consequently, consider an increased preconstruction budget, if they decide to award their project through a negotiating method.

The method adopted for awarding was expected to impact the budget directly. An impact was found, but it was actually an indirect impact on the budget variances. As discussed, the length of the preconstruction phase is significantly different in negotiated projects, compared to hard bid projects. The preconstruction time was one of the elements that directly and significantly impacted the budget variances. From these results, it can be concluded that the awarding methods may indirectly impact budget variances.

To avoid unwanted budget variances, project owners should pay attention to the method adopted for awarding and note that if they have a negotiated project, there is a possibility that they experience major budget variances during the preconstruction phase.

Delivery Methods

Decisions related to the project method of delivery (CM@R, DB, and DBB) are should be considered as they may impact the project budget (Bingham, 2014). The delivery method refers to the system that project owners will consider for budgeting and organizing the architectural, engineering, and construction (AEC) delivery. Project owners know the importance of this element and usually prioritize it during the early planning phases. However, the result of the study indicates that this element does not impact budget variances. Therefore, budget variances did not differ significantly by delivery method. Although decisions related to the delivery methods seem important, project owners can delay decisions about delivery method and prioritize other critical elements.

Public or Private Projects

Decisions related to if a project will be publicly or privately commissioned is another preconstruction element. Anecdotally, commissioning a project publicly or privately is considered critical to controlling a budget during the preconstruction phase. However, the results indicate that this element does not have a major impact on actual budget variances. This means that the method used for commissioning a project is not likely to influence whether or not there will be major budget increases or savings on the specific project. Project owners can delay decisions related to this element as they are prioritizing other important elements impacting budget variations.

Construction Manager's Initial Budget Time Frame

Decisions related to when a CM will be involved with a project budget usually occur during early programming. Project owners sometimes make decisions regarding the timing of CM involvement - during the early phases or later after the major design-related decisions are finalized. The results of this study indicate that the time frame when a CM develops the initial budget does not impact the project budget variances. This element also does not impact the duration of the preconstruction phase. It can be concluded that the budget and preconstruction time variances do not differ significantly when comparing projects with early CM involvement to projects with late CM involvement.

Although the time frame of CM involvement seems to be an important element, project owners should not hurry to make decisions about it and can wait until they finalize other critical elements.

Skin (Façade) Changes

Changes in the skin, or façade, of a project relate to changes in the materials and systems considered for a building's envelope. Although the building skin is a design-related decisions, anecdotally, owners may assume that discussions related to their project's skin should happen during the early decision-making process along with discussions about other basic elements such as the budget goal, the type of structure, where the financing is coming from, and the purpose of the project. This assumption also exists within CMs and the estimating team. There is a common presupposition that decisions about the building's skin (facade) should be prioritized during the early decision-making process.

The results of this analysis, interestingly indicate that decisions about the building skin are not critical in how they impact variances to the project budget. Although changes in a building skin were expected to impact the budget variances, the results showed that budget variances do not differ significantly when comparing projects with skin changes versus projects with no skin changes. Project owners should note that although they may intend to prioritize this element, they can wait and not worry about it until they have made other critical decisions.

BIM

Using BIM in a project, specifically during the preconstruction phase, is a decision that is usually discussed during the early programming. We cannot completely claim that using BIM will decrease budget variances, but we have evidence of an indirect relationship between BIM and the timing of a preconstruction, from when the first budget is developed until when the buyout is completed.

The year when a project is planned to be developed (project recency) was found to be related to the duration of the preconstruction phase. The results indicated that projects developed in 2018 had a shorter preconstruction phase, by an average of 79.5 days, compared to projects developed in 2017. This means that the duration of the preconstruction phase is greater in older projects compared to projects developed in recent years. This difference may be due to several different factors; for example, recent projects may be more likely to leverage technology and BIM, which, as explained in the literature review chapter, decreases the time associated with the estimator's activities (Hannon, 2017). In confirming the findings from previous studies, the results of this study indicate that projects developed in recent years used BIM more often for cost estimating purposes.

From these two results, we can claim that using BIM during the preconstruction phase reduces the length of this phase and may impact the buyout process. We can also conclude that in recent projects, people who worked during the preconstruction and buyout process are more familiar with using BIM for cost estimating purposes. Additionally, CMs, in general, are more willing to use BIM during their preconstruction phase. This is an important element for project owners to note. If they use BIM during the preconstruction phase, they are more likely to have a shorter preconstruction period and, consequently, are more likely to have a reduction in the preconstruction budget.

As discussed previously, the preconstruction time is one of the critical elements impacting the budget variances. From these results, it can be concluded that using BIM for cost estimating purposes indirectly impacts project budget variances during the preconstruction phase. To prevent unwanted budget variances, owners should prioritize this element during the decision-making process.

Due to the selection criteria considered for the sample as well as each of the studied projects originating from a single company, there may be some skewness in the results. Future researchers may assess a cross-section of projects from multiple companies to further investigate the role of BIM in preconstruction.

Overall Estimating Time

The length of the preconstruction and the timeline specified for estimating is another preconstruction element that should be discussed during early planning and programming. This element can be influenced by other preconstruction elements such as the estimating team's effort, using BIM, the method adopted for awarding, etc. The result shows the importance of this element in relation to budget variances.

The longer the preconstruction phase, the more likely the project's budget was to increase. This finding shows the importance of setting up a clear timeline for the preconstruction phase and collaborating with the design and estimating team upfront to avoid an unplanned lengthy preconstruction phase. This is a critical decision that project owners should consider as they are making decisions about when to start the estimating activities and when to complete the buyout and start the construction. The findings also underpin the importance of having a capable estimating team that is committed to the decided timelines and manages its activities in a way to meet the owner's deadline.

Category 2: Team Actions Related Decisions - The Owner's and CM's Involvement

Other preconstruction elements impacting budget variances relate to the team's efforts and dynamics. These elements are grouped under the second group: Team Action Related Decisions. This group includes elements that are related to the contractor's team and the different efforts that they are executing in delivering a successful project such as submitting RFIs, practicing VEs, updating the BIM model, adhering to the tracking schedule, etc.

The severity of elements included in this group in relation to project budget variances indicates the importance of investing in a capable and productive estimating team to minimize significant budget variances. Discussions about which estimating team should be contracted is a critical decision that should be prioritized by project owners during the decision-making process. The findings related to how the team's actions impact the budget variances are discussed individually below.

Model Update Frequency

Model update frequency refers to the estimating team's effort in using and updating the Revit model for budget estimating purposes. The team's effort in updating the model impacts both the budget variances and the length of preconstruction. The results indicate that the more effort an estimating team puts into the model update, the more likely they experience major increases in their project budget.

Working more with the project model and having budget increases may not look appealing to project owners. There might be different reasons behind this result. There may be various details and information about a project requirement included in the model which as explained by Masfiled, Ugwu, and Doran (1994), will impact the budget. The estimating team may need to update the cost associated with these requirements in the budget and this could significantly change the budget. Identifying the reasons of having budget variances from model updates is not the focus of this study. Future research may further elucidate the relationship between model updates and budget.

Interestingly, the model update frequency impacts the timing of a preconstruction. This result is specifically true for negotiated projects. The results indicate that the more effort the estimating team puts into the model update, the more likely that a shorter preconstruction period would be experienced. Project owners should note that the productivity and quality of their estimating team in working with the model is a factor in having a shorter preconstruction period and, consequently, having a reduction in the preconstruction budget. This is an important decision for owners, specifically if they have a limited budget for preconstruction.

Since the design team typically provides the initial Revit and BIM model to the estimating team, providing the BIM model is a critical consideration for project owners and designers within the early decision-making process. In addition to the importance of providing BIM for cost analysis purposes, project owners should pay attention to the importance of having a capable estimating team that can work with the model and update the budget.

Number of Submitted RFIs

The number of submitted RFIs is an indicator of the CM team's effort to request information about project ambiguities from the design team. This element also represents the estimating team's ability to understand the project requirements, coordinate with the design team, identify project ambiguities, and request the design team to clarify the project drawings, specs, and model. The results show the importance of this element in relation to budget variances and this specifically applies to hard bid projects.

The results indicate that the number of submitted RFIs and budget variances are negatively correlated. The more RFIs that were submitted, the less likely the project's budget was to vary. Besides the importance of delivering a high-quality design package with fewer ambiguities, this tells us the importance of the estimating team's effort in understanding the project and how following up with any unclear information in the documents will impact the overall budget variances. The conventional wisdom might be that many RFIs is a sign of a poor on incomplete design. However, in the preconstruction phase, having many RFIs is an indicator of the estimating team's diligence to clearly understand the project. Since the design is frequently not yet complete yet in this phase, questions related to the design are expected. If the estimating team spends time and follows up with more information from the design team, they will be able to develop a high-quality budget estimate and will have fewer variances in their budget. This is a critical element that project owners should consider; a more diligent project estimating team will more fully investigate the details of the design (as indicated by the number of RFIs submitted) which will lead to more budget stability. This also shows the importance of investing in a productive estimating team that requests more information to get a deeper understanding of the design documents that will lead to fewer significant budget variances.

Providing VEs

Providing VEs is another preconstruction element related to the team's effort in providing different alternatives to the project owners. Decisions related to providing VEs are considered by project owners when an estimating team gets involved with budgeting a project. This element was identified to impact budget variances. The results were specifically true for hard bid projects.

More important than the provision of VEs by estimating teams is the owner's willingness to review and accept the provided VEs. The results indicate that there is a major budget decrease, an average decrease of $32,248,137, in projects with VEs provided and accepted compared to projects with VEs provided but not accepted. This means that if project owners get involved with providing VEs, review, and accept VEs as they receive them from an estimating team, they are more likely to experience a major budget decrease. It is also important to invest in a productive estimating team capable of putting forth more effort into practicing VEs and providing material and budget alternatives to the owner. Additionally, it is important to contract with a well-known estimating team that has strong relationships with subcontractors since many of the suggested VEs are usually suggestions from capable subcontractors.

Providing VEs also impact the duration of the preconstruction phase. The results indicate that the duration of the preconstruction phase is greater in projects with VEs provided and accepted compared to projects with no VEs provided. Project owners should note that if they are planning to provide VEs, the process of receiving and reviewing VEs can take time and is likely to affect the length of their preconstruction phase. Consequently, this process may indirectly translate to an increased budget during the preconstruction phase. This finding was expected since providing VEs involve the project owners, project team, and even subcontractors in different collaborating and decision-making processes, which typically adds time to the overall preconstruction period.

Budget Update Frequency

The number of times the estimating team updated a project budget is an element that was expected to impact the budget directly. An impact was found, but it was an indirect one. Results indicate that updating the budget more frequently is associated with a longer preconstruction period. As discussed, the preconstruction time was one of the elements that directly and significantly impacted the budget variances. From these results, it can be concluded that the budget update frequency indirectly impacts the budget.

Budget updates may happen because of different factors such as receiving changes in the drawings, specifications, and clarifications as well as receiving new information about the project requirements, either from the design team or the owners. Project owners should note that as the estimating team receives more frequent information about a project, in general, the more frequently they are required to update the budget, and this will cause the preconstruction period to be longer. Accordingly, they should plan for an increased preconstruction budget.

One implication of these findings is that the project owners and design team should provide a project delivery package of high quality, in specific time phases, and preferably earlier rather than later. The project delivery package includes all the design, specifications, requirements, and clarifications about the project. They should avoid providing single pieces of information frequently (which can be in the form of an addendum) and have fewer design packages with more information and higher quality. Project owners should discuss these elements upfront if they want to avoid having a longer estimating time and unwanted budget variances. This result also shows the importance of having a productive estimating team capable of recognizing changes in the project requirements, putting forth more effort, and updating the budget accordingly.

Tracking the Schedule

The team's effort in updating and following a project schedule also represents the estimating team's capability to understand the time impact of changes that occur during the preconstruction phase. The importance of providing a realistic schedule and following up with that is emphasized by previous studies (Tafazzoli, 2017). However, the results show that this element does not have a major impact on the budget variances during the preconstruction phase.

This means that involving the scheduling department and tracking the schedule during the preconstruction phase does not help prevent major budget variances or even save money for a specific project. Decisions regarding tracking the schedule can be safely delayed while other important decisions impacting budget variation are prioritized.

Category 3: Design-Related Decisions - The Owner's and Designer's Involvement

Other preconstruction elements impacting the budget variances are related to the design aspect of a project. These elements are grouped under the third group: Design-Related Decisions. Examples of the included elements are providing the model site assessment and equipment allocation, model design errors, design changes, etc. The impact of the included elements on project budget variances and in some cases, preconstruction time, underpins the importance of hiring a capable design team that can provide a high-quality design package with fewer errors and ambiguities to minimize the budget and time variation during the preconstruction phase.

There are elements included in this section that are model-based and impact project budget variances and preconstruction time. In addition to hiring a productive design team, the project owners should note the importance of using BIM and deliver a high-quality Revit model with more details and fewer errors to minimize the unwanted budget variances.

Decisions about hiring a capable design team and delivering a high-quality model are critical and should be prioritized by project owners during the decision-making process. The findings related to the impact of the design-related elements on the budget variances are discussed individually below.

Site Assessment and Equipment Allocation

The model site assessment is one of the elements provided by the design team in the Revit model. Anecdotally, owners may not pay attention to what details and information are included in their project models. The results indicate that providing a project site assessment in the model causes a major increase in the budget. Modeling the project site and having budget increases may not look appealing to project owners. There might be different reasons behind this result. Understandably, providing the site model and its related details enables the estimating team to benefit from the provided information. The estimating team would be more aware of project site requirements in that they should apply their related budget to the estimate. Consequently, this causes increases in the budget.

The equipment allocation, defined as the specification of a building's mechanical and electrical equipment, is another element provided by the design team in the model. Project owners should note that if their design team puts forth more effort in providing equipment allocations in the model, they are more likely to provide additional information and requirements about the project, which requires the estimating team to apply a related budget to the estimate which causes the project budget to increase significantly.

Experiencing budget variances from these model-based elements (site assessment and equipment allocation) is not necessarily a negative point since they can help the project get closer to reality and cause the budget to be changed based on the actual requirements of the project. To control for this, project owners should consider the importance of decisions related to providing site assessment and equipment allocation during the decision-making process to help the estimating team evaluate the budget more realistically.

Model Design Errors

The number of design errors in a model reflects the quality of the design package delivered to the estimating team. The results indicate that projects with more design errors in their models are more likely to have greater budget variances. Since the delivered model will be used for the cost estimation and analyses, the more errors that exist, the more variations in the budget will occur.

Model design errors are also related to preconstruction time. The results indicate that the preconstruction period is longer in projects with more design errors in their models. These two results indicate that a low-quality model with more errors will cause increases in both project budget variances and the duration of the preconstruction period.

The results related to design errors highlight the importance of investing in a productive design team that provides a higher quality model. Project owners should also invest in a productive estimating team that is able to work with the model and identify its errors. With the right investments on the right estimating and design team, the project owners will have fewer design errors and experience fewer variances in the budget, and a shorter preconstruction period. To avoid these issues, owners should prioritize this element during the decision-making process.

Major Changes

The number of major changes represents changes in project scope and sub-scopes. Having major changes in a project is considered critical to controlling a budget (Anderson et al. 2007). However, the results indicate that this element does not have a major impact on budget variances during the preconstruction phase. This means that avoiding scope and sub-scope changes in a project does not help prevent major budget increases or even save money for the specific project. Project owners can delay decisions about major changes and prioritize other important elements impacting budget variances. Interestingly, additional results show that major scope and sub-scope changes will impact the length of the preconstruction period. In projects with a significant number of major changes, the length of the preconstruction phase is longer.

Taken together, findings regarding the impact of major changes on budget variation and the duration of the preconstruction period indicate that owners should prioritize decisions about major changes and collaborate with the design team. Specifically, if the duration of the preconstruction period is important to the owner and they have a limited preconstruction budget, this is an element that they should take into consideration.

Time of Major Changes

The time frame during which major scope and sub-scope changes are made to a project (early, middle, and late during the preconstruction phase) is the next design-related element. Anecdotally, the time frame when major changes happen is considered critical to controlling budget variances. There is a belief among project teams that later scope changes may cause more significant impact on the budget than earlier scope changes. Previous studies also emphasized the importance of late design documents in relation to the timing of a project (Gebrehiwet & Luo, 2017). However, the results of this study indicate that this belief is not necessarily true and the budget variances were not significant in projects with later scope changes.

This does not mean that having later changes will not cause budget variances in a project. But it does mean that having later changes will not cause more significant budget variances, compared to changes made during earlier phases. Project owners should not feel that they are handcuffed and thus cannot make necessary changes because it is late in the process. They should note that major changes will affect their project budget no matter whether it is during early or later phases.

This is an interesting finding that may decrease owners' worries about having late scope and sub-scope changes. The finding also supports the importance of CMs providing good customer service by allowing the project owner to make scope or sub-scope changes when necessary. The timing of major changes is one of the decisions that project owners can delay and not prioritize during their decision-making process.

Design Changes

Changing the design is another element that is considered critical to controlling a budget (Mansfield et al 1994, Akogbe et al. 2013, Tafazzoli 2017). Although the results did not indicate a direct impact of design changes on the budget, there is evidence of an indirect relationship between design changes and budget variances. The results indicate that design changes impact other elements that have a direct impact on budget variances.

The findings indicate that there is a major increase in the project size, by an average of 122,335 sf, when a project design changes. This is specifically true for hard bid projects. The major increases in project size were not observed when the project design does not change. The importance of project size and its direct impacts on budget variances were discussed earlier in this chapter. From these results, we can asset that there is an indirect relationship between design changes and budget variances.

To prevent unwanted budget variances, the project owners should avoid design changes since this element not only impacts other critical elements, but also impacts budget variances indirectly. Project owners should make decisions about their project designs upfront, have proper collaboration with the design team, and avoid changes in the design during later preconstruction phases.

Category 4: Project-Specific Decisions - The Owner's, CM's, and Designer's Involvements

Preconstruction includes project risk-related elements that are grouped under the fourth group: Project-Specific Decisions. These elements are about the project contingencies, fees, permits, escalations, and other elements that are usually considered and are set up by the CMs as they develop a project budget.

The results provided in this group are not a basis of decisions. However, they are the CMs' risk-related decisions and help project owners better understand how these elements will change, given any major variation in their budget. Findings in this group are also for CMs to note that if they experience budget variances, they would make major changes in the amount of risk-related elements in their estimate proposal.

The demographic data related to these elements are provided in Table 5 in chapter 3. Many of these specific elements were not significantly related to budget variances; however, there is interesting information in these data that needs to be further researched by future studies. An overview is provided here.

In 84% of projects, the considered contingency either stayed the same or decreased during the preconstruction phase. These findings may be explained by a number of reasons. The CMs may try to lower the budget to be competitive or may have had fewer concerns about unknowns as they were getting close to the end of the preconstruction phase. Similar findings were identified in data from other risk-related elements such as builder's risk insurance (BRI), permit, escalation, sub-default rate, fees, reimbursements, permit, bond and insurance (PBI), and general requirements. Owners may think that the numbers they see for these elements in the received proposal are fixed. But as the project design and budget develop, they will see variations in these numbers.

Another important point to note is that the range of percentages may appear negligible. For instance, the range of percentages considered for construction contingency in the studied projects was -1% to 0%. The lowest value of the range, -1%, may seem trivial but 1% of a total budget of $350M project is $3.5M and in some projects can be half of the contractor's fee. Owners should always pay attention to these percentages and not get confused with the seemingly small percentage variations. Additional results related to the risk-related elements that impact budget variances are described below.

Escalation

In general, CMs consider the cost of escalation as they develop a project budget. The importance of escalation in relation to the budget was emphasized by previous studies (Anderson et al. 2007). The result of this study confirms the previous findings and indicates that projects with major budget variances usually have significant variations in the amount considered for escalation.

Escalation is an element that CMs usually consider to protect their budget from price fluctuations. This number heavily relies on the CM's understanding of market condition and can vary from time to time. But, from the results, it can be understood that the variation in this element is not solely dependent on the market condition and can be adjusted by CMs based on variations in the project budget. This result is specifically true for negotiated projects. Project owners should always watch for this element and expect to have variations in it whenever there are major variations in their project budget.

General Conditions and Requirements

General conditions and requirements are elements that CMs usually consider for the cost of resources that are required for staffing such as superintendents, trucks, fuel, and the cost required to run a project such as a trailer, cleaning, dumpster, etc. Anecdotally, the cost of general conditions and requirements is considered as a fixed number with minimal changes. However, the results interestingly show that the cost of general conditions and requirements could significantly decrease if a project experiences significant budget increase.

There may be a rationale for variations in general conditions and requirements. For instance, CMs may find out that they will be able to manage the cost of staffing and site requirements and drop their cost just to be competitive and be closer to the project target budget.

What is important for project owners to note is that they are likely to receive major decreases in the number of general conditions and requirement items proposed by their CM if they have major changes in their project budgets.

Building Permit

The cost of the building permit is influenced by different factors such as the city, district, project type, size, structure, etc. The overall cost of the permit is calculated and incorporated into the budget by CMs. The permit is another element whose cost is usually considered as a fixed rate with minimal variations for a project unless there is a major change in a city legislature or in a project design. However, the results interestingly show that permit costs can significantly decrease if a project experiences major increases in the budget. This result is specifically true for hard bid projects.

CMs may find permit cost as another element that they will be able to decrease just to be competitive with their bidding proposal. Finding the reason behind these variations is not the focus of this study. What is important for project owners to note is that they may observe variations in the cost of the permit specifically if they have major increases in the project budget later along the preconstruction phase.

Design Fee and Reimbursements (DFR)

The DFR is another element whose cost is included by CMs in a project budget. This element is more about the charges from the design team for their performance of duties. Interestingly, the results indicate that any major increases in the project budget may lead to a significant increase in the cost of the DFR. This means that the charges from the design team are mainly reliant on a project budget and variations in the budget would cause the DFR to also change. This result is specifically true for hard bid projects. Project owners should be aware of possible major increases in the amount of the DFR if they have major increases in the project budget.

Sub-Default Rate

The sub-default is another risk-related element considered by CMs as they develop a budget to cover for potentially bonding subcontractors at the prime contract stage. This element is used when CMs are hiring subcontractors to do a scope of work. Depending on the size of the subcontractor's contract and their financial status, CMs may be required to bond specific subcontractors. Instead of going through and bonding individual subcontractors or guessing which ones will be required at a budgeting stage, CMs may consider a fixed rate, such as 1.1% on the full cost of work.

The results indicate that sub-default is tied to the project budget and by any major variations in the project budget, the rate of sub-default will significantly change. This result is specifically true for hard bid projects. These variations may be due to CMs finding out that there are more risks associated with bonding subcontractors when a project budget increases. What is important for project owners to note is that they are likely to observe major increases in this sub-default rate proposed by their CM if they have major increases in their project budgets.

Interpretation Summary

The results of the data analyses were described as the goals of providing a decision-making guide were kept in mind. Overall, there are many project elements that would impact the project budget variances and even the time needed to complete preconstruction. These elements can be decided during the early and pre-planning phases, can be related to the team's actions, the design aspect of a project, and even be related to risk-related considerations. For better understanding and having an overall picture of how preconstruction elements impact the budget variation, the results are summarized in Table 36 below.

Table 34

Overall results summary table

Group	Sig Elements	Impact on	Not Sig Elements	Group
Early & critical project decisions	Overall estimating time Project size Construction type Awarding methods BIM Project recency	Δ Budget	Target budget CMs Similar Experience Project Function Location Delivery methods CMs initial budget timeframe Skin (façade) change Public/ private Early structural information Structural change Location Change Early programming CM initial budget timeframe Early location	Early & critical project decisions
Team's actions related decisions	Model updates Number of submitted RFIs Provided VEs Budget update Tracking schedule		Documentation of cost changes Element cost analysis Poor communication and coordination Average estimating time	Team's actions related decisions
Design-related decisions	Model site assessment Model equipment allocation Design errors Design changes		Number of major changes Time of major changes Structural model Detailed material in the model	Design-related decisions
Project-specific decisions	Escalation General condition General requirements Permit Sub-default rate DFR		Construction contingency BRI PBI Fee Owner contingency Design contingency	Project-specific decisions

This study started with collecting 61 preconstruction elements. Out of those elements, only 21 of them were identified to impact the budget variations either directly or indirectly. Knowing the impact of these elements on the budget variances will help project owners prioritize their important decisions and help them make the most beneficial decisions when managing their project budget and even the preconstruction time.

Although the focus of the study is on project budget variances, results related to the impact of preconstruction elements on the time needed to complete the preconstruction phase were identified. These results may represent complementary information for owners who are worried about the preconstruction timing and have a limited preconstruction budget. As discussed earlier, the budget and time were two of the three indicators of a project's success. By making decisions about the critical elements impacting budget variations and even the preconstruction time, project owners will be able to achieve more success in their project and manage the decision-making process more productively.

Chapter 6: Conclusions and Recommendations

The purpose of this study was to use results from the analysis of preconstruction elements on budget variances to inform project owners on critical decisions that they have to prioritize in order to minimize budget variances in their project. It was also the purpose of the study to inform project owners on commonly accepted decisions that are not critical and can be given a lower priority in order to focus on more critical decisions. The end goal of the study was to develop a guidance and decision-making tool that project owners will be able to use to assess the impact of their decisions. Furthermore, the aim of this project was to inform the industry about the value of a decision-making tool rooted in numeric information as opposed to other existing tools that utilize subjective information.

General Recommendation for Project Owners

The ultimate goal of preconstruction is to arrive at a design, budget, and schedule that meets the owner’s needs. One critical component of this process is to control budget variances because failing to have budget certainty increases the risk of poor project outcomes such as poor project quality and inaccurate project financing. Failing to minimize budget variances also causes owners to be faced with more uncertainty regarding the project’s financial viability. These uncertainties will directly impact the length of the planning phase and when the project can start. To prevent unwanted variations in a budget, project owners should be familiar with preconstruction elements that cause budget instabilities, prioritize their decisions ahead of time, and be equipped to make better decisions during the preconstruction phase.

Project owners usually start with general ideas to set up their project, such as what is the purpose of their project and where the financing is coming from. Equally important as discussing these general ideas, project owners should consider the importance of having a productive decision-making process and bringing the project team to the table. Owners should discuss the critical decisions with the project team and if they are short on time, use the provided guidelines and tools to prioritize more important decisions to expedite the process. There are many preconstruction elements that significantly impact budget variances and preconstruction time. Not only is it critical to be familiar with these elements, but also owners should educate the rest of the project team, including designers and CMs, about decisions related to these critical elements and make them implement these decisions into their practices.

Given the critical nature of the project budget variances and timeline, owners should be concerned with understanding the project team's responsibilities, performance, contractual, and risk-related boundaries. What is important is how the project team is able to implement the recommended solutions based on a specific project that they are working on. The project team should ideally be in agreement on prioritization of the critical decisions, but this can be difficult because design firms and contractors have their own ways of implementing these solutions. This is why the owners should educate themselves about the project team that they will contract with and make sure that the team has the same culture to avoid these differences, to enhance the decision-making process, to work productively, and to accomplish best practices. Owners should also look at the involvement of the project team members and their willingness to work productively with each other. They should look for a project team that understands its responsibilities and is willing to come to the table to help with enhancing the decision-making process, is capable of coming up with solutions to resolve issues, is able to execute the decisions made, and is adept at the use of advanced software platforms (such as BIM) to accomplish the owners' critical decisions for minimizing budget variances.

Owners should understand the importance of prioritizing critical decisions that significantly impact their project budget and make sure that everyone on the project team understands the critical nature of these decisions and is willing to implement recommended solutions to enhance the process. Here is where the existence of a decision-making tool plays a role in educating the owners to assess the significance of their decisions and what they should expect regarding budget variances if they practice what they have planned for. For aiding project owners with a better decision-making process and reducing the risk of having budget variances during the preconstruction phase, a report of critical preconstruction decisions that should be considered by project owners is provided in this study. This report is provided in four main categories: early and critical project decisions, team action-related decisions, design-related decisions, and project-specific decisions.

Early and Critical Project Decisions - The Owner's, CM's, and Designer's Involvements

Discussions included in this section are about critical elements representing the overall characteristic of a project such as the purpose of a project, financing, overall design, façade, etc. Project owners usually discuss decisions about these elements during early programming stages. Many of these elements have been identified to impact budget variances as well as the time needed to complete the preconstruction phase. There are some elements that are anecdotally believed to be critical but were not shown by any analyses to have an impact on budget variances. These elements are also included in the discussion. The main conclusion from the early and critical project decisions are listed with no order of importance and are as follows:

1. Project owners should discuss about the length of preconstruction and set the timeline for when to start the estimating activities and when to complete the buyout. Owners should discuss about these timelines with the project team and make sure that they are committed to

the set deadlines. These timelines are to help the project team with what they are required to deliver, their responsibilities, and the deadline that they have to meet. This result was consistent with discussions from Hunter (2014).

2. To control for budget variances, project owners should prioritize decisions related to the project size (building area) up front and collaborate with the design team accordingly. They should avoid changes in the size of their project during later parts of the preconstruction phase. This finding was consistent with results from Potts et al. (2014).
3. Project owners should carefully watch budget-related decisions if they have renovation projects. They should note that there is a possibility of having major budget variances in these construction types. This finding was not noted in the literature.
4. To prevent unwanted budget variances, project owners should consider the method adopted for awarding their project. Projects awarded through the negotiated process tend to have a longer preconstruction phase and this may indirectly lead to major budget variances during the preconstruction phase. This finding was not noted in the literature.
5. Decisions related to using BIM during the preconstruction phase should be prioritized. Project owners should note that if they use BIM during this phase, they are likely to have a shorter preconstruction, a reduction in their preconstruction budget, and indirectly fewer budget variances. This finding was not noted in the literature.
6. Project owners should not rush in making decisions about their project target budget. They should note that setting up a target budget will not help them with reducing budget variances and may negatively impact the time needed to complete their preconstruction phase. This finding was not noted in the literature.

7. Project owners should not spend a lot of time reviewing CMs' experience on similar projects. This does not mean that it is not important to contract with a highly reputed CM with years of experience. It means that if owners have a specific project, such as a unique federal museum, and their reputed CM does not have expertise on that specific project, they should not be concerned about it. This result was not in alignment with results from Hampton et al. (2012) and Tafazzoli (2017).
8. Project owners should not be concerned about the functionality of their project. Even if there is a possibility of having a multi-use building and they are not sure what specific functionalities will be included, owners should not be worried about it. This finding was inconsistent with results from Potts et al. (2014).
9. Project owners should not spend a lot of time on making decisions about finalizing the location of their project. This element is not going to cause major budget variances in their project. However, if they are concerned with the preconstruction timing and have a limited preconstruction budget, they should note that projects developed in eastern regions are more likely to have a longer preconstruction phase. This finding was consistent with results from Anderson et al. (2007) and Al-Reshaid et al. (2005).
10. Commissioning a project publicly or privately is a decision that owners can wait on. No major impact on budget variances was identified when comparing public versus private projects. This finding was not noted in the literature.
11. Project owners can delay making decisions about the delivery method. The budget variances were not significantly different by delivery method. This result was not consistent with findings from Bingham (2014).

12. Decisions related to when a CM will be involved with a project budgeting should not be prioritized. Involving CMs from early stages does not cause major variances in the budget compared to when CMs are involved during later phases. This finding was not noted in the literature.
13. Project owners can delay finalizing decisions related to their project skin (façade). This element was expected to be critical; however, it was identified to not cause major budget variances. This finding was not noted in the literature.

Team Actions Related Decisions - The Owner's and CM's Involvements

To minimize budget variances, project owners should note the importance of investing in a capable and productive estimating team since many of the preconstruction elements impacting budget variances and even the time needed for preconstruction are related to their effort in providing a high-quality estimate, willingness to work with BIM, and collaborating with the project team. The main conclusions from the team action-related decisions are listed with no order of importance and are as follows:

1. The estimating team's capabilities in understanding the project and following up with unclear information in the documents in terms of submitting RFIs will impact the budget variances. The budget variances were fewer in projects with more submitted RFIs. This finding was not noted in the literature.
2. The estimating team's capabilities in practicing VEs may lead to decreases in a project budget. Besides the capability of the estimating team, the owner's willingness to review and accept VEs is a key factor in having successful VE practices. In addition, the reputation of the contractor and their relationship with subcontractors play a role since many suggested

VEs are recommendations from trade partners. This finding was consistent with results from Mansfield et al. (1994), Anderson et al. (2007), and Potts et al. (2014).

3. The estimating team's capability in updating the Revit model for cost estimating purposes impacts budget variances. Besides the willingness of the estimating team in working with technology, the capability of the contractor company in adopting BIM and working with the provided models is important for minimizing budget variances. If owners were short on time or have a limited budget for preconstruction, they should note that the capability of the team in updating the model helps with having a shorter preconstruction phase. This finding was not noted in the literature.
4. The estimating team's capability in updating the budget more frequently helps with having a shorter preconstruction phase and indirectly impacts the budget variances. Owners should plan on how many budget deliveries they are expecting to receive from a CM and coordinate appropriately with the estimating team up front. This finding was not noted in the literature.
5. Project owners should note that specifying a budget to involve the scheduling department and tracking the project schedule during the preconstruction phase is not critical. Owners can wait and not prioritize decisions related to this element. This finding was not noted in the literature.

Design-Related Decisions - The Owner's and Designer's Involvements

To avoid issues related to budget variances, project owners should note the importance of investing in a productive design team since many of the preconstruction elements impacting budget variances are related to low-quality design packages and the capability of the design team in providing model-based information. The main conclusion from the design related decisions are listed with no order of importance and are as follows:

1. Project owners should consider the importance of providing model site assessment and equipment allocation from the design team to control for budget variances. These model-based information may help with the budget to be changed based on the actual requirements of the project. This result is in alignment with findings from Tafazzoli (2017).
2. Project owners should note the importance of delivering a high-quality design package with fewer design errors since the design errors is one of the key elements causing variations in the budget. This result is in alignment with findings from Tafazzoli (2017), Craigie (2015), and Anderson et al. (2007).
3. Project owners should note that having design changes later during the preconstruction phase indirectly causes budget variances. They should note that it is important to prioritize decisions related to the design changes up front and collaborate with the design team accordingly. This result is in alignment with findings from Mansfield et al. (1994).
4. Project owners should note that decisions related to having major scope and sub-scope changes are critical. They should prioritize this decision and collaborate with the design team. This result was consistent with findings from Craigie (2015) and Anderson et al. (2007).
5. Project owners should note that the time when the scope and sub-scope changes will be made in a project is not important. Project owners can wait and not prioritize this decision. This result was not consistent with findings from Gebrehiwet and Luo (2017).

Project-Specific Decisions - The Owner's, CM's, and Designer's Involvements

Project owners should always watch for risk-related elements and discuss about them with their CMs as they deliver a budget proposal. Owners should note that these elements are likely to change with any major variations in a project budget. The main conclusions from the project-specific decisions are listed with no order of importance and are as follows:

1. The considered amount for construction contingency, BRI, permit, escalation, sub-default, fees, reimbursements, PBI, and general requirements are likely to stay the same or decrease during the preconstruction phase. Project owners should note that these risk-related elements can be changed and used as a tool to control for the project budget.
2. Project owners should be aware that the amount considered for escalation in the proposal may not completely based on the market condition and can be dependent on the project budget variances. This result was consistent with findings from Tafazzoli (2017) and Anderson et al. (2007).
3. The considered rates for general condition, general requirement, and permit are flexible and can be dependent on the project budget variances. These elements can be used by CMs as a tool to control for a project budget.
4. Charges from the design team in terms of design fee and reimbursements are dependent on the project budget and can change with variances in a project budget. This result was consistent with findings from Del Puerto et al. (2016).
5. The considered rate for bonding subcontractors is tied to the project budget. Project owners should note that there might be more risk associated with bonding subcontractors when they have major increases in their project budget. This finding was not noted in the literature.

The Prioritization Guide

The major contribution of this study is to aid project owners with prioritizing critical preconstruction elements and making better decisions to reduce the risk of having budget variances during the preconstruction phase. For this purpose, the study prioritization guide was developed.

This study started with an idea of developing a decision-making tool. The most effective decision-making tool provides more concrete information about the impact of a decision when existing unknowns occur along a continuum. Therefore, in response to the study research question three, the more appropriate application of these findings would be a decision-making guideline rather a tool. This decision-making guide was developed to direct owners' focus and their decision. Rather than focusing on just making decisions, this guide will direct owners on when and how to prioritize decisions. The full study prioritization guide is in Appendix A.

Project owners can refer to this guideline once the project schematic information is available to work out how to prioritize their decisions and when each critical decision must be made. This information will also help owners to hold back on finalizing some decisions that are not critical especially if there are other parties that need to provide input into the decisions on project aspects. The practicality of this guideline is not limited to the project owners. The project team, including CMs and designers, can also use this guideline to identify the owners' critical decisions and expectations and be better prepared for these critical decisions, by planning for it ahead of time.

Impact of The Study

It was noted in this study that variances in budget happened in a majority of construction projects. This is partly because owners are not aware of the magnitude of their decisions and how they may lead to instabilities in a project budget. Often, owners focus on decisions that they believe are critical, but these decisions may not be critical and should not be prioritized. A better strategy for the owner would be to focus on more important decisions that would minimize major variances in the project budget. The other outcome of the study for the industry was to highlight the importance of owners working with the rest of the team and adopting the provided guidelines, practicing it during their decision-making process, and being equipped to maximize budget certainties ahead of time.

An additional impact of the study is to point out the value to the industry of making decisions based on objective information. The results of the study proved that researchers in the construction field can work with advanced software platforms to collect information and they do not need to rely on human judgment or interviews to develop their results. These findings may inform a shift in the industry.

Limitations

Measuring numeric values was the focus of this study and other historical data that were subjective and not numeric are not included. Although a comprehensive list of critical preconstruction elements is included in this research, there may be other subjective elements that were not collected and not included in the study analyses. In addition, the majority of projects reviewed in this study are non-federal commercial buildings. Therefore, the findings of this study may not be generalizable to federal projects.

The next limitation is related to using BIM as the data collection method in this study. Since studying objective data was the focus of this study and for this aim, a BIM advance platform was used. Inherent even in a seemingly objective environment are the people that manage the preconstruction process and generate BIM data. These people may make decisions based on their own experiences, biases, or, in the very least, based on information available at the time. This means that there may be some subjectivities in how the BIM data is created and subsequently conceived of.

Recommendations for Future Research

This research may be further advanced through the following recommendations:

I. Adding subjective elements to the decision-making tool: Since the study decision-making tool was based on numeric data, many budget-related elements that could be identified by talking to preconstruction professionals were not included in it. Examples of these elements are: where is the financing coming from? What is the contract's intent? What are the owner and project team looking for from the first stage? Future researchers may study these elements and find out if they are related to budget variances during the preconstruction phase.

II. Studying the quality aspect of a project: Of the three outcomes, budget, time, and quality, the budget was completely studied in this research. Additional results related to the preconstruction time were also identified. However, the quality aspect of a project was highly subjective and not reviewed. Future researchers can focus on quality and identify its relationship to the budget variances.

III. Identifying legitimate reasons behind variances in the risk-related elements in relation to the budget: In this study, it was identified that the considered rate for risk-related elements such as considered contingency, BRI, permit, escalation, sub-default, fees, reimbursements, PBI, and general requirements either stayed the same or decreased during the preconstruction phase. This is an area for future researchers to identify the legitimate reasons behind these findings as why these rates are manipulated when a major budget variance is experienced.

IV. Identifying the reason behind the positive correlation between model updates and budget variances: From the analyses, it was identified that the team’s effort in updating the BIM model increases the likelihood of having major budget variances. Future researchers can focus on this topic and identify the reasons for budget variances.

V. Developing and testing a more robust decision-making tool. Based on the results identified in this study, a more appropriate application was to develop a prioritization guideline rather than a tool. Future researchers may develop and test decision-making tools that elucidate the risks associated with each decision or set of decisions.

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Appendix A: Prioritization Guide for Preconstruction Decisions

The study decision-making guideline includes four main categories: early and critical project decisions, team actions related decisions, design-related decisions, and project-specific decisions. In front of each category, preconstruction elements related to that category are listed. These preconstruction elements are followed by arrows pointing to the timeline when those decisions should be discussed during the preconstruction decision-making process.

Category	Element	Decision Timeline		
		Feasibility & Schematic Decisions	Schematic Decisions	Post Schematic/ DD through Permit Set Decisions
Early & Critical Project Decisions - The Owner's, CM's, and Designer's Involvements	Overall preconstruction period	→		
	Project size (building area)	→		
	Construction type (renovation, new construction, mix of both)	→		
	Awarding method	———	→	
	BIM	———	→	
	The year when a project will be developed	→		
	Target budget	———	———	→
	CMs similar experiences	———	———	→
	Project function	———	———	→
	Location of the project	→		
	Delivery methods	———	———	→

Category	Element	Decision Timeline: Feasibility & Schematic Decisions	Schematic Decisions	Post Schematic/ DD through Permit Set Decisions
Early & Critical Project Decisions - The Owner's, CM's, and Designer's Involvement	CMs initial budget timeframe	—	—	→
	Skin (façade)	—	—	→
	Public/ private project	—	—	→
Team Actions Related Decisions - The Owner's and CM's Involvement	Model updates	→		
	Submitting RFIs	→		
	Providing VEs	→		
	Tracking schedule	—	—	→
Design-Related Decisions - The Owner's and Designer's Involvement	Model site assessment	→		
	Model equipment allocation	→		
	Design errors	→		
	Design changes	—	→	
	Major scope and sub-scope changes	—	—	→
	Time of major scope and sub-scope changes	—	—	→
Project-Specific Decisions - The Owner's and CM's Involvement	Escalation	→		
	General conditions and requirement	→		
	Building permit	→		

Category	Element	Decision Timeline		
		Feasibility & Schematic Decisions	Schematic Decisions	Post Schematic/ DD through Permit Set Decisions
Project-Specific Decisions - The Owner's and CM's Involvement	Sub-default rate	⟶		
	Design fee and reimbursements	⟶		

Appendix B: Lists of Study Data Analysis

This appendix provides lists of different analyses identified during the data analysis process. The analyses are provided in seven different tables. The first table, table B1, shows the correlation analyses in all reviewed projects (n=61). The second table, table B2, shows the results of the ANOVA and t-test analyses in all of the studied projects. Following that, table B3 provides the results of the Chi-Square analyses in all of the studied projects.

This study included additional analyses in separate negotiated and hard bid projects. These additional analyses included correlation, ANOVA, and t-test once in negotiated projects and once in hard bid projects. These additional analyses are provided in Table B4 to B7.

Table B1

Results from correlation analyses

No.	Items	Correlated to	Statistical Values
1	Number of major changes	Overall budget	r (60) = .261, p = .044.
2	Number of major changes	Target budget overrun or cut	r (57) = .168, p = .212
3	Number of major changes	RFIs	r (60) =.042, p= .754
4	Number of major changes	average time spent on budget updating	r (60) = -.009, p= .949
5	Number of major changes	general requirement	r (60) = .046, p = .728
6	Number of major changes	general condition	r (61) = .056, p = .671
7	Number of major changes	building risk insurance	r (60) = .031, p = .814
8	Number of major changes	design fee & reimbursement	r (60) = .084, p = .523
9	Model update	Overall budget	r (61) = .720, p = .000
10	Model update	Target budget overrun or cut	r (58) = .115, p = .389
11	Model update	Average time spend on budget updating	r (61) = -.249, p = .058
12	Model update	RFIs	r (61) = -.016, p = .904
13	Model update	Design error and omissions	r (61) = .302, p = .021
14	Model update	Number of times that the budget is updated	r (61) = .250, p = .052
15	Design errors	RFIs	r (58) = .127, p = .348
16	Design errors	Average time spend on budget updating	r (58) = .288, p = .03
17	Design errors	Design, fee, and reimbursement (DFR)	r (61) = .031, p = .817
18	RFIs	Overall budget	r (60) =-.040, p = .759
19	RFIs	Target budget overrun or cut	r (57) =-.115, p = .395
20	RFIs	Design, fee, and reimbursement (DFR)	r (60) = -.066, p = .616
21	Budget updates	Overall budget	r (61) = .074, p = .572

Table B1 (Continued)

No.	Items	Correlated to	Statistical Values
22	Budget updates	Target budget overrun or cut	r (58) = -.006, p = .963
23	Budget updates	RFIs	r (61) = .109, p = .409
24	Average time spend on budget updating	Number of major changes	r (59) = -.009, p = .949
25	Overall estimating time	Number of major changes	r (60) = .271, p = .036
26	Average time spend on budget updating	Budget update	r (59) = .060, p = .650
27	Overall estimating time	Budget update	r (61) = .395, p = .002
28	Average time spend on budget updating	RFIs	r (59) = .082, p = .543
29	Average time spend on budget updating	Overall budget	r (59) = -.114, p = .388
30	Average time spend on budget updating	Target budget overrun or cut	r (56) = .225, p = .096
31	Average time spend on budget updating	Design, fee, and reimbursement (DFR)	r (59) = -.080, p = .545
32	Overall estimating time	Overall budget	r (61) = -.288 p = .077
33	Overall estimating time	Target budget overrun or cut	r (58) = .097, p = .467
34	Project size	Budget updates	r (61) = .119, p = .362
35	Project size	Model updates	r (61) = .844, p = .000
36	Project size	Value of accepted VEs	r (61) = -.64, p = .627
37	Project size	RFIs	r (61) = .013, p = .920
38	Project size	Number of major changes	r (61) = .092, p = .485
39	Project size	Design errors	r (58) = .381, p = .000
40	Project size	Overall budget changes	r (61) = .850, p = .000
41	Project size	Target budget overrun or cut	r (58) = .226, p = .088
42	Project size	Average time spend on budget updating	r (61) = .023, p = .866
43	Project size	Overall estimating time	r (61) = .248, p = .054
44	Project size	General condition	r (61) = .117, p = .370
45	Project size	General requirement	r (61) = -.027, p = .835
46	Project size	Building risk insurance (BRI)	r (61) = -.133, p= .309
47	Project size	Permit, bond, insurance (PBI)	r (61) = -.178, p= .171
48	Project size	Fees	r (61) = .028, p= .833
49	Project size	Sub default rate	r (61) = .015, p= .908
50	Project size	Construction contingency	r (61) = .024, p= .855
51	Project size	Design contingency	r (61) = -.047, p= .720
52	Project size	Owner contingency	r (61) = .022, p= .867
53	Project size	Design, fee, and reimbursement (DFR)	r (61) = -.026, p= .843
54	Target budget	RFIs	r (52) = .130, p = 357
55	Target budget	Value of accepted VEs	r (53) = .146, p = .296
56	Target budget	Target budget overrun or cut	r (52) = -.077, p = .587
57	Target budget	Overall budget	r (53) = .291, p = .034
58	Target budget	General condition	r (53) = .456, p = .001
59	Target budget	General requirement	r (53) = -.108, p = .440
60	Target budget	Building risk insurance (BRI)	r (53) = -.702, p = .609

Table B1 (Continued)

No.	Items	Correlated to	Statistical Values
61	Target budget	Permit, bond, insurance (PBI)	r (53) = -.227, p = .101
62	Target budget	Fees	r (53) = .073, p = .605
63	Target budget	Sub default rate	r (53) = .093, p = .508
64	Target budget	Construction contingency	r (53) = .120, p = .393
65	Target budget	Design contingency	r (53) = -.022, p = .873
66	Target budget	Owner contingency	r (53) = .116, p = .409
67	Target budget	Design, fee, and reimbursement (DFR)	r (53) = -.093, p = .507
68	General requirement	Target budget overrun or cut	r (58) = .-.047, p = .728
69	General requirement	Overall budget	r (61) = -.027, p = .834
70	General requirement	General condition	r (61) = -.222, p = .085
71	General requirement	Building risk insurance (BRI)	r (61) = .046, p = .723
72	General requirement	Permit, bond, insurance (PBI)	r (61) = -.001, p = .993
73	General requirement	Fees	r (61) = .014, p = .912
74	General requirement	Sub default rate	r (61) = .015, p = .907
75	General requirement	Escalation	r (61) = .038, p = .774
76	General requirement	Construction contingency	r (61) = .020, p = .880
77	General requirement	Design contingency	r (61) = .119, p = .361
78	General requirement	Owner contingency	r (61) = .016, p = .904
79	General requirement	Design, fee, and reimbursement (DFR)	r (61) = -.019, p = .884
80	General condition	Target budget overrun or cut	r (58) = .143, p = .286
81	General condition	Overall budget	r (61) = .063, p = .628
82	General condition	Building risk insurance (BRI)	r (61) = -.012, p = .924
83	General condition	Permit, bond, insurance (PBI)	r (61) = -.109, p = .405
84	General condition	Fees	r (61) = -.018, p = .889
85	General condition	Sub default rate	r (61) = .032, p = .808
86	General condition	Escalation	r (61) = -.406, p = .001
87	General condition	Construction contingency	r (61) = .025, p = .851
88	General condition	Design contingency	r (61) = .026, p = .845
89	General condition	Owner contingency	r (61) = .026, p = .845
90	General condition	Design, fee, and reimbursement (DFR)	r (61) = -.150, p = .249
91	Permit	Target budget overrun or cut	r (58) = .000, p = .997
92	Permit	Overall budget	r (61) = -.022, p = .864
93	Permit	Building risk insurance (BRI)	r (61) = .098, p = .455
94	Permit	Permit, bond, insurance (PBI)	r (61) = .107, p = .411
95	Permit	Fees	r (61) = .737, p = .000
96	Permit	Sub default rate	r (61) = .065, p = .618
97	Permit	Escalation	r (61) = .120, p = .361
98	Permit	Construction contingency	r (61) = .028, p = .832
99	Permit	Design contingency	r (61) = .001, p = .992
100	Permit	Owner contingency	r (61) = -.031, p = .814

Table B1 (Continued)

No.	Items	Correlated to	Statistical Values
101	Permit	Design, fee, and reimbursement (DFR)	r (58) = .033, p = .806
102	Building risk insurance (BRI)	Target budget overrun or cut	r (61) = .107, p = .431
103	Building risk insurance (BRI)	Overall budget	r (61) = -.111, p = .395
104	Building risk insurance (BRI)	Permit, bond, insurance (PBI)	r (61) = .217, p = .093
105	Building risk insurance (BRI)	Fees	r (61) = .051, p = .694
106	Building risk insurance (BRI)	Sub default rate	r (61) = .012, p = .928
107	Building risk insurance (BRI)	Escalation	r (61) = .263, p = .042
108	Building risk insurance (BRI)	Construction contingency	r (61) = -.010, p = .936
109	Building risk insurance (BRI)	Design contingency	r (61) = .106, p = .414
110	Building risk insurance (BRI)	Owner contingency	r (61) = -.049, p = .706
111	Building risk insurance (BRI)	Design, fee, and reimbursement (DFR)	r (61) = .007, p = .956
112	Permit, bond, insurance (PBI)	Target budget overrun or cut	r (58) = -.061, p = .648
113	Permit, bond, insurance (PBI)	Overall budget	r (61) = -.127, p = .331
114	Permit, bond, insurance (PBI)	Fees	r (61) = .013, p = .921
115	Permit, bond, insurance (PBI)	Sub default rate	r (61) = .065, p = .617
116	Permit, bond, insurance (PBI)	Escalation	r (61) = .104, p = .429
117	Permit, bond, insurance (PBI)	Construction contingency	r (61) = -.049, p = .709
118	Permit, bond, insurance (PBI)	Design contingency	r (61) = .031, p = .812
119	Permit, bond, insurance (PBI)	Owner contingency	r (61) = -.003, p = .979
120	Permit, bond, insurance (PBI)	Design, fee, and reimbursement (DFR)	r (61) = .138, p = .289
121	Sub default rate	Target budget overrun or cut	r (58) = .055, p = .680
122	Sub default rate	Overall budget	r (61) = .020, p = .879
123	Sub default rate	Fees	r (61) = -.017, p = .895
124	Sub default rate	Escalation	r (61) = -.032, p = .810
125	Sub default rate	Construction contingency	r (61) = -.032, p = .810
126	Sub default rate	Design contingency	r (61) = .132, p = .311
127	Sub default rate	Owner contingency	r (61) = -.017, p = .895
128	Sub default rate	Design, fee, and reimbursement (DFR)	r (61) = .019, p = .884
129	Fees	Target budget overrun or cut	r (58) = .009, p = .945
130	Fees	Overall budget	r (61) = .034, p = .796
131	Fees	Escalation	r (61) = -.039, p = .765
132	Fees	Construction contingency	r (61) = .030, p = .818
133	Fees	Design contingency	r (61) = -.019, p = .887

Table B1 (Continued)

No.	Items	Correlated to	Statistical Values
134	**Fees**	**Owner contingency**	**r (61) = -.017, p = .899**
135	Fees	Design, fee, and reimbursement (DFR)	r (61) = .016, p = .900
136	Escalation	Target budget overrun or cut	r (58) = .117, p = .381
137	Escalation	Overall budget	r (60) = -.250, p = .054
138	Escalation	Construction contingency	r (60) = .206, p = .114
139	Escalation	Design contingency	r (60) = .195, p = .136
140	Escalation	Owner contingency	r (60) = .a, p = .000
141	Escalation	Design, fee, and reimbursement (DFR)	r (60) = .063, p = .635
142	Design, fee, and reimbursement (DFR)	Target budget overrun or cut	r (58) = -.025, p = .853
143	Design, fee, and reimbursement (DFR)	Overall budget	r (61) = -.036, p = .783
144	Construction contingency	Target budget overrun or cut	r (58) = -.049, p = .717
145	Construction contingency	Overall budget	r (61) = .016, p = .905
146	Construction contingency	Design contingency	r (61) = -.094, p = .472
147	Construction contingency	Owner contingency	r (61) = -.971, p = .000
148	Construction contingency	Design, fee, and reimbursement (DFR)	r (61) = .006, p = .963
149	Design contingency	Target budget overrun or cut	r (58) = -.061, p = .650
150	Design contingency	Overall budget	r (61) = -.006, p = .963
151	Design contingency	Owner contingency	r (61) = -.146, p = .261
152	Design contingency	Design, fee, and reimbursement (DFR)	r (61) = -.058, p = .659
153	Owner contingency	Target budget overrun or cut	r (58) = .a, p = .000
154	Owner contingency	Overall budget	r (61) = .028, p = .828
155	Owner contingency	Design, fee, and reimbursement (DFR)	r (61) = .016, p = .900
156	Design errors	Overall budget change	r (58) = .425, p = .001

Table B2

Results from ANOVA and t-test analyses

No.	Items	Associated with	Statistical Values
1	Number of major changes	Provided VEs	t (43) = -.103, p = .919
2	Number of major changes	Tracking schedule	t (53) = .269, p = .789
3	Time of major changes	Overall budget change	F (3,52) = 1.864, p= .146
4	Time of major changes	Target budget overrun or cut	F (4,50) = .665, p= .577
5	Time of major changes	RFIs	F (3,54) = .504, p= .681
6	CMs initial budget timeframe	Overall budget change	F (4,55) = .200, p= .968
7	CMs initial budget timeframe	Target budget overrun or cut	F (4,45) = 1.625, p= .185
8	CMs initial budget timeframe	RFIs	F (5,54) = .432, p= .824
9	CMs initial budget timeframe	Value of accepted VEs	F (5,55) =.370, p = .867
10	CMs initial budget timeframe	Average time spend on budget updating	F (5,53) =.471, p = .796
11	CMs initial budget timeframe	Overall estimating time	F (5,55) = 1.736, p = .142
12	CMs initial budget timeframe	Number of major changes	F (5,54) = 2.565, p = .037
13	CMs initial budget timeframe	General requirement	F (5,55) = .072, p = .996
14	Design errors	Provided VEs	t (46) = -2.665, p = .011
15	Site assessment in the model	RFIs	t (51) = 1.437, p = .157
16	Site assessment in the model	Average time spent on budget updating	t (52) = .109, p = .914
17	Site assessment in the model	Overall time spent on budget updating	t (52) = -.261, p = .795
18	Equipment allocation in the model	RFIs	t (52) = -.133, p = .895
19	Equipment allocation in the model	Average time spend on budget updating	t (53) = -.347, p = .730
20	Equipment allocation in the model	Overall estimating time	t (53) = -1.465, p = .149
21	Material Detail in the Model (Average)	RFIs	t (50) = -1.167, p = .249
22	Material Detail in the Model (Average)	Average time spend on budget updating	t (51) = -1.192, p = .239
23	Material Detail in the Model (Average)	Overall estimating time	t (51) = -1.951, p = .057
24	Design changes	RFIs	t (54) = .512, p = .611
25	Design changes	Design, fee, and reimbursement (DFR)	t (54) = .965, p = .339
26	Design changes	Overall budget change	t (54) = -1.214, p = .230
27	Design changes	Target budget overrun or cut	t (52) = -.683, p = .498
28	Using BIM	RFIs	F (3,56) = .705, p = .553
29	Using BIM	Value of accepted VEs	F (3,57) =.639, p = .593
30	Using BIM	Overall budget	F (3,57) =.399, p = .754
31	Using BIM	Target budget overrun or cut	F (3,54) =.519, p = .671
32	Using BIM	Average time spend on budget updating	F (3,55) = .295, p = .829
33	Using BIM	Design contingency	F (3,57) = 1.252, p = .299
34	Using BIM	Owner contingency	F (3,57) = 1.126, p = .346
35	Using BIM	Number of major changes	F (3,56) =.207, p = .891
36	Using BIM	Budget update	F (3,57) =.270, p =.846

Table B2 (Continued)

No.	Items	Correlated to	Statistical Values
37	Using BIM	Design, fee, and reimbursement (DFR)	F (3,57) =1.277, p = .291
38	Provided VEs	Overall budget	F (2,58) = .470, p = .627
39	Provided VEs	Target budget overrun or cut	F (2,55) = .203, p = .817
40	Provided VEs	Design, fee, and reimbursement (DFR)	F (2,58) = 1.213, p = .305
41	RFIs	Provided VEs	F (2,57) = 1.308, p = .278
42	RFIs	Tracking schedule	t (58) = -.510, p = .612
43	Tracking schedule	Overall budget	t (59) = 1.050, p = .298
44	Tracking schedule	Target budget overrun or cut	t (56) = .856, p = .395
45	Tracking schedule	Escalation	t (54) = -.348, p = .729
46	Tracking schedule	Overall estimating time	t (59) = -1.385, p = .171
47	Tracking schedule	Average time spent on budget updating	t (57) = -1.099, p = .276
48	Budget updates	Time of major changes	F (7,51) = .434, p = .876
49	Average time spend on budget updating	Time of major changes	F (3,53) = 2.389, p = .079
50	Overall estimating time	Time of major changes	F (36,22) = .576, p = .933
51	Average time spend on budget updating	Provided VEs	F (2,56) = 1.771, p = .180
52	Overall estimating time	Provided VEs	F (2,58) = 4.452, p = .016
53	Project function	RFIs	F (10,50) = 1.897, p = .068
54	Project function	Overall budget change	F (6,50) = 1.366, p = .247
55	Project function	Target budget overrun or cut	F (6,47) = .871, p = .521
56	Project function	Design errors	F (10,47) = .411, p = .935
57	Project function	Budget updates	F (10,50) = 2.355, p = .023
58	Project function	Target budget	F (10,37) = .662, p = .751
59	Project function	General requirement	F (10,50) = .458, p = .909
60	Project function	General condition	F (10,50) = 1.462, p = .182
61	Project function	Building risk insurance (BRI)	F (10,50) = .447, p = .916
62	Project function	Permit, bond, insurance (PBI)	F (10,50) = 1.715, p = .103
63	Project function	Fees	F (10,50) = .902, p = .539
64	Project function	Sub default rate	F (10,50) = .4311.577, p = .000
65	Project function	Escalation	F (10,49) = 1.00, p = .457
66	Project function	Construction contingency	F (10,50) = .281, p = .983
67	Project function	Design contingency	F (10,50) = .459, p = .908
68	Project function	Owner contingency	F (10,50) = .365, p = .956
69	Project function	Design, fee, and reimbursement (DFR)	F (10,50) = .337, p = .966
70	Project function	Budget percentage changes	F (6,50) = 1.565, p = .177
71	Awarding method	Overall budget change	t (59) = .621, p = .537
72	Awarding method	Target budget overrun or cut	t (35) = .218, p = .829
73	Awarding method	Average time spend on budget updating	t (57) = .858, p = .395
74	Awarding method	Overall estimating time	t (59) = 4.376, p = .000
75	Awarding method	Number of major changes	t (58) = 3.899, p = .000

Table B2 (Continued)

No.	Items	Correlated to	Statistical Values
76	Awarding method	General condition	t (59) = .463, p = .645
77	Awarding method	General requirement	t (59) = -1.166, p = .248
78	Awarding method	Building risk insurance (BRI)	t (59) = -5.36, p = .594
79	Awarding method	Permit, bond, insurance (PBI)	t (59) = -4.48, p = .656
80	Awarding method	Fees	t (59) = -.831, p = .409
81	Awarding method	Sub default rate	t (59) = -.883, p = .381
82	Awarding method	Construction contingency	t (59) = -1.181, p = .242
83	Awarding method	Design contingency	t (59) = -1.416, p = .162
84	Awarding method	Owner contingency	t (59) = -.831, p = .409
85	Awarding method	Design, fee, and reimbursement (DFR)	t (59) = .414, p = .680
86	Project size	Time of major changes	F (49,9) = .403, p = .980
87	Project size	Using BIM	F (50,10) = .792, p = .723
88	Project size	Provided VEs	F (50,10) = 14.363, p = .000
89	Project size	Tacking schedule	t (59) = -.959, p = .341
90	Project size	Site assessment in the model	t (52) = -1.994, p = .051
91	Project size	Equipment allocation in the model	t (53) = -2.774, p = .008
92	Project size	Material Detail in the Model (Average)	t (51) = .697, p = .489
93	Project size	Design changes	t (54) = -1.704, p = .094
94	Delivery methods	Target budget overrun or cut	F (3,31) = .189, p = .903
95	Delivery methods	General requirement	F (3,37) = 2.122, p = .114
96	Delivery methods	General condition	F (3,37) = .549, p = .652
97	Delivery methods	Building risk insurance (BRI)	F (3,37) = .984, p = .411
98	Delivery methods	Permit, bond, insurance (PBI)	F (3,37) = 1.928, p = .142
99	Delivery methods	Fees	F (3,37) = 1.122, p = .353
100	Delivery methods	Sub default rate	F (3,37) = .189, p = .903
101	Delivery methods	Construction contingency	F (3,37) = 5.639, p = .003
102	Delivery methods	Design contingency	F (3,37) = 2.587, p = .068
103	Delivery methods	Owner contingency	F (3,37) = 5.715, p = .003
104	Delivery methods	Design, fee, and reimbursement (DFR)	F (3,37) = .095, p = .962
105	Delivery methods	Overall budget change	F (3,37) = .637, p = .596
106	Delivery methods	Target budget overrun or cut	F (3,35) = .541, p = .658
107	Delivery methods	Average time spend on budget updating	F (3,36) = 1.453, p = .244
108	Delivery methods	Overall estimating time	F (3,37) = 1.534, p = .222
109	Project location	Overall budget change	F (2,58) = .272, p = .763
110	Project location	Target budget overrun or cut	F (2,34) = 6.473, p = .004
111	Project location	Average time spend on budget updating	F (2,56) = 7.575, p = .001
112	Project location	General condition	F (2,58) = .363, p = .697
113	Project location	General requirement	F (2,58) = .178, p = .837

Table B2 (Continued)

No.	Items	Correlated to	Statistical Values
114	Project location	Building risk insurance (BRI)	F (2,58) = 1.192, p = .311
115	Project location	Permit, bond, insurance (PBI)	F (2,58) = 1.553, p = .220
116	Project location	Fees	F (2,58) = .188, p = .829
117	Project location	Sub default rate	F (2,58) = .180, p = .836
118	Project location	Construction contingency	F (2,58) = .718, p = .492
119	Project location	Design contingency	F (2,58) = .347, p = .708
120	Project location	Owner contingency	F (2,58) = .188, p = .829
121	Project location	Design, fee, and reimbursement (DFR)	F (2,58) = .182, p = .834
122	Construction Type	General requirement	F (2,58) = .261, p = .771
123	Construction Type	General condition	F (2,58) = 4.128, p = .021
124	Construction Type	Building risk insurance (BRI)	F (2,58) = .865, p = .426
125	Construction Type	Permit, bond, insurance (PBI)	F (2,58) = 3.892, p = .026
126	Construction Type	Fees	F (2,58) = .220, p = .803
127	Construction Type	Sub default rate	F (2,58) = 2.861, p = .065
128	Construction Type	Escalation	F (2,57) = .282, p = .755
129	Construction Type	Construction contingency	F (2,58) = .418, p = .661
130	Construction Type	Design contingency	F (2,58) = .101, p = .904
131	Construction Type	Owner contingency	F (2,58) = .220, p = .803
132	Construction Type	Design, fee, and reimbursement (DFR)	F (2,58) = 4.349, p = .017
133	Construction Type	Target budget overrun or cut	F (2,55) = .772, p = .467
134	Construction Type	Overall budget change	F (2,58) = .224, p = .800
135	Construction Type	Budget percentage changes	F (2,58) = 4.194, p = .020
136	Construction Type	Average time spend on budget updating	F (2,55) = .772, p = .467
137	Construction Type	Overall estimating time	F (2,58) = 1.441, p = .245
138	Construction Type	General condition	F (2,60) = 4.128, p = .021
139	Construction Type	General requirement	F (2,58) = .261, p = .771
140	General requirement	Tracking schedule	t (59) = -1.229, p = .224
141	General condition	Tracking schedule	t (59) = -1.444, p = .257
142	Building risk insurance (BRI)	Tracking schedule	t (59) = -1.370, p = .176
143	Escalation	Tracking schedule	t (58) = -.512, p = .611
144	Construction contingency	Tracking schedule	t (59) = 1.359, p = .179
145	Project recency	Average time spend on budget updating	F (2,56) = 4.356, p = .017
146	Project recency	Overall budget	F (2,58) = 1.163, p = .320
147	Project recency	Target budget overrun or cut	F (2,55) = 3.460, p = .038

Table B2 (Continued)

No.	Items	Correlated to	Statistical Values
148	Early location identification	Overall budget	F (2,53) = .593, p = .556
149	Early location identification	Target budget overrun or cut	F (2,51) = .686, p = .508
150	Early programming	Overall budget	F (3,57) = .096, p = .962
151	Early programming	Target budget overrun or cut	F (3,54) = .348, p = .791
152	Public v. private project	Overall budget	t (59) = -1.119, p = .268
153	Public v. private project	Target budget overrun or cut	t (56) = -1.597, p = .116
154	Skin (façade) changes	Overall budget	t (34) = -.803, p = .428
155	Skin (façade) changes	Target budget overrun or cut	t (28) = -.498, p = .623
156	Mixed used projects	Overall budget	t (59) = -.645, p = .522
157	Mixed used projects	Target budget overrun or cut	t (56) = .239, p = .812
158	Structural Model	Overall budget change	F (2,55) = .331, p = .720
159	Structural Model	Target budget overrun or cut	F (2,52) = .514, p = .604
160	Early structure Information	Overall budget change	F (3,56) = .067, p = .977
161	Early structure Information	Target budget overrun or cut	F (3,53) = .680, p = .568
162	Structural changes	Overall budget change	t (33) = .182, p = .857
163	Structural changes	Budget percentage change	t (33) = .524, p = .604
164	Structural changes	Target budget overrun or cut	t (30) = .677, p = .503
165	Model update	Time of major changes	F (3,55) = .705, p = .553
166	CMs Previous Experience	Budget percentage change	t (59) = .792, p = .432
167	CMs Previous Experience	Overall budget change	t (59) = -.308, p = .759
168	Site assessment in the model	Overall budget change	t (52) = -3.135, p = .003
169	Equipment allocation in the model	Overall budget change	t (53) = -3.470, p = .001
170	Setting up target budget	Overall budget change	t (46) = -.623, p = .536
171	Setting up target budget	Budget percentage change	t (46) = .171, p = .865
172	Setting up target budget	Target budget overrun or cut	t (45) = .529, p = .461
173	Awarding methods	Overall estimating time	t (59) = 4.376, p = .000

Table B3

Results of the correlation analyses in negotiated projects

No.	Items	Correlated to	Statistical Values
1	Project size	Overall budget change	r (36) = .851, p = .000
2	Project size	Budget percentage change	r (36) = .042, p = .809
3	Project size	Target budget overrun or cut	r (34) = -.836, p = .000
4	Budget update	Overall budget change	r (36) = .087, p = .613
5	Budget update	Budget percentage change	r (36) = -.092, p = .595
6	Budget update	Target budget overrun or cut	r (34) = -.106, p = .549
7	Model update	Overall budget change	r (36) = .833, p = .000
8	Model update	Budget percentage change	r (36) = .028, p = .871
9	Model update	Target budget overrun or cut	r (34) = -.794, p = .000
10	General requirement	Overall budget change	r (36) = -.173, p = .313
11	General requirement	Budget percentage change	r (36) = -.463, p = .005
12	General requirement	Target budget overrun or cut	r (34) = -.013, p = .948
13	Permit	Overall budget change	r (36) = .859, p = .859
14	Permit	Budget percentage change	r (36) = .061, p = .722
15	Permit	Target budget overrun or cut	r (34) = -.073, p = .681
16	Builders risk insurance	Overall budget change	r (36) = -.095, p = .509
17	Builders risk insurance	Budget percentage change	r (36) = .037, p = .636
18	Builders risk insurance	Target budget overrun or cut	r (34) = .128, p = .443
19	Permit, bond, insurance	Overall budget change	r (36) = -.905, p = .582
20	Permit, bond, insurance	Budget percentage change	r (36) = .037, p = .829
21	Permit, bond, insurance	Target budget overrun or cut	r (34) = .128, p = .469
22	Sub default rate	Overall budget change	r (36) = .025, p = .887
23	Sub default rate	Budget percentage change	r (36) = .042, p = .809
24	Sub default rate	Target budget overrun or cut	r (34) = -.006, p = .973
25	Fee	Overall budget change	r (36) = .040, p = .817
26	Fee	Budget percentage change	r (36) = .044, p = .800
27	Fee	Target budget overrun or cut	r (34) = -.064, p = .717
28	Escalation	Overall budget change	r (35) = -.384, p = .023
29	Escalation	Budget percentage change	r (35) = -.006, p = .973
30	Escalation	Target budget overrun or cut	r (34) = .231, p = .188
31	Construction contingency	Overall budget change	r (36) = .024, p = .888
32	Construction contingency	Budget percentage change	r (36) = -.023, p = .894
33	Construction contingency	Target budget overrun or cut	r (34) = -.044, p = .806
34	Owner contingency	Overall budget change	r (36) = .034, p = .844
35	Owner contingency	Budget percentage change	r (36) = .041, p = .813
36	Owner contingency	Target budget overrun or cut	r (34) = ., p = .000
37	General condition	Overall budget change	r (36) = .154, p = .370
38	General condition	Budget percentage change	r (36) = -.549, p = .001
39	General condition	Target budget overrun or cut	r (34) = -.046, p = .798

Table B3 (Continued)

No.	Items	Correlated to	Statistical Values
40	Design Fee and Reimbursement	Overall budget change	r (36) = .005, p = .978
41	Design Fee and Reimbursement	Budget percentage change	r (36) = .230, p = .176
42	Design Fee and Reimbursement	Target budget overrun or cut	r (34) = -.006, p = .974
43	Design contingency	Overall budget change	r (36) = .109, p = .526
44	Design contingency	Budget percentage change	r (36) = .095, p = .581
45	Design contingency	Target budget overrun or cut	r (34) = -.059, p = .739
46	Overall estimating time	Overall budget change	r (36) = .277, p = .102
47	Overall estimating time	Budget percentage change	r (36) = -.031, p = .858
48	Overall estimating time	Target budget overrun or cut	r (34) = -.113, p = .524
49	Average time spend on budget updating	Overall budget change	r (34) = -.284, p = .103
50	Average time spend on budget updating	Budget percentage change	r (34) = -.151, p = .392
51	Average time spend on budget updating	Target budget overrun or cut	r (32) = .136, p = .459
52	Design errors	Overall budget change	r (33) = .374, p = .032
53	Design errors	Budget percentage change	r (33) = -.069, p = .705
54	Design errors	Target budget overrun or cut	r (31) = -.070, p = .707
55	Major changes	Overall budget change	r (36) = .254, p = .134
56	Major changes	Budget percentage change	r (36) = .315, p = .061
57	Major changes	Target budget overrun or cut	r (34) = -.058, p = .745

Table B4

Results of the ANOVA and t-test analyses in negotiated projects

No.	Items	Associated with	Statistical Values
1	BIM	Overall budget change	F (3,32) = .252, p = .859
2	BIM	Budget percentage change	F (3,32) = .127, p = .944
3	BIM	Target budget overrun or cut	F (3,30) = .051, p = .984
4	CMs initial budget timeframe	Overall budget change	F (3,32) = .235, p = .871
5	CMs initial budget timeframe	Budget percentage change	F (3,32) =.040, p = .989
6	CMs initial budget timeframe	Target budget overrun or cut	F (3,30) = .077, p = .972
7	Construction type	Overall budget change	F (2,33) = 1.032, p = .367
8	Construction type	Budget percentage change	F (2,33) = 4.228, p = .023
9	Construction type	Target budget overrun or cut	F (2,31) = .069, p = .933
10	Delivery method	Overall budget change	F (3,18) = 2.112, p = .134
11	Delivery method	Budget percentage change	F (3,18) = 1.688, p = .205
12	Delivery method	Target budget overrun or cut	F (3,17) = .019, p = .996
13	Design Change	Overall budget change	t (29) = -.697, p = .492
14	Design Change	Budget percentage change	t (29) = .030, p = .162
15	Design Change	Target budget overrun or cut	t (28) = .453, p = .862
16	Detailed material in the model	Overall budget change	F (4,29) = .067, p = .991
17	Detailed material in the model	Budget percentage change	F (4,29) = .071, p = .990
18	Detailed material in the model	Target budget overrun or cut	F (4,27) = .416, p = .795
19	Programming	Overall budget change	t (22) = -.286, p = .778
20	Programming	Budget percentage change	t (22) = -.433, p = .669
21	Programming	Target budget overrun or cut	t (20) = .235, p = .817
22	Early Structure	Overall budget change	t (21) = -.007, p = .994
23	Early Structure	Budget percentage change	t (21) = .301, p = .818
24	Early Structure	Target budget overrun or cut	t (19) = .440, p = .548
25	Equipment allocation	Overall budget change	t (30) = -1.960, p = .059
26	Equipment allocation	Budget percentage change	t (30) = .439, p = .664
27	Equipment allocation	Target budget overrun or cut	t (28) = .010, p = .092
28	Function	Overall budget change	F (8,27) = .580, p = .785
29	Function	Budget percentage change	F (8,27) = 2.790, p = .022
30	Function	Target budget overrun or cut	F (8,25) = 1.432, p = .232
31	Location	Overall budget change	F (2,33) = .366, p = .696
32	Location	Budget percentage change	F (2,33) = .444, p = .645
33	Location	Target budget overrun or cut	F (2,31) = .761, p = .476
34	Mixed used building	Overall budget change	t (34) = -1.420, p = .165
35	Mixed used building	Budget percentage change	t (34) = .669, p = .508
36	Mixed used building	Target budget overrun or cut	t (32) = 1.465, p = .153
37	Public or private project	Overall budget change	t (34) = -1.242, p = .223
38	Public or private project	Budget percentage change	t (34) = .205, p = .839

Table B4 (Continued)

No.	Items	Correlated to	Statistical Values
39	Public or private project	Target budget overrun or cut	t (27) = -2.439, p = .022
40	Site assessment	Overall budget change	t (31) = -1.880, p = .070
41	Site assessment	Budget percentage change	t (31) = .263, p = .556
42	Site assessment	Target budget overrun or cut	t (29) = .039, p = .151
43	Skin change	Overall budget change	t (28) = -.314, p = .756
44	Skin change	Budget percentage change	t (28) = -.514, p = .589
45	Skin change	Target budget overrun or cut	t (26) = -.654, p = .519
46	Structural change	Overall budget change	t (27) = .431, p = .670
47	Structural change	Budget percentage change	t (27) = .554, p = .584
48	Structural change	Target budget overrun or cut	t (25) = .354, p = .726
49	Structure model is provided	Overall budget change	t (28) = .381, p = .706
50	Structure model is provided	Budget percentage change	t (28) = .126, p = .901
51	Structure model is provided	Target budget overrun or cut	t (26) = -1.210, p = .237
52	Target budget	Overall budget change	t (25) = -.235, p = .816
53	Target budget	Budget percentage change	t (25) = -.267, p = .792
54	Time of major changes	Overall budget change	F (2,32) = 2.067, p = .143
55	Time of major changes	Budget percentage change	F (2,32) = 1.638, p = .210
56	Time of major changes	Target budget overrun or cut	F (2,30) = .981, p = .387
57	Tracking schedule	Overall budget change	t (34) = .907, p = .371
58	Tracking schedule	Budget percentage change	t (34) = 1.324, p = .194
59	Tracking schedule	Target budget overrun or cut	t (32) = -.915, p = .367
60	Project recency	Overall budget change	F (2,33) = .249, p = .781
61	Project recency	Budget percentage change	F (2,33) = .811, p = .453
62	Project recency	Target budget overrun or cut	F (2,31) = .253, p = .778

Table B5

Results of the correlation analyses in hard bid projects

No.	Items	Correlated to	Statistical Values
1	Project size	Overall budget change	r (25) = .602, p = .001
2	Project size	Budget percentage change	r (25) = .237, p = .255
3	Project size	Target budget overrun or cut	r (22) = -.134, p = .552
4	Budget update	Overall budget change	r (25) = .063, p = .764
5	Budget update	Budget percentage change	r (25) = -.122, p = .561
6	Budget update	Target budget overrun or cut	r (22) = -.405, p = .061
7	Model update	Overall budget change	r (25) = .105, p = .618
8	Model update	Budget percentage change	r (25) = .104, p = .622
9	Model update	Target budget overrun or cut	r (22) = -.058, p = .799
10	General requirement	Overall budget change	r (25) = -.049, p = .818
11	General requirement	Budget percentage change	r (25) = .024, p = .908
12	General requirement	Target budget overrun or cut	r (22) = -.041, p = .857
13	Permit	Overall budget change	r (25) = -.304, p = .139
14	Permit	Budget percentage change	r (25) = -.460, p = .021
15	Permit	Target budget overrun or cut	r (22) = .085, p = .708
16	Builders risk insurance	Overall budget change	r (25) = -.211, p = .347
17	Builders risk insurance	Budget percentage change	r (25) = -.216, p = .301
18	Builders risk insurance	Target budget overrun or cut	r (22) = -.086, p = .702
19	Permit, bond, insurance	Overall budget change	r (25) = -.239, p = .249
20	Permit, bond, insurance	Budget percentage change	r (25) = .222, p = .287
21	Permit, bond, insurance	Target budget overrun or cut	r (22) = .235, p = .292
22	Sub default rate	Overall budget change	r (25) = .000, p = .998
23	Sub default rate	Budget percentage change	r (25) = .471, p = .017
24	Sub default rate	Target budget overrun or cut	r (22) = .166, p = .461
25	Fee	Overall budget change	r (25) = .054, p = .798
26	Fee	Budget percentage change	r (25) = .233, p = .262
27	Fee	Target budget overrun or cut	r (22) = -.181, p = .419
28	Escalation	Overall budget change	r (25) = .080, p = .703
29	Escalation	Budget percentage change	r (25) = -.061, p = .773
30	Escalation	Target budget overrun or cut	r (22) = -.001, p = .998
31	Construction contingency	Overall budget change	r (25) = -.039, p = .852
32	Construction contingency	Budget percentage change	r (25) = -.341, p = .095
33	Construction contingency	Target budget overrun or cut	r (22) = -.083, p = .712
34	General condition	Overall budget change	r (25) = -.202, p = .333
35	General condition	Budget percentage change	r (25) = -.167, p = .424
36	General condition	Target budget overrun or cut	r (22) = -.144, p = .523
37	Design Fee and Reimbursement	Overall budget change	r (25) = .527, p = .007
38	Design Fee and Reimbursement	Budget percentage change	r (25) = .735, p = .000

Table B5 (Continued)

No.	Items	Correlated to	Statistical Values
39	Design Fee and Reimbursement	Target budget overrun or cut	r (22) = .237, p = .288
40	Design contingency	Overall budget change	r (25) = -.227, p = .276
41	Design contingency	Budget percentage change	r (25) = .112, p = .592
42	Design contingency	Target budget overrun or cut	r (22) = .053, p = .814
43	Overall estimating time	Overall budget change	r (25) = .151, p = .471
44	Overall estimating time	Budget percentage change	r (25) = -.065, p = .756
45	Overall estimating time	Target budget overrun or cut	r (22) = .128, p = .569
46	Average time spend on budget updating	Overall budget change	r (25) = .267, p = .197
47	Average time spend on budget updating	Budget percentage change	r (25) = .080, p = .702
48	Average time spend on budget updating	Target budget overrun or cut	r (22) = .186, p = .407
49	Design errors	Overall budget change	r (24) = .678, p = .000
50	Design errors	Budget percentage change	r (24) = .254, p = .230
51	Design errors	Target budget overrun or cut	r (21) = .033, p = .888
52	Major changes	Overall budget change	r (24) = .400, p = .053
53	Major changes	Budget percentage change	r (24) = .350, p = .094
54	Major changes	Target budget overrun or cut	r (22) = -.101, p = .655
55	RFIs	Overall budget change	r (25) = -.401, p = .047
56	RFIs	Budget percentage change	r (25) = -.203, p = .330
57	RFIs	Target budget overrun or cut	r (22) = -.594, p = .004

Table B6

Results of the ANOVA and t-test analyses in hard bid projects

No.	Items	Associated with	Statistical Values
1	BIM	Overall budget change	F (2,22) = .213, p = .810
2	BIM	Budget percentage change	F (2,22) = .177, p = .839
3	BIM	Target budget overrun or cut	F (2,19) = .121, p = .887
4	CMs initial budget timeframe	Overall budget change	F (4,20) = .594, p = .671
5	CMs initial budget timeframe	Budget percentage change	F (4,20) =.452, p = .770
6	CMs initial budget timeframe	Target budget overrun or cut	F (3,18) = .657, p = .589
7	Construction type	Overall budget change	F (2,22) = .178, p = .838
8	Construction type	Budget percentage change	F (2,22) = .361, p = .701
9	Construction type	Target budget overrun or cut	F (2,19) = .463, p = .637
10	Delivery method	Overall budget change	F (2,16) = .092, p = .913
11	Delivery method	Budget percentage change	F (2,16) = .148, p = .863
12	Delivery method	Target budget overrun or cut	F (2,15) = .687, p = .518
13	Design Change	Overall budget change	t (23) = -.620, p = .541
14	Design Change	Budget percentage change	t (23) = .443, p = .662
15	Design Change	Target budget overrun or cut	t (20) = 1.027, p = .317
16	Detailed material in the model	Overall budget change	F (2,21) = .122, p = .886
17	Detailed material in the model	Budget percentage change	F (2,21) = .905, p = .420
18	Detailed material in the model	Target budget overrun or cut	F (2,18) = 1.275, p = .303
19	Programming	Overall budget change	t (2) = -.025, p = .982
20	Programming	Budget percentage change	t (2) = 2.252, p = .153
21	Programming	Target budget overrun or cut	t (2) = .479, p = .679
22	Equipment allocation	Overall budget change	t (21) = -3.505, p = .002
23	Equipment allocation	Budget percentage change	t (21) = -.995, p = .331
24	Equipment allocation	Target budget overrun or cut	t (18) = .345, p = .734
25	Function	Overall budget change	F (8,16) = 1.868, p = .137
26	Function	Budget percentage change	F (8,16) = .892, p = .545
27	Function	Target budget overrun or cut	F (7,14) = .723, p = .656
28	Location	Overall budget change	F (2,22) = 4.457, p = .024
29	Location	Budget percentage change	F (2,22) = .251, p = .780
30	Location	Target budget overrun or cut	F (2,19) = .212, p = .811
31	Mixed used building	Overall budget change	t (23) = 1.067, p = .297
32	Mixed used building	Budget percentage change	t (23) = -.597, p = .556
33	Mixed used building	Target budget overrun or cut	t (20) = -.492, p = .628
34	Public or private project	Overall budget change	t (23) = .400, p = .693
35	Public or private project	Budget percentage change	t (23) = .313, p = .757
36	Public or private project	Target budget overrun or cut	t (20) = -.490, p = .629
37	Site assessment	Overall budget change	t (19) = -2.878, p = .010
38	Site assessment	Budget percentage change	t (19) = -2.051, p = .054

Table B6 (Continued)

No.	Items	Correlated to	Statistical Values
39	Site assessment	Target budget overrun or cut	t (17) = -2.494, p = .413
40	Skin change	Overall budget change	t (4) = -.561, p = .067
41	Skin change	Budget percentage change	t (4) = -.311, p = .604
42	Skin change	Target budget overrun or cut	t (4) = -.654, p = .771
43	Structural change	Overall budget change	t (3) = -4.229, p = .024
44	Structural change	Budget percentage change	t (3) = -.439, p = .690
45	Structural change	Target budget overrun or cut	t (3) = 11.830, p = .001
46	Structure model is provided	Overall budget change	t (21) = .776, p = .446
47	Structure model is provided	Budget percentage change	t (21) = .656, p = .519
48	Structure model is provided	Target budget overrun or cut	t (19) = -.595, p = .559
49	Target budget	Overall budget change	t (19) = .268, p = .792
50	Target budget	Budget percentage change	t (19) = .952, p = .353
51	Target budget	Target budget overrun or cut	t (18) = .667, p = .513
52	Time of major changes	Overall budget change	F (2,20) = .842, p = .446
53	Time of major changes	Budget percentage change	F (2,20) = 1.185, p = .326
54	Time of major changes	Target budget overrun or cut	F (2,18) = .056, p = .945
55	Tracking schedule	Overall budget change	t (23) = .803, p = .430
56	Tracking schedule	Budget percentage change	t (23) = .755, p = .458
57	Tracking schedule	Target budget overrun or cut	t (20) = .328, p = .747
58	Project recency	Overall budget change	F (2,22) = 2.753, p = .086
59	Project recency	Budget percentage change	F (2,22) = 2.458, p = .109
60	Project recency	Target budget overrun or cut	F (2,19) = .200, p = .820
61	VEs	Overall budget change	t (19) = 2.149, p = .045
62	VEs	Budget percentage change	t (19) = 1.596, p = .127
63	VEs	Target budget overrun or cut	t (16) = -1.975, p = .066