IMPACT OF CHANGE ORDERS ON THE COST PERFORMANCE OF MASS TIMBER CONSTRUCTION PROJECTS

By

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ABSTRACT

One of the major barriers to the widespread adoption of mass timber as a material is lack of knowledge. This lack of knowledge further promotes issues like high production and construction costs. The construction industry in the United States has been reluctant to accept mass timber as a new technology owing to these higher initial costs. Consequently, the most critical factor affecting the selection of a construction material is its cost performance.

A successful construction project is governed by its cost performance. Although, the cost performance of a project can be affected by cost overruns and change orders. These project costs can be optimized by reducing the time. Owing to its prefabricated nature, mass timber construction can cut down time. While change orders negatively affect the time of a project, there is a need to understand their impact on mass timber construction.

This study analyzes the impact of change orders on the cost performance of mass timber construction projects. The expected deliverables are to quantify and understand the most common causes of change orders in mass timber projects. The researcher believes that this study is a steppingstone toward the widespread adoption of mass timber as a construction material. Project data was collected for 34 projects from General Contractors around the country. Pearson's correlation, descriptive statistics, and ANOVAs were used to analyze the data collected. This study observed the relationship between the mass timber scope and the mass timber change orders. Along with that the project delivery methods and their impact on the construction costs were studied. The author believes a more widespread adoption of mass timber is beneficial through project team integration and reduction of change order costs.

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CHAPTER 1 INTRODUCTION

1.1. Overview

1.1.1. Background

The construction sector contributes significantly to the global environmental burden due to its consumption of raw materials and energy (Niu et al. 2021). Mass timber construction has become a viable alternative to conventional structural materials owing to sustainably managed forests and forest products, prefabricated products, speed of installation, and its relative weight (Campbell 2020). Mass timber is a structural product made from dimensional veneer or lumber that is emerging as a sustainable alternative to conventional materials like steel and concrete (Campbell 2019). Despite its growing popularity, a reluctance in the use of mass timber construction over conventional steel and concrete construction has been observed. Figure 1.1 shows the number of mass timber projects in the country until September 2023 that are completed/under construction/in the design phase.

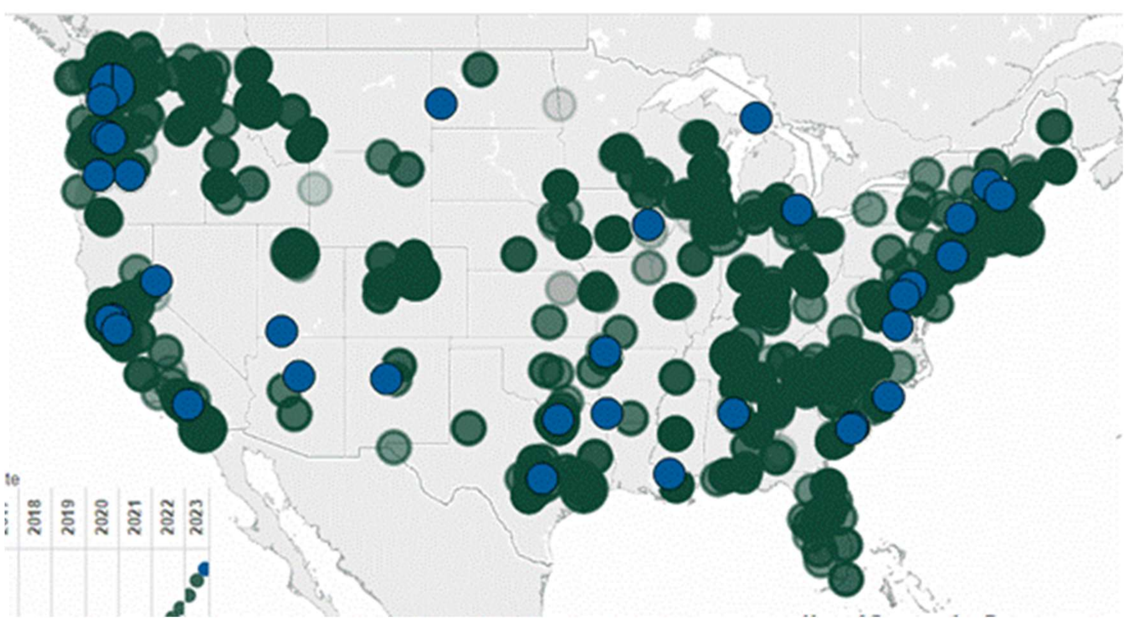

Figure 1.1: Mass Timber projects in the United States Source: WoodWorks.com

It can be observed from this figure that mass timber construction is being adopted primarily in the Northeast and Southwest regions of the country. To encourage the adoption of mass timber construction projects in other regions of the country, we need to understand the barriers faced by the mass timber industry.

1.1.2. Major Barriers to the Adoption of Mass Timber

Knowledge Deficit

According to Ahmed and Arocho (2020), one of the major barriers to the widespread adoption of mass timber construction is the lack of knowledge and experience. A study by Mallo and Espinoza (2015) states that more than half of the industry professionals were unaware of mass timber construction. Similarly, Smith et al. (2015) stated that a majority of industry professionals were not familiar with mass timber construction and techniques. While mass timber construction has gained popularity since 2015, the level of awareness among professionals remains an issue (Ahmed and Arocho 2021a). This deficit of knowledge and awareness can also influence the production capacity of mass timber materials. Zelaya (2020) determined that a lack of knowledge can be a barrier to the production capacity of mass timber materials.

Material Unavailability

Along with a knowledge deficit, the manufacturers are not able to keep up with the ever-increasing demand for mass timber materials. Thus, a bottleneck situation is created in the product manufacturing phase. Although, Zelaya (2020) suggests that the manufacturing companies indicated reduced investment in manufacturing mass timber products due to low demand as a major cause for reduced production. A study conducted by Ahmed and Arocho (2020) suggests that the unavailability of material is a key hurdle in the widespread adoption of mass timber construction. There is a need to break this vicious cycle of supply and demand to increase the adoption of mass timber construction. The unavailability of materials may lead to increased production costs of mass timber material.

High Production Costs

Mass Timber Costs Compared to Conventional Steel or Concrete Structures	References
6%	Fragiacomo et al. (2009)
5%	Ahmed and Arocho (2020)
6.43%	Ahmed and Arocho (2021)
-20%	Agyekum-Mensah (2021)
-6%	Kremer & Ritchie (2018)

Table 1.1: Variability in Mass Timber Costs

The correlation between the deficit of knowledge, design and cost uncertainty, and the unavailability of material leads to an increase in the production cost of mass timber products. Increased production costs impact mass timber products' cost competitiveness compared to conventional construction products like concrete and steel (Ahmed and Arocho 2020). Multiple studies compared the construction costs of mass timber construction with steel and concrete. According to Ahmed and Arocho (2020), mass timber construction costs 5 % more when compared to other types of construction. Fragiacomo et al. (2009), compared the cost of construction for timber with steel and concrete buildings and concluded that timber costs 6 % more compared to steel or concrete options. Another study by Ahmed and Arocho (2021) concluded that mass timber construction is 6.43 % higher than concrete construction. Although, a study conducted by Agyekum-Mensah (2021) reveals that timber frame structures were 20 % cheaper when compared to steel framed structures. Similarly, Kremer and Ritchie (2018) concluded that mass timber construction is 6 % cheaper when compared to concrete construction. The varied results from these studies suggest there is no alignment between the projected costs for mass timber construction. Table 1.2 shows the variability in results from different studies. This inconsistency reinforces the premise that lack of knowledge about mass timber products is a barrier to widespread adoption. Consequently, this dearth of knowledge creates a gap in the literature on the cost performance of mass timber construction. When compared with the abundant information on conventional construction materials like steel and concrete, mass timber lacks sufficient cost performance data (Ahmed and Arocho 2022). There is a need to study this cost performance data to encourage the widespread adoption of mass timber construction. When determining the future success of mass timber products, cost competitiveness is an important factor (Ahmed and Arocho 2021).

High Insurance Costs

Apart from higher production costs, high insurance premiums can impact mass timber construction projects. Insurance companies have been slow to adopt new technology like mass timber construction (DLR Group 2018). General contractors and developers often observe higher insurance premiums for mass timber construction projects (McLain and Brodahl 2021). The novel nature of mass timber in the United States contributes to a dearth of historical loss data and reference projects (McLain and Brodahl 2021). Consequently, insurance companies are observing a conservative approach by presuming higher risks (Marsh McLennan 2021). Higher risks lead to increased insurance premiums. Due to limited project capacities, multiple insurance companies may be involved to limit risk exposure (Marsh McLennan 2021; Came

2022). Furthermore, this could lead to higher insurance premiums. McLain and Brodahl (2021) suggest working with experienced insurers to develop better insurance premiums.

1.1.3. Cost Performance in Construction Projects

Cost competitiveness can be affected by cost overruns. Cost overruns tend to impact the cost performance of a project. This impact increases the financial burden on numerous stakeholders (Sinesilassie et al. 2017). The factors affecting the cost performance of a project are the project manager's lack of knowledge, unclear project scope, inefficient work by the project manager, and conflicts amongst stakeholders (Sinesilassie et al. 2017; Alhammadi and Memon 2020). Additionally, cost overruns have been a major source of concern for all construction projects (Asiedu and Adaku 2019). There is a need to study the effect of cost overruns in mass timber construction projects to determine their cost performance.

Asiedu and Adaku (2019) distinguished causes of construction project overruns into four major categories – 1) change orders, 2) inadequate planning and supervision, 3) faulty economic environment, and 4) improper coordination amongst stakeholders. Hanna et al. (2002) suggests that change orders affect the project directly or indirectly resulting in direct cost increases and a labor productivity deficit. The basic aim of a construction project is timely completion within the estimated budget, and change orders are one of the most critical aspects of a project that affect both schedule and cost performance (Shreshtha 2018).

1.1.4. Change Orders and Mass Timber Construction

Change orders are unavoidable during the construction phase of most projects (Ahmed and Arocho 2021). Change orders are a document written to the contractor authorizing a change in work entailing the scope of change and its influence on cost/time in a project (Khalifa and Mahamid 2019). Several studies have been conducted on the effect of change orders on conventional construction materials like steel and concrete. However, there is little data available on the effect of change orders on mass timber construction. Apart from cost overruns, change orders also delay the project schedule. A delay is defined as an extension or termination of a part of a project due to unforeseen circumstances (Faridi and El-Sayegh 2006). Faridi and El-Sayegh (2006) revealed preparation and approval of drawings, changes, slow decision-making process, and insufficient pre-planning as some of the main causes of delays in construction projects. Minimal data is available on the causes or effects of delays in mass timber construction projects. A study conducted in the UK calculated delays in mass timber construction projects. This study determined that only 7% of the projects studied had delays directly related to mass timber construction (Waugh Thistleton Architects 2018). This suggests that the prefabricated nature of mass timber products helps in planning ahead and reducing potential delays in mass timber construction projects.

Ahmed and Arocho (2021) discussed the impacts of poor pre planning and collaboration between project stakeholders like designers, consultants, contractors, subcontractors, etc. This study focuses on the change orders in mass timber construction projects and their impact on project's cost performance.

1.1.5. A Case for Mass Timber Construction

The following case study demonstrates the use of mass timber construction and how prefabricated material can save project costs and time.

- Project Name: Brock Commons Tallwood House
- Location: University of British Columbia, Vancouver
- Owner: University of British Columbia, Student Housing and Hospitality Services
- Architect: Acton Ostry Architects Inc.

- General Contractor: Urban One Builders
- Mass Timber Supplier: Structurlam
- Completion: May 2017

The Brock Commons Tallwood House is an 18-story student residence housing at the University of British Columbia. This is the first mass timber hybrid structure to have 18 stories and one of the tallest mass timber structures at that time. The structure consists of cross-laminated timber (CLT) floor panel assemblies along with glued-laminated timber (GLT) and parallel strand lumber (PSL) columns (figures 1.3 and 1.4). Due to efficient coordination and prefabricated elements, the erection was completed two months ahead of schedule when compared to the original. This led to the project getting completed two months early in May 2017. The learning curve and increased efficiency of the trades acted as vital factors in the early delivery of the project. In order to meet and exceed the rigorous timeline, the contractor adopted strategies like integrative planning, consistent communication, and early involvement of project stakeholders (Designers, consultants, contractors, major trades, and manufacturers). Early completion led to saving project costs. The construction cost for this project was $40.5 million as compared to the approved project budget of $51.5 million. Thus, early completion may have saved $11 million in construction costs compared to budgeted costs. Cost savings of $11 million may have been caused by multiple reasons like 1) over budgeting due to novel nature of mass timber, or 2) reduction in general conditions or general requirements due to reduced time. There can be many different reasons for cost savings, it is assumed that Projects like Brock Commons Tallwood House generate the opportunity for future projects to implement shorter project durations and reduce schedule time.

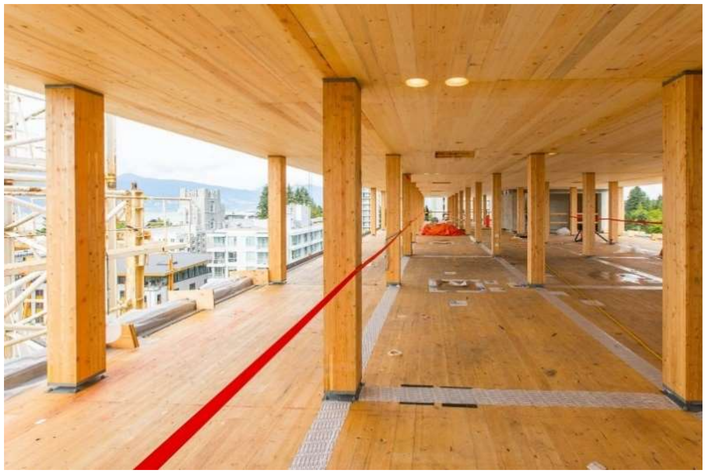

Figure 1.2: GLT columns Source: Thinkwood.com

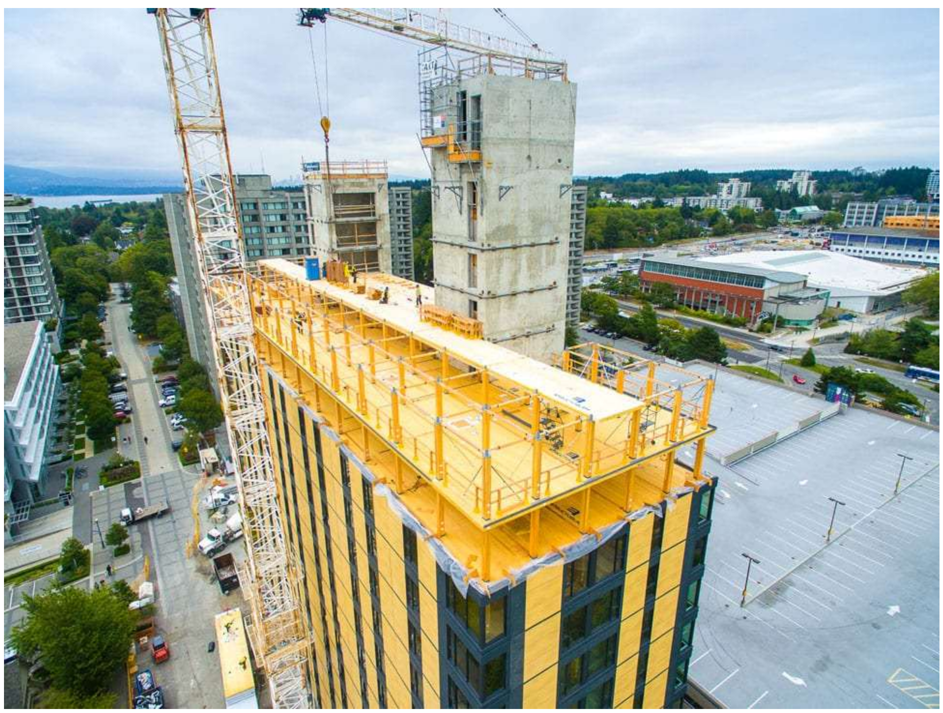

Figure 1.3: Erection of CLT and GLT members Source: Thinkwood.com

1.2. Research Need

Project costs have always influenced the construction industry. In a 2017 report, BCCA laid out priorities upheld by the construction industry. These were making money to sustain businesses and maximizing the value of capital. Owing to the importance of money, the report listed five barriers to the adoption of mass timber construction:

1. Lack of knowledge
2. Low project costs are prioritized
3. Lack of standardization across the supply chain
4. Lack of experience/ technical expertise
5. Price volatility in bids due to lack of knowledge

The major barrier to the adoption of mass timber construction projects is regulated by initial material costs. There is little to no data available on material or construction costs for mass timber construction. Similarly, a singular study has been published on cost performance and the impact of change orders on mass timber construction. This study is essential to enhance the economic knowledge base for mass timber construction. Also, there is a need to determine the cost-effectiveness of mass timber products to encourage widespread adoption. More research and awareness need to be spread to increase the reach of the mass timber knowledge base. The pre-construction planning processes in mass timber projects are not efficient leading to conflicts between all the stakeholders involved like designers, manufacturers, subcontractors, and code officials. These conflicts stem from the lack of knowledge of mass timber as a construction material. This study attempts to determine the value of timber beyond initial cost and schedule savings. This effort is guided by the following questions:

RQ #1: What does the project delivery method with some level of integration contribute towards the cost performance of mass timber construction projects?

H_0: Cost performance of mass timber projects is independent of the level of integration in project delivery methods.

H_1: Cost performance of mass timber projects is dependent on the level of integration in project delivery methods.

RQ #2: How do mass timber-related change orders affect the actual project costs of mass timber construction projects?

H_0: Mass timber-related change orders have no effect on actual project costs when compared to the scope of mass timber work.

H_1: Mass timber-related change orders have a negative effect on actual project costs when compared to the scope of mass timber work.

RQ #3: What are the tools to develop an efficient project delivery method to reduce conflicts and changes in the latter part of mass timber construction projects?

1.3. Goals and Objectives

This study focuses on the change orders in mass timber construction projects and their effect on cost overruns to substantiate cost competitiveness for mass timber products. This study aims to develop guidelines for an efficient project delivery method to strengthen the execution of mass timber construction projects.

Objective #1: To understand factors affecting the cost performance of mass timber construction projects.

Objective #2: To identify the causes of change orders in mass timber construction projects.

Objective #3: Develop guidelines to improve the cost performance of mass timber construction projects by implementing project delivery methods.

1.4. Methods and Research Activities

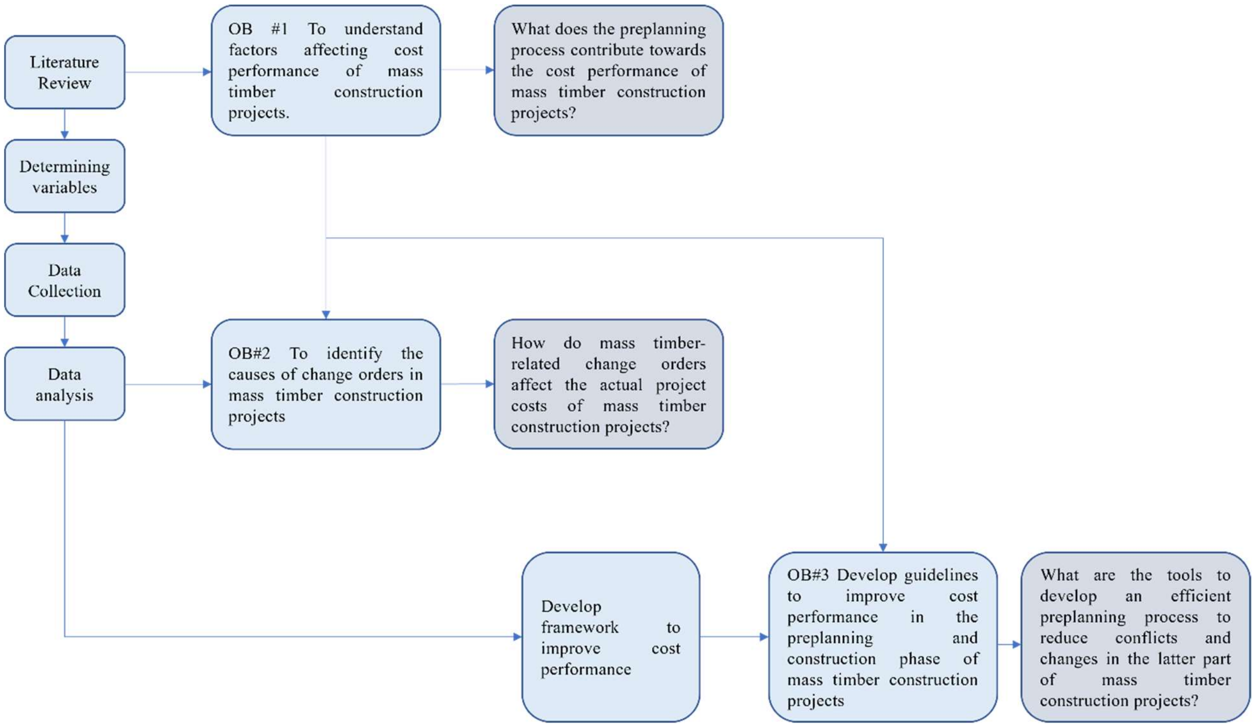

Figure 1.4: Research Methodology

The main goal of this project is to understand and improve the cost performance of mass timber construction projects.

Objective #1: To understand factors affecting cost performance of mass timber construction projects.

<u>Step 1- Literature Review:</u>

This step is intended to explore the previous contributions to the knowledge base and understand the state of mass timber construction through literature. Existing literature on causes and effects of change orders will be studied. This data would be used to understand the most common factors in conventional construction projects and their sources. The acquired data will be applied to mass timber construction and its associated costs. This will help identify the research gaps related to cost performance of mass timber construction. Further expansion on the cost-related data on mass timber construction projects will be provided in Chapter 2.

Objective #2: To identify the causes and effects of change orders in mass timber construction projects.

Step 2- Determining variables:

The literature review was used to identify variables. These variables were used to create a guideline for the data collection process. Factors causing change orders in mass timber construction projects were identified using the collected data.

Step 3- Data collection:

This step intends to collect change order-related data from mass timber construction companies. To determine the cost impact of these change orders, actual project costs and actual mass timber costs were studied. The costs of change orders will be identified and compared with the mass timber-related change orders to benchmark potential change orders for mass timber. Various independent variables like project type, construction type and project delivery methods were studied.

Step 4- Data analysis:

Upon retrieving the dataset, the main causes of the mass timber-related change orders were assessed. The change orders were classified into four different sources: owner, architect, contractor, and others.

Along with this, the cost performance of mass timber-related change orders was calculated based on actual costs. This helped in determining the monetary impact of change orders.

Step 5- Testing of data:

The data collected from leading mass timber construction companies will be tested using Descriptive statistics, Pearson's correlation, and ANOVAs to validate.

Objective #3: Develop guidelines to improve cost performance in the preplanning and construction phase of mass timber construction projects.

Step 6- Development of cost-performance framework:

Understanding the most common mass timber-related changes would help minimize the causes and impacts of such changes. This step includes the preparation of guidelines to help improve the cost performance of mass timber construction projects.

1.5. Scope and Limitations

This study focuses on mass timber-related change orders collected from mass timber construction companies. The analysis will focus on the United States construction industry only. The geographical diversity of the dataset will be limited due to the novel nature of mass timber construction. The majority of projects are located on the western part of the country due to their widespread adoption and proximity to manufacturing facilities in those regions. The study assumes accurate data was provided by the participants, there is no way for the author to verify the data provided by them. The data is limited to the information provided by the participant, not all the data fields requested by the author were provided by the participants. The data set is made up of 34 projects using mass timber construction. The author is aware that one participant is overrepresented in the dataset due to the dearth of participants working in the field of mass timber construction. The overrepresented participant consists of 25 projects out of the 34 projects. The classification of data is undertaken by the author's best knowledge and judgment of the construction industry. One of the major limitations of the data is the small sample size. The data collected is field data and was captured from an uncontrolled environment, thus leading to more variability. This small sample size led to fewer degrees of freedom leading to difficulty in multivariate analysis. Thus, forcing the author to use correlation statistical analysis to understand the data. Lastly, collection of cost related data from construction companies is challenging. Companies willing to share the data with the author were selected for this study. Thus, the data collected is not random.

CHAPTER 2 LITERATURE REVIEW

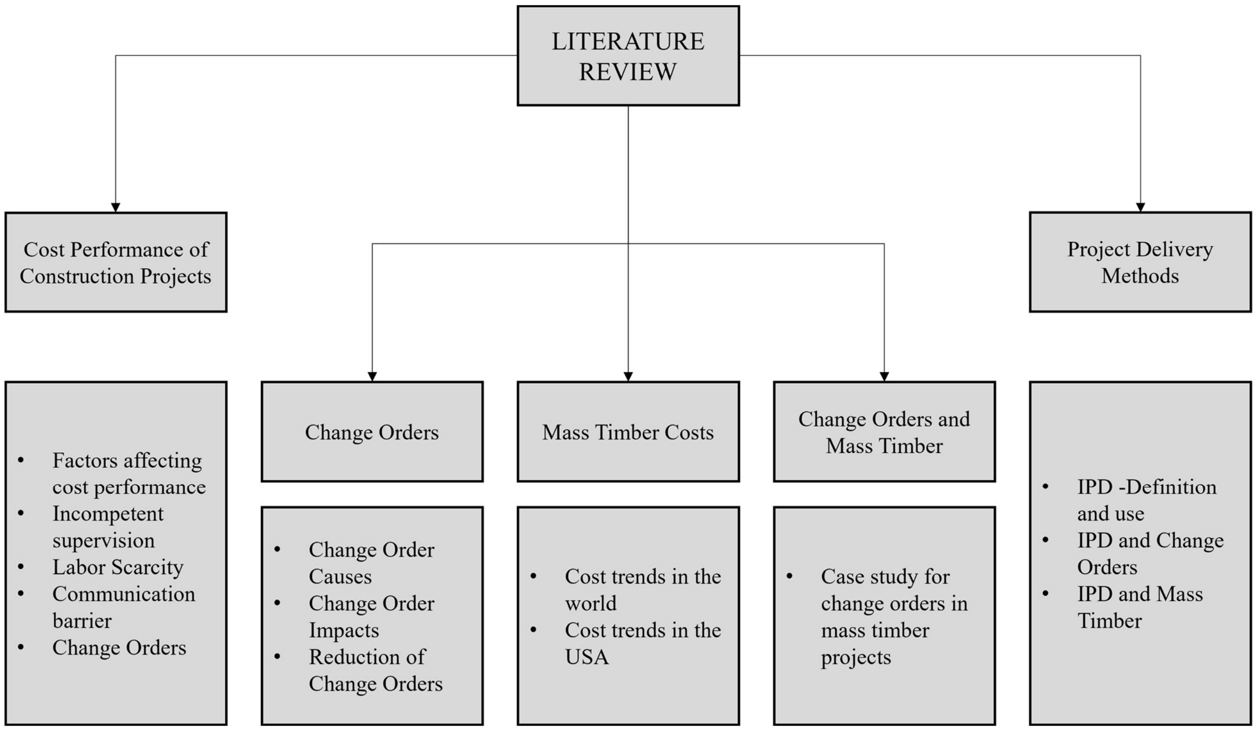

Figure 2.1: Literature Review Outline

This chapter intends to comprehensively review the background of the area of study. It will assist in developing the methodology, and data collection and analysis methods. Figure 2.1 depicts an outline for literature review. The literature review is designed to recognize background information on cost performance and its effect on mass timber construction. To harness the vast nature of data available, this chapter is divided into five segments: 1) cost performance of construction projects, 2) change orders, 3) mass timber costs, 4) change orders and mass timber, and 5) integrated project delivery.

The first section focuses on factors affecting the cost performance of construction projects. It will compile factors affecting the cost performance of construction projects like flawed planning and supervision, weak economic environment of the industry, poor communication between stakeholders, and change orders.

The second section focuses on the meaning of change orders. It also compiles key factors causing change orders. Furthermore, this section focused on the impacts of change orders leading to strategies to reduce change orders.

The third section focuses on mass timber and its construction costs. Costs related to mass timber have evolved around the world and this section studies the cost trends for mass timber performance compared to conventional construction around the world. Additionally, cost trends in the United States are studied to understand the performance of mass timber around the country.

The fourth section aims to talk about change orders in mass timber construction. It is evident that there is a gap in knowledge in this section and there is a need to fill this gap to provide a better understanding of change orders in mass timber.

The fifth section talks about project delivery systems and how to efficiently apply them to achieve desired benefits. Integrated project delivery is the focus of the discussion, and its collaborative nature might help in the reduction of change orders in mass timber construction.

2.1. Factors Affecting the Cost Performance of Projects

Construction projects contribute majorly to the economic development of a country (Musarat et al. 2021). The delivery of these projects is dependent on two main factors - cost and time. Cost performance is dependent on the timely delivery of the project. According to Garsden (1995), cost and time are correlated. A delay in time/schedule adversely affects the cost and profitability of a construction project. Cost performance is recognized as an important criterion to measure project success (Meeampol and Ogunlana 2006; Knight and Fayek 2000). Many techniques have been developed to reduce project delivery times and costs. However, the construction industry is experiencing inadequate cost performance leading to cost overruns (Alhammadi and Memon 2020). Cost overrun can be defined as the costs beyond the scope of the original estimate (Knight and Fayek 2000). Cost overrun concerns have been observed in projects all around the world for many years (Alhammadi and Memon 2020; Asiedu and Adaku 2019).

To understand the causes of cost overruns, identification of their source is important. Cost overruns can be detected through various statistics like labor productivity reports, cost reports, project delays, daily schedules, rise in rework, and interruption in work, etc (Knight and Fayek 2000). To reduce such cost overruns, the recognition of the factors causing cost overruns is crucial. Asiedu and Adaku (2019) classified four key causes of cost overruns. These causes are 1) flawed planning and supervision, 2) weak economic environment of the construction industry, 3) poor communication between responsible stakeholders, and 4) change orders.

2.1.1. Flawed Planning and Supervision

Incompetent supervision can affect project planning, costs, and site management which might lead to variations in cost and time (Mansfield et al. 1994; Meeampol and Ogunlana 2006). Mansfield et al. (1994) identified the leading causes of flawed supervision as a deficit in knowledge and experience, incompetent project scheduling, and minimal productivity. Although, a lack of proper supervision on construction projects leads to productivity issues (Dahlin and Pesamaa 2021). Similarly, the study conducted by Durdyev (2020) termed imprecise estimates and project scheduling as significant causes of cost overruns. Thus, the absence of accurate estimates, schedules, monitoring, and control mechanisms can impact project success (Asiedu and Adaku 2019; Durdyev 2020). To prevent flawed planning and supervision, adequate stakeholder expertise can be incorporated in the pre-construction and planning stage (Durdyev 2020).

2.1.2. Weak Economic Environment of the Construction Industry

Inflation leads to economic volatility due to unpredictable labor, material, and equipment costs in construction (Musarat et al. 2021). Thus, a construction project may face cost overruns owing to variations in the initial and final budget. To curb the variations in the budgets, the inflation factor should be considered before concluding the estimate (Musarat et al. 2021). Inflation is one of the major causes of a skilled labor shortage in construction (Richardson 2018). 93% of contractors surveyed by AGC (2022) reported having a scarcity of skilled labor. Gomar et al. (2002) contemplated brief work duration, unemployment between jobs, and frequent layoffs as driving factors for the skilled labor shortage. Furthermore, Gomar et al. (2002) and Kim et al. (2020) believe labor shortages can lead to cost overruns and schedule delays. AGC (2022) indicated the issue of a skilled labor shortage is critical which might negatively affect project health.

2.1.3. Poor Communication Between Responsible Stakeholders

A lack of proper communication between designers and clients can lead to cost variances or potential change orders due to disparities in knowledge (Asiedu and Adaku 2019). Poor communication is one of the predominant issues that can negatively affect project health

(Suleiman 2022). According to a study conducted by Suleiman (2022), the major factors for poor communication are a direct result of a lack in proper communication strategies, efficient project stakeholder representatives, accurate and accessible project information, and mutual understanding between stakeholders. Whereas, a study conducted by Rahman and Gamil (2019), suggested fear of communication as a dominant factor leading to a strained workplace environment.

Therefore, to avoid delay in the project duration, a comprehensive design brief, contingency plans, project details, and specifications should be discussed to alleviate discrepancies (Asiedu and Adaku 2019).

2.1.4. Change Orders

A change order is created owing to changes in the initial scope of work (Pourrostam and Mansournejad 2011). These changes are followed by a change in scope, methods, cost, or time (Pourrostam and Mansournejad 2011). Most change orders negatively impact the project and may lead to time and cost overruns, disputes between stakeholders, or disruption to construction activities (Khalifa and Mahamid 2019). A contractor has the right to equal adjustment in cost and time to compensate for change orders (Asiedu and Adaku 2019). Change orders are discussed more in the following sections.

2.2. Change Orders in Construction Projects

In the construction industry, change orders are unavoidable (Ahmed and Arocho 2021). Verrastro and Baum (2022) define change orders as "*an adjustment to the contract written by the Architect and to be signed by the Owner, Architect, and Contractor to agree upon 1) Change in work, 2) Contract sum adjustment, if any, and 3) Contract time adjustment if any*." According to Naji and Naser (2022), change orders negatively affect project performance. Change orders may alter the relationship between the owner, the architect, and the contractor. Change orders can lead to contractual disputes among stakeholders along with legal repercussions (Shrestha and Fathi 2019; Khalifa and Mahamid 2019). The number of changes in a project determines the severity of legal repercussions. If there are fewer or no changes, the likelihood of delay claims or legal repercussions is reduced (Shrestha and Fathi 2019). To save project costs from legal bills, there is a need to prevent such legal disputes/repercussions due to a plethora of change orders. Khalifa and Mahamid (2019) talk about the misinterpretation of modified clauses or loose ends to increase profitability by contractors. Although, a lack of effective change order management techniques is observed. In most projects, a common approach is to include a contingency in the contract budget to prevent cost overruns due to change orders (Khalifa and Mahamid 2019). In order to reduce the number of change orders, it is imperative to understand the factors causing such change orders.

2.2.1. Factors Causing Change Orders

Sr no.	**Factors Causing Change Orders**	**References**	**C/O Driving Source**
1	Financial constraints of the Owner	Khalifa and Mahamid (2019); Olawale and Sun (2010); Badawy (2021); Sunday (2010)	Owner
2	Financial constraints of the Contractor	Pourrostam et al. (2011); Sunday (2010)	Contractor

Table 2.1: Causes of Change Orders

Table 2.1 (cont'd)

3	Previous projects delays	Pourrostam et al. (2011); Wu et al. (2004)	Other
4	Acceleration of work	Pourrostam et al. (2011); Badawy (2021)	Contractor
5	Decrease in quality of workmanship	Khalifa and Mahamid (2019); Pourrostam et al. (2011), Gunduz and Mohammad (2019); Sunday (2010)	Contractor/ Other
6	Weather impact beyond prediction	Pourrostam et al. (2011), Olawale and Sun (2010); Hsieh et al. (2004); Chan and Kumaraswamy (1997)	Other
7	Change of schedule	Pourrostam et al. (2011); Alaryan et al. (2014); Sunday (2010)	Owner

Table 2.1 (cont'd)

8	Change of scope/work	Khalifa and Mahamid (2019); Pourrostam et al. (2011); Alaryan et al. (2014); Alnuaimi et al. (2010); Mpofu et al. (2017); Badawy (2021); Sunday (2010); Oyewobi et al. (2016)	Owner
9	Exploitation of contract terms by Contractor	Pourrostam et al. (2011); Alnuaimi et al. (2010); Olawale and Sun (2010); Sunday (2010)	Contractor
10	Changes in Design/Specifications	Pourrostam et al. (2011); Alnuaimi et al. (2010); Olawale and Sun (2010); Mpofu et al. (2017); Badawy (2021); Hsieh et al. (2004); Chan and Kumaraswamy (1997); Sunday (2010); Oyewobi et al. (2016)	Designer/ Owner

Table 2.1 (cont'd)

11	Errors/Omissions in design	Khalifa and Mahamid (2019); Alaryan et al. (2014); Hsieh et al. (2004); Alnuaimi et al. (2010); Mpofu et al. (2017); Badawy (2021); Chan and Kumaraswamy (1997); Wu et al. (2004); Sunday (2010); Oyewobi et al. (2016)	Designer
12	Lack of coordination by contractor	Khalifa and Mahamid (2019); Alnuaimi et al. (2010); Mpofu et al. (2017); Chan and Kumaraswamy (1997); Sunday (2010); Oyewobi et al. (2016)	Contractor
13	Differing/Unforeseen site conditions	Khalifa and Mahamid (2019); Alaryan et al. (2014); Badawy (2021); Hsieh et al. (2004); Chan and Kumaraswamy (1997); Wu et al. (2004); Sunday (2010)	Other

Table 2.1 (cont'd)

14	Unrealistic schedule by Contractor	Alnuaimi et al. (2010); Olawale and Sun (2010); Mpofu et al. (2017)	Contractor
15	Constructability issue	Alnuaimi et al. (2010); Chan and Kumaraswamy (1997); Wu et al. (2004); Oyewobi et al. (2016)	Designer
16	Misinterpretation of contract scope/terms	Olawale and Sun (2010); Badawy (2021); Sunday (2010)	Designer/ Contractor
17	Labor productivity/availability issues	Mpofu et al. (2017); Sunday (2010)	Other

Table 2.1 represents various causes of change orders derived from the literature review. The change orders were further classified into four different categories with respect to their driving sources as follows: 1) Owner, 2) Contractor, 3) Designer, 4) Other. While identifying the causes of change orders, the most common factors of change orders were observed. They are enumerated below.

1. Changes in design/specifications,
2. Changes in scope/work,
3. Errors/omissions in design,
4. Lack of coordination by contractor, and
5. Differing/Unforeseen site conditions.

2.2.2. Impacts of Change Orders

As discussed before, change orders can cause delays in schedule, cost overruns, delays of interdependent activities, and disputes between stakeholders (Pourrostam et al. 2011). The following table 2.2 is used to identify the effect/impact of change orders from the available literature.

Sr no.	Impacts of Change Orders	References
1	Project cost overruns	Alaryan et al. (2014); Alnuaimi et al. (2010); Pourrostam et al. (2011); Gunduz and Mohammad (2019); Sunday (2010); Oyewobi et al. (2016); Alzara (2022)
2	Longer duration of individual activities	Alaryan et al. (2014)
3	Schedule delay	Alaryan et al. (2014); Alnuaimi et al. (2010); Pourrostam et al. (2011); Sunday (2010); Oyewobi et al. (2016); Alzara (2022)

Table 2.2: Impacts of Change Orders

Table 2.2 (cont'd)

4	Extra expenses for contractor	Alaryan et al. (2014); Alnuaimi et al. (2010); Pourrostam et al. (2011); Gunduz and Mohammad (2019); Oyewobi et al. (2016); Alzara (2022)
5	Payment delays	Alaryan et al. (2014); Gunduz and Mohammad (2019); Alzara (2022)
6	Inception of Claims/disputes	Alnuaimi et al. (2010); Pourrostam et al. (2011); Oyewobi et al. (2016); Alzara (2022)
7	Affect labor productivity	Alnuaimi et al. (2010); Hanna and Iskandar (2017); Gunduz and Mohammad (2019); Kermanshachi et al. (2021); Alzara (2022)
8	Affect succeeding activities	Pourrostam et al. (2011)

Table 2.2 (cont'd)

9	Loss of future projects with the same or different owner	Gunduz and Mohammad (2019); Oyewobi et al. (2016)
10	Decrease project quality	Gunduz and Mohammad (2019); Alzara (2022)

While identifying the impacts of change orders, the most common impacts of change orders were observed:

1. Project cost overruns,
2. Schedule delay,
3. Extra expenses for contractors,
4. Claims/ disputes, and
5. Affect labor productivity.

2.2.3. Minimizing Change Orders

Understanding the causes and impacts of change orders can assist in prevention of change orders. Changes in design can be avoided by establishing a detailed design and identifying the risk of potential design changes during the design phase (Olawale and Sun 2010; Pourrostam et al. 2012). Similarly, Kermanshachi et al. (2021) also suggests that detailed and complete designs in the bid documents can help avoid changes. According to Pourrostam et al. 2012, clarity in objectives and scope of work can result in fewer change orders. Olawale and Sun (2010) suggests a holistic approach to the scheduling process incorporating all durations like lead times, detailed site logistics, and integrated collaborations. Furthermore, project schedules are often developed using informal knowledge alone, not including formal knowledge of evidence-based calculations. These schedules should be based on the use of formal and informal knowledgebase of an experienced scheduler to obtain accurate project durations (Olawale and Sun 2010). Timely informing the relevant project stakeholders of a potential change order can help in early mitigation to avoid cost and time overruns (Olawale and Sun 2010). Extensive pre-planning and scheduling processes might not be able to eliminate change orders completely. However, minimizing the number of change orders is plausible. In conclusion, anticipation and planning for change orders before the construction phase might help in the reduction of change orders. Key performance indicators like value engineering, constructability evaluations, and improved designs are essential in minimizing change orders (Ahmed 2021).

2.3. Mass Timber and its Costs

Cost competitiveness is essential in determining if a project will succeed in the long run. According to Mallo and Espinoza (2016), the most crucial factors affecting the decision to choose a structural material are its cost and economic performance. DLR (2018) states that construction costs can be decreased by reducing the time to build a structure. Owing to its prefabricated nature, mass timber construction can cut down construction time. A study by Mallo and Espinoza (2016) determined a 61.1% reduction in construction time compared to concrete and steel frame structures. Furthermore, due to the rising labor costs, a reduction in construction time predicts cost savings. However, when compared to other construction materials, the cost of mass timber contributes significantly to the total project costs (Chaggaris et al. 2021b). Scouse et al. (2020) also concluded that mass timber construction costs are significantly higher when compared to conventional concrete construction. Total project costs can be dictated by mass timber costs (Liang et al. 2021; Chaggaris et al. 2021a). In a study conducted by Scouse et al. (2020), mass timber was a significant contributor, 38% of the total project costs. Burback and Pei (2017) observed a 21% increase in the cost of mass timber when compared to light-framed wood structures. A trend of higher mass timber construction costs can be observed in literature.

2.3.1. Mass Timber Cost Trends Around the World

No	Project	Location	Market Standard ($/SF)	Actual Costs ($/SF)	Cost Variation	Building Type
1	Bridport House	London, UK	213.33	198.23	-7%	Housing
2	Carlisle Lane Lofts	London, UK	213.33	305.28	43%	Housing
3	Massive Living	Graz, Austria	213.33	182.5	-14%	Housing
4	SmartLIFE Centre	Cambridge, UK	312.27	257.92	-17%	Institutional
5	UBC Earth Systems Science Building	Vancouver, Canada	312.27	276.85	-11%	Institutional
6	UBC Okanagan Fitness and Wellness Centre	Kelowna, Canada	284.25	343.11	21%	Institutional

Table 2. 3: Conventional Construction vs. Mass Timber Costs in the World

Smith et al. (2015) analyzed the economic performance of mass timber construction compared to conventional construction. The study focused on projects around the world in countries like the United Kingdom, Austria, and Canada. Table 2.3 assesses the variation in mass timber construction costs against conventional construction costs. A housing development in London, UK known as 'Bridport House' revealed cost savings of 7 % over conventional construction. Likewise, 'Massive Living', a housing development in Graz, Austria indicated 14 % cost savings. However, another housing development in London, UK ‘Carlisle Lane Lofts’ showed a cost variation of 43 % when compared to conventional construction. A cost disparity is observed between the two developments in London. This disparity can be due to various reasons like lack of experience, lack of knowledge, supply chain issues, coordination issues, etc.

‘SmartLIFE Centre’ in Cambridge, UK revealed 17 % cost savings compared to conventional construction methods. Similarly, ‘UBC Earth Systems Science Building’ also showed cost savings of 11 % over conventional construction. Although, ‘UBC Okanagan Fitness and Wellness Centre’ showed 21 % cost variation from conventional construction. Amongst all the cases studied, 67 % of cases projected cost savings when compared to conventional construction. These cost savings can be attributed to a reduction in the scheduled time. Smith et al. (2015) indicated that cost savings are directly proportional to the project schedule. Compared to the United States, mass timber is a widely accepted construction material in Europe and Canada (Structurlam 2022). While knowledge and labor barriers persist around the world (Smith et al. 2015), there is a need to study and build more mass timber projects to boost widespread adoption of mass timber.

2.3.2. Mass Timber Cost Trends Around the United States

No	Project	Location	Market Standard ($/GSF)	Actual Costs ($/GSF)	Cost Variation	Building Type
1	1 De Haro	San Francisco, CA	385	392	2%	Office
2	The ICE Blocks	Sacramento, CA	193	205	6%	Office
3	Clay Creative	Portland, OR	190	213	12%	Office
4	District Office	Portland, OR	210	233	11%	Office
5	Barracuda Condos	Madison, WI	174	202	16%	Housing
6	Ascent	Milwaukee, WI	200	190	-5%	Housing
7	INTRO	Cleveland, OH	212	215	1%	Housing
8	The Canyons	Portland, OR	186	210	13%	Housing

Table 2. 4: Market Standard vs. Mass Timber Costs in the US

A study conducted by WoodWorks (2022) analyzed about mass timber construction costs compared to conventional market standards in the United States. Table 2.4 displays the variation in mass timber construction project costs against conventional market standards in the United States. An office building in San Francisco, CA known as '1 De Haro' observed a 2 % rise in construction costs when compared to the market standard. Similarly, 'The ICE Blocks' in Sacramento, CA observed a 6 % variation in the mass timber costs and market standards. Whereas two office buildings in Portland, OR 'Clay Creative' and 'District Office' surpassed the market standards by 12 % and 11 % respectively. While looking at the housing market in Wisconsin, two contradictory costs were observed. 'Barracuda Condos' portrayed 16 % variation. Whereas 'Ascent' showed a negative 5 % variation leading to 5 % cost savings when compared to the standard market costs. Comparably, 'INTRO, Cleveland' in Cleveland, OH showed mass timber costs to have a minimal variation of 1 % from the conventional costs. However, A housing development in Portland, OR known as 'The Canyons' revealed 13 % cost variations when compared to standard market costs (The Wood Products Council 2022). A few schedule delays were observed in the projects studied. Although, these delays were due to unforeseen problems like COVID-19 Pandemic, wildfires, extended lead times, and Suez Canal obstructions. Apart from the unforeseen problems, one project dealt with a misconstrued perception of mass timber impacts by subcontractors. A stronger General Contractor might help prevent change orders/delays (WoodWorks 2022). Variability in the cost performance of mass timber structures was observed in table 2.4. This variability is observed throughout building types and locations. Projects in Oregon still observe a significant percentage increase in costs even after having proximity to manufacturing facilities. This cost uncertainty is dictated by the unavailability of resources and knowledge on mass timber construction.

2.4. Change Orders in Mass Timber Construction

There is a dearth of available data for change orders in mass timber construction. Ahmed (2021) studied construction costs and change orders in an 18-story mass timber building in Canada. The study calculated a 6.4 % increase in construction costs for using mass timber as a material. The study also revealed that only 5.85 % of total change orders were related to mass timber as a construction material. The cost of these change orders was $94,000, contributing 4.38 % to the total change order costs. The connection between construction costs and change orders related to mass timber was negligible (Ahmed 2021). This revealed that mass timber-related change orders do not significantly impact mass timber construction costs when compared to procurement and installation costs (Ahmed 2021). The change orders revealed major cause for them was a communication barrier between project stakeholders (Ahmed 2021). Furthermore, the project used integrated project delivery (IPD) as the delivery method. A poor application of IPD can be observed in this project due to a substantial amount of change orders (Ahmed and Arocho 2021). The incorporation of strategies like building information modeling (BIM), integrated project delivery (IPD), and an experienced project management team will aid in minimizing the number of change orders (Ahmed 2021). The study had a few shortcomings due to the nature of the data collected. This data is based on a singular building, and it is difficult to generalize the findings (Ahmed and Arocho 2021). There is a need to expand this study to further evaluate the effect of change orders on the cost performance of mass timber construction projects. This can be achieved by increasing the sample size and evaluating project teams to understand the actual impact of change orders on project health.

2.5. Project Delivery Methods

Plugge (2007) discussed that expectations of change orders increase in projects with no level of integration like Design-Bid-Build projects. Whereas there is less risk involved for change orders in projects with some level of integration like design-build, CM at risk, or design-assist project delivery. Projects with some level of integration, costs, and changes can be better identified at the beginning of the project methods (Plugge 2007). The author proposes the use of a higher level of integration of project teams to anticipate and plan for changes in a project. Staub-French et al. (2021) assumes the successful implementation of Integrated Project Delivery, BIM, and VDC and their influence on supporting project teams across project phases.

Integrated Project Delivery

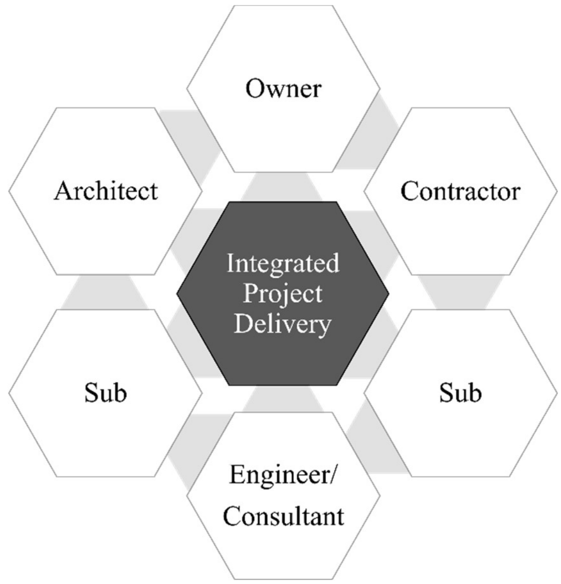

Figure 2. 2: Integrated Project Delivery Structure

As discussed by Ahmed and Arocho (2021), IPD can be used to lower the occurrence or impact of change orders. To increase project efficiency, integrated project delivery focuses on collaboration and communication among major project stakeholders (Liu 2013). Figure 2.2 shows the collaboration of various stakeholders including but not limited to the Owner, Architect, Contractor, Subcontractors, and Engineers. According to AIA and AIA CC (2007), IPD is "*a project delivery method that connects people, systems, business structures, and practices into a process that effectively uses the formal and informal knowledge of all stakeholders to enhance project outcomes, boost owner profit, eliminate waste, and optimize across all design, fabrication, and construction stage*s". Direct communication to major stakeholders (formerly divided by contractual levels) leaves less room for errors, time overruns, or misinterpretation of documents (Riley et al. 2005). AIA and AIA CC (2007) define the key principles of IPD as: 1) shared respect and faith, 2) shared risks or profits based on project success, 3) collaboration in making decisions, 4) early participation of key stakeholders, 5) setting targets at an early stage, 6) detailed scheduling and planning, 7) unrestricted communication, 8) suitable software and technology like building information modelling (BIM), 9) project direction and team. These principles guide the team toward a successful application of an integrated project delivery system.

Schedule, Costs, and Change Orders

A collaborative project delivery system like IPD can be utilized to enhance project value and improve owner satisfaction (Ashcraft 2022). Goodland et al. (2019) studied three projects in Canada to analyze their project delivery methods.

Project Name	**priMed Mosaic Centre**	**St. Jerome's University**	**Jacobson Hall, Trinity Western University**
Project Delivery Method	Full IPD	Full IPD	Design-Build
Gross Floor Area (SF)	32,300	12,310	60,000
Project Start	Apr-2014	Oct-2013	Mar-2018
Targeted Completion	Aug-2015	Aug-2016	Sep-2018
Actual Completion	Mar-2015	May-2016	Sep-2018
Schedule Variation (%)	31	9	0
Targeted Cost ($)	11,355,667	47,000,000	13,100,000

Table 2. 5: IPD and Change Orders

Table 2.5 (cont'd)

Actual Cost ($)	11,355,667	47,000,000	13,100,000
Cost Variation	0	0	0
No. of RFIs	0	Few	N/A
No. of Change Orders	0	0	7
Mass Timber Structure	Yes	No	Yes

Project schedule variances and change orders are discussed in table 2.5 for three projects. It is observed from this table that projects with IPD as delivery methods had fewer change orders. Two of the projects in the study are mass timber projects. It is observed that the project with the delivery method as IPD "priMed Mosaic Centre" had zero change orders. Whereas the project with the delivery method as Design-Build "Jacobson Hall, Trinity Western University" had seven change orders. It can be inferred from this study that IPD can be a solution to reduce or eliminate change orders for mass timber projects. IPD is indicated to be a promising project delivery method to minimize change orders at the source. Although there is a shared risk with IPD project participants, shared rewards can be much more beneficial to all the project participants.

CHAPTER 3 RESEARCH METHODOLOGY

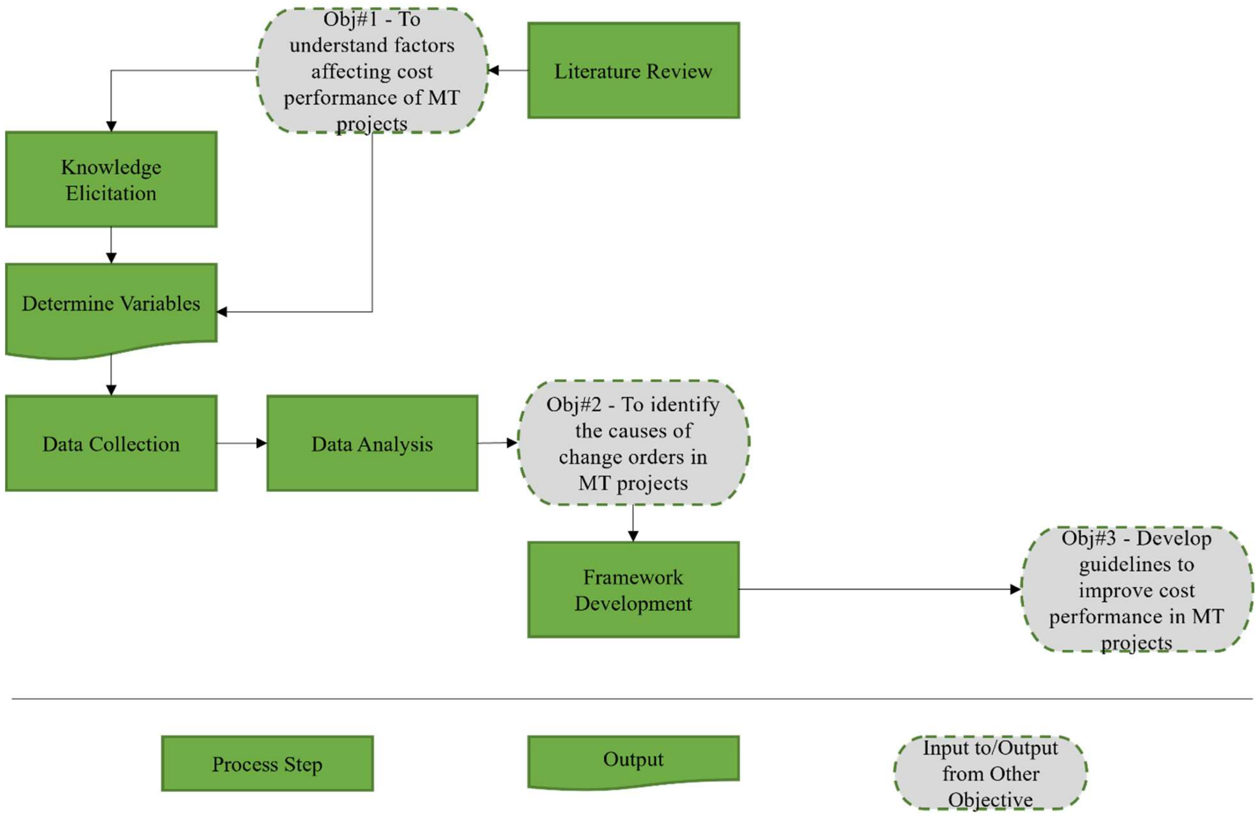

Figure 3.1: Research Methods and Outputs

This chapter builds on the foundation developed by chapters 1 and 2 to provide the research approach and methodology. It attempts to further elaborate on the three research objectives discussed in section 1.3.

The first research objective includes steps to conduct literature and document review which condenses cost performance in construction projects, causes and effects of change orders, and costs associated with mass timber construction projects. This data is further utilized to develop data collection and analysis methods to assess change order costs associated with mass timber projects. The literature review is further elaborated in chapter 2.

The second research objective is developed as a direct result of data collected from leading General Contractor's working on mass timber construction projects. Collection and analysis of mass timber-related change order data is used to identify the causes of change orders in mass timber projects.

The third research objective builds on the knowledge collected from the previous steps. The driving sources of change orders, effect of change orders on building and construction typology, correlation of change orders with project delivery methods, and ultimately change order cost impacts will be identified in further steps to develop a framework for the causes and effects of change orders in mass timber projects. This framework will further expand to create guidelines to improve the cost performance of mass timber projects.

3.1. Objective 1: To Understand Factors Affecting the Cost Performance of Mass Timber Construction Projects

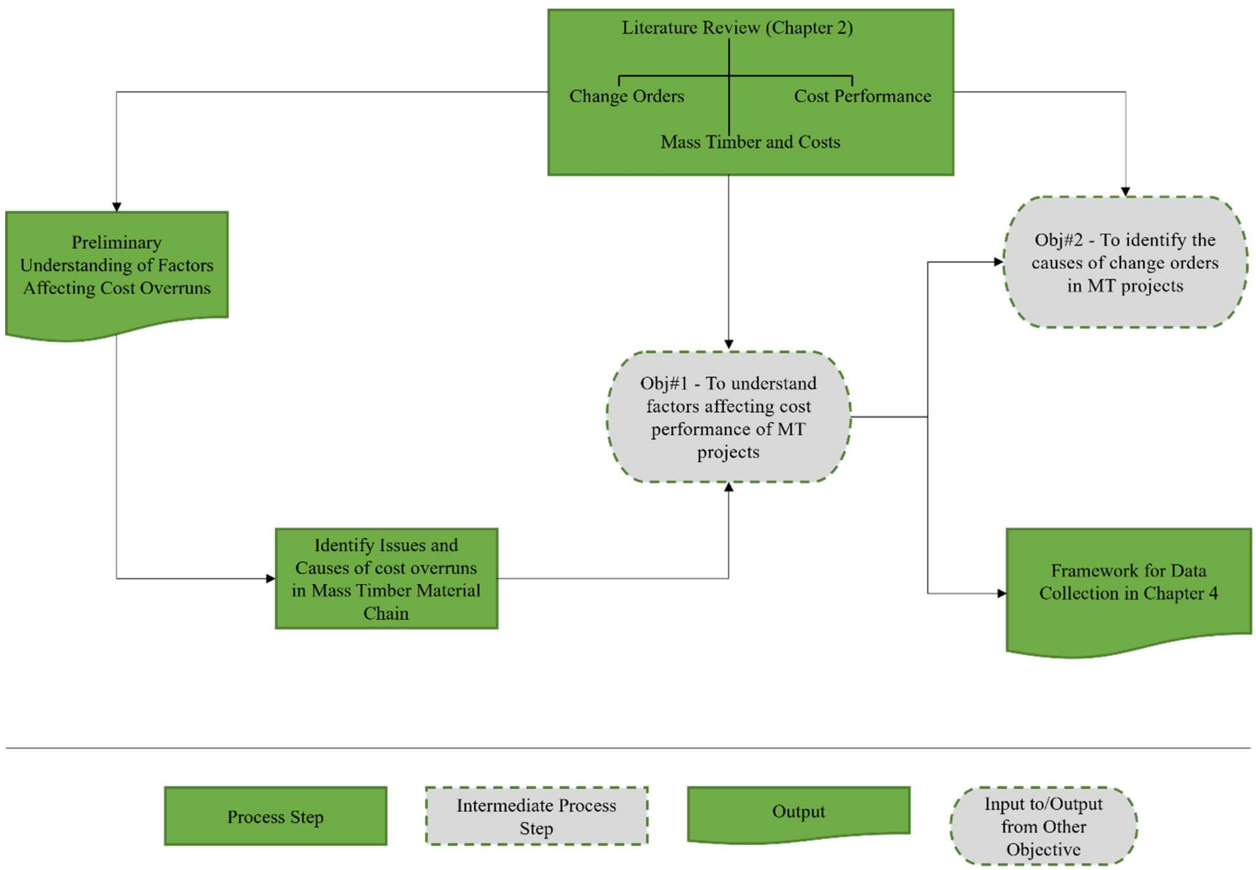

Figure 3.2: Objective 1 Methods and Outputs

The primary goal of Objective 1 is to acquire a better understanding of the causes and effects of change orders in mass timber construction projects. To achieve this goal, a comprehensive literature review will be conducted to provide some groundwork and comprehend the current state of the knowledge. The literature review indicated the lack of available knowledge in terms of mass timber, change orders, and its related costs. To understand these missing links, the cost performance of steel/concrete construction projects was studied to help narrow down the common causes of cost overruns. Further, Change Order literature was studied to understand the causes and drivers of change orders in a project. Concurrently, the literature surrounding mass timber construction costs and risks was studied to identify the underlying dearth of data. The focus areas of the literature review were used to develop data collection and analysis strategies to obtain project-related data from leading General Contractors. The literature for change orders and mass timber costs was reviewed to develop a data collection method. The culmination of the literature review and consultation of experts in mass timber industry led to the formation of a refined data collection and analysis methodology. Fig 3.2 represents the methods and expected outputs for objective 1. The deliverables from the first objective served as a direct input to the steps involved in Objective 2 to understand the causes and effects of change orders.

3.2. Objective 2: To Identify the Causes of Change Orders in Mass Timber Construction Projects

The primary goal of objective 2 is to analyze field data from mass timber construction projects to understand factors causing change orders. It can be divided into 2 parts: a) Data Collection and, b) Data Analysis. The data from Chapter 2 is used to refine data analysis methods. Figure 3.3 represents methods and outputs for objective 2.

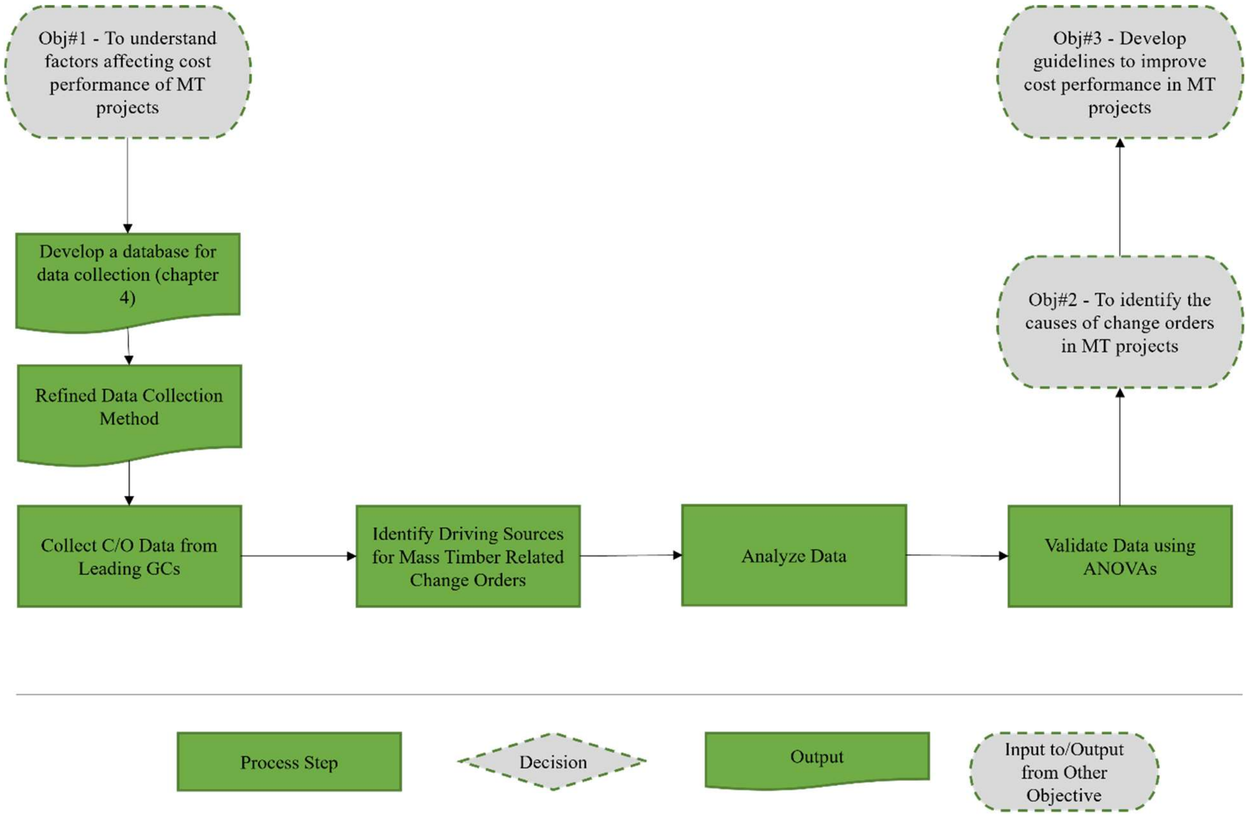

Figure 3.3: Objective 2 Methods and Outputs

3.2.1. Data Collection

After a rigorous review of the existing literature, gaps in available data led to developing data collection parameters. These parameters were dictated by the conversations with industry professionals working on mass timber construction projects. The parameters were further revised in many iterations upon reviewing the quality of the dataset. The list of variables collected for the mass timber-related change order data is discussed in Table 3.2. These variables were created as a spreadsheet input for data collection. This study was divided into two levels of study – Project level and change order level to recognize project level factors as well as individual change order level factors. The following variables were considered for the data collection process for this study.

Dependent Variables

Actual Cost: This variable considers the actual total costs for the entire project to understand the cost implications of various changes throughout the duration of a project. This cost gives field data to understand the health of the project.

Actual Cost MT: This variable refers to actual total costs for the scope of mass timber. This can help understand any positive or negative impacts on the actual costs for this scope.

Total CO Cost: This variable considers the actual cost of all change orders in the project. This will help to understand the scale of all change orders in the project.

CO Cost MT: This variable considers the actual cost of all mass timber-related change orders in the project. This will help identify the cost implications of each change order for the overall project.

Independent Variables

Number of CO: This variable refers to the total number of change orders in the entire project including mass timber-related change orders.

Number of MT CO: This variable consists of mass timber-related change orders in the entire project. This helped determine the size of mass timber-related change orders to the total change orders, and scope of mass timber.

Location and Year: This variable serves to identify the cost indices of the location of the project compared to the national average. The location factor plays a huge role in determining the cost of any project. Depending on the state, city, and the year, project costs vary tremendously. This variable is used to normalize all the project related costs to the national average for the year 2023.

CO Source: This variable helps to identify the source and drivers of change orders. These sources are split into 4 types namely – Owner, Designer, Contractor, and Others. This source will help identify the responsible party for the change orders. Others include change order sources like unforeseen problems, subcontractors, suppliers, and any other sources that were not captured above.

Construction Phase: This variable helps identify the construction phase the change order was developed in. These phases are split into 3 categories namely – Pre Construction, Construction and Closeout to understand the phase where most Change orders have been observed.

Gross Area: This variable serves to understand the size of the project in terms of square feet.

Building Type: This variable helps to identify the various building types of the projects studied. These types are split into 4 categories namely – Office, Multi-Family, Higher Education and Other.

Construction Type: This variable helps to understand various construction types for the projects studied. The construction type is split into two types – namely IV and not IV. Type IV construction consists of heavy timber construction including mass timber construction (IBC 2018). All other construction types are grouped into Not IV category to streamline the process.

Project Delivery Methods: This variable refers to the project delivery method used for the mass timber construction project. The project delivery is split into two types – namely Some Integration and No Integration. Some integration categories consist of project delivery methods like Design Build, Design Assist, and CM at Risk. Whereas the no integration category consists of Design-Bid-Build project delivery method.

		Variable	Type	Levels
Dependent Variables		Actual Cost	Continuous	N/A
		Actual Cost MT	Continuous	N/A
		Total CO cost	Continuous	N/A
		CO cost MT	Continuous	N/A
Independent Variables	**Quantitative**	Number of CO	Continuous	N/A
		Number of MT CO	Continuous	N/A
		Location and Year	Continuous	N/A
		Gross area	Continuous	N/A
	Qualitative	CO Source	Categorical	Owner, Contractor, Designer, Other
		Construction Phase	Categorical	Pre Construction, Construction, Closeout
		Building Type	Categorical	Office, Multi-Family, Higher Education, Other
		Construction Type	**Categorical**	IV, Not IV
		Project Delivery Method	**Categorical**	Some Integration, No Integration

Table 3. 1: List of Variables

3.2.3. Data Analysis and Results

Due to the novel nature of mass timber, there is not enough projects available to obtain information from a wide range of projects. This study attempted to collect data from the leading general contractors (GC's) from around the country. Due to a small sample size, the collected data was analyzed on two levels. Project level and change order level. On the project level, statistical analysis methods like Pearson's correlation, ANOVAs, and descriptive statistics were used to understand the data. Whereas, on the change order level the data was further divided into two levels, owner-derived change orders and all types of change orders. Similar to the project-level data, statistical analysis methods like ANOVAs and descriptive statistics were used for these levels to understand the data. The data analysis process is further elaborated in Chapter 5.

3.3. Objective 3: Develop Guidelines to Improve Cost Performance in the Preplanning and Construction Phase of Mass Timber Construction Projects

The primary goal of objective 3 is to create a framework to improve the cost performance of mass timber projects. The data obtained in objective 3.2 serves as an input to further develop the guidelines.

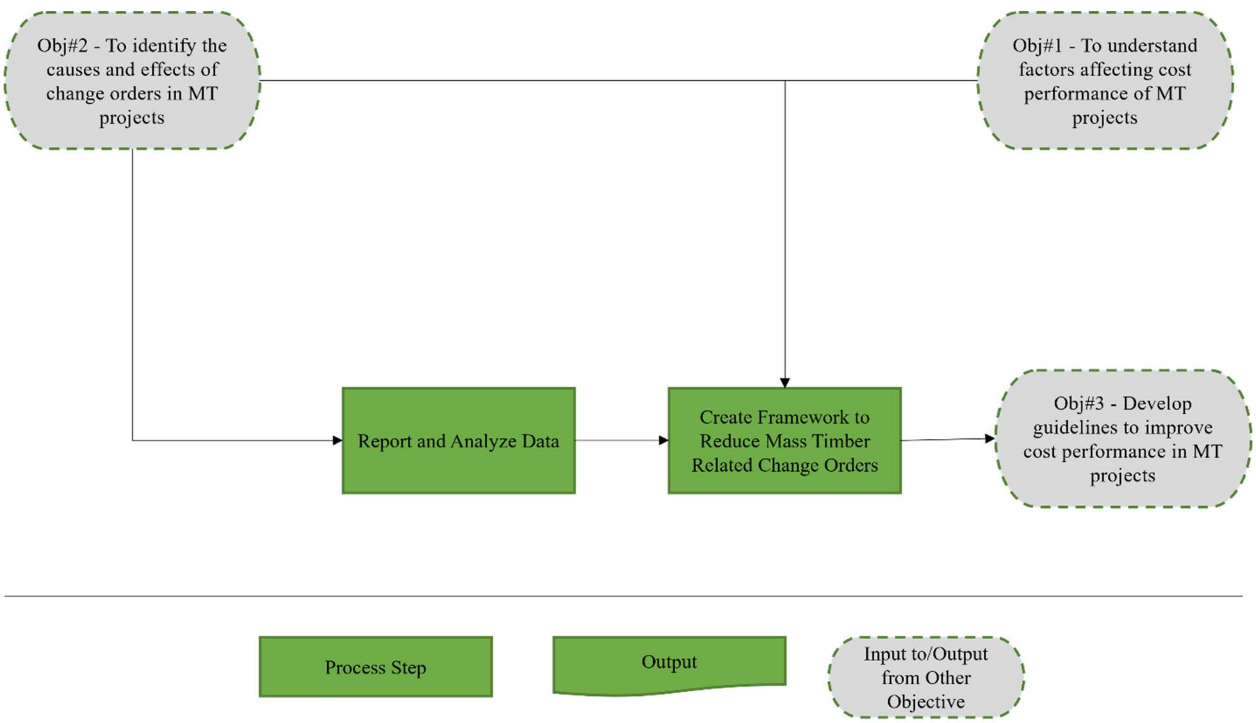

Figure 3.3: Objective 3 Methods and Outputs

Suggestions and guidelines will be construed by this study to help find the root cause of change orders and how to reduce them. This study attempts to fill the gap in cost performance knowledge of mass timber construction to help stakeholders in the construction industry.

CHAPTER 4 DATA COLLECTION

This chapter intends to discuss the data collection process undertaken to identify variables in change orders in mass timber construction. This chapter further expands on the data collection processes discussed earlier in chapter 3.

4.1. Data Collection Process

In order to obtain critical data, general contractors (GC's) and installers around the country were approached. Due to lack of availability of an abundant sample size, participants willing to contribute to the mass timber knowledge were selected. The participants were approached to obtain required information via email, phone calls, and online meetings. The author shared a data collection spreadsheet with all participants to complete. All participants were given the choice of filling out the spreadsheet or sharing the data for the author to filter out. After the initial spreadsheet was filled out, the author approached the participants multiple times to clarify various doubts in the spreadsheet. Table 4.1 shows a sample spreadsheet shared with the participants. For the projects with the raw data, the author filtered out mass timber-related change orders based on author's best knowledge. This study relies on the data provided by all participants and considers the data provided to be accurate. Similarly, there is no way for the author to verify the quality or accuracy of the raw data provided.

Variables	Project no.		
Budgeted Cost for Entire Project	Enter Value		
Actual Cost for Entire Project	Enter Value		
Budgeted Cost for Mass Timber	Enter Value		
Actual Cost for Mass Timber	Enter Value		
Budgeted Time for Entire Project	Enter Value		
Actual Time for Entire Project	Enter Value		
Budgeted Time for Mass Timber	Enter Value		
Actual Time for Mass Timber	Enter Value		
Gross Area	Enter Value		
Total Mass Timber SF	Enter Value		
Building Type	Select Building Type		
State	Select State		
City	Enter Value		
Year of Commencement	Enter Value		
Year of Completion	Enter Value		
Construction Type	Select Construction Type		
Project Delivery Method	Select Project Delivery Method		
Total cost of CO for entire project	Enter Value		
Total cost of CO for Mass Timber	Enter Value		
Scope of Mass Timber	Enter Scope		
Change Orders (CO)	1	2	3
CO Source	Select CO Source	Select CO Source	Select CO Source
CO cost	Enter Value	Enter Value	Enter Value
Construction Phase	Select Construction Phase	Select Construction Phase	Select Construction Phase
CO Reason	Enter Value	Enter Value	Enter Value

Table 4. 1: Sample Data Collection Spreadsheet

A total of 34 projects were studied to understand the causes and impacts of these change orders. The data collected was confidential and all the projects are referred to as numbers. Out of the 34 projects, 25 projects were collected from the same participant. Having a major contribution of data from one participant is the limitation of this study. Due to its novel nature, there is a dearth of participants working in mass timber construction. As the use of mass timber grows, more participants can be reached out for future expansion of this study. Out of the remaining projects, projects 27 and 28 belonged to the same participant. Similarly, projects 29 and 30 belonged to the same participant. Projects 29 and 30 are currently in construction and data was collected up to the initial data collection date. This assumption was an assumption used for this study. Projects 2, 3, 4, 9, 11, 14, 17, 20, 22, 23, and 24 the participant worked only for the mass timber scope of the project. Although the participating General Contractors (also known as participants) were common for a few projects, the project teams and circumstances were different for every project. Every project and their observations were unique, although the project management techniques might be similar for projects with the same participant.

During the data collection process, all the cost data was normalized using the historical cost indexes by RSMeans data. All the cost data was normalized to the national 30 city average for January of 2023. This step ensures that there is no disparity between all projects on the basis of State, City or Year of construction. This is an important step to achieve a consistent dataset due to the varying cost index in every city. For projects based in cities not on the historical cost indexes, the city closest to the location was selected for accurate normalization.

The data was collected on two levels, 1. Project level data and 2. Change Order level data. Due to limitations of data, the individual change order level was further bifurcated into two levels – 1. All change order types and 2. Owner driven change orders. During the data collection process, the author was able to identify change orders with the source only as the Owner for 25 projects. This was a direct result of the limitations of the field data in an uncontrolled environment. This led to an additional level of analysis for owner driven change orders.

4.2. Project Level Data

The data collection process led to cleaning of the data due to limitations of the data. A few variables like time were eliminated to keep the data consistent across all the projects. Table 4.2 represents the project level data collected. Sample size for project level data was 34 projects. Variables like building type, construction type, project delivery method and costs were identified after cleaning the project level data. Total MT CO costs/ gross area variable was developed in an attempt to normalize the change order costs. This normalization metric was used to normalize costs across all the projects due to variability in the scale and cost of projects. This metric was used to identify outliers in the dataset by calculating the upper and lower boundary using turkey method. Three outliers were identified from the 34 projects. These outliers were eliminated while analyzing data using ANOVAS.

Sr-No.	PROJECT	Building Type	Construction Type	Project Delivery Method	Total MT CO Costs/Gross Area
1	1	Office	Not IV	No Integration	-0.244
2	2	Other	Not IV	No Integration	4.405
3	3	Multi-Family	IV	No Integration	1.111
4	4	Other	Not IV	No Integration	2.019
5	5	Higher Education	Not IV	No Integration	1.640
6	6	Office	Not IV	No Integration	3.607
7	7	Multi-Family	IV	Some Integration	0.122
8	8	Other	Not IV	Some Integration	8.217
9	9	Office	Not IV	Some Integration	1.721
10	10	Other	Not IV	Some Integration	0.000
11	11	Other	Not IV	No Integration	2.949
12	12	Other	Not IV	No Integration	2.538

Table 4. 2: Collation of Project Level Data

Table 4.2 (cont'd)

13	13	Office	Not IV	No Integration	0.711
14	14	Higher Education	Not IV	Some Integration	8.265
15	15	Other	Not IV	Some Integration	105.939
16	16	Office	Not IV	Some Integration	44.915
17	17	Other	Not IV	No Integration	0.464
18	18	Office	Not IV	No Integration	-3.853
19	19	Multi-Family	Not IV	No Integration	1.023
20	20	Other	Not IV	No Integration	25.980
21	21	Higher Education	Not IV	No Integration	5.200
22	22	Higher Education	Not IV	Some Integration	5.504
23	23	Higher Education	IV	Some Integration	2.847
24	24	Other	Not IV	Some Integration	8.678
25	25	Other	Not IV	Some Integration	1.407
26	26	Multi-Family	IV	Some Integration	1.769
27	27	Office	IV	Some Integration	4.322
28	28	Other	Not IV	Some Integration	0.000
29	29	Multi-Family	Not IV	Some Integration	4.377
30	30	Multi-Family	Not IV	Some Integration	3.227
31	31	Other	Not IV	No Integration	0.923
32	32	Other	IV	Some Integration	1.264
33	33	Higher Education	Not IV	Some Integration	7.780
34	34	Higher Education	Not IV	Some Integration	0.949

4.3. Change Order Level Data

The source of change orders consisted of responsible parties for the change order namely Owner, Contractor, Designer, and others. This would help to determine the major contributor towards mass timber-related change orders. Due to the limitations discussed earlier, this data also reviews only the Owner driven change orders to understand if there is any significance in this dataset.

4.3.1. All Change Order Types

Sample size for all change order types level data was 239 change orders. After the data cleaning, variables for "All Change Order Types" were building type, construction type, project delivery method, CO source, construction phase, and costs. This data helped us to understand the source and phase for every change order. This level for data collection was necessary due to the small sample size of the dataset. All the change Orders have been considered independent observations in this level of analysis. Table 4.3 shows a sample data collection table for “All types of Change Orders”. MT CO Cost/ Gross Area variable was developed in an attempt to normalize the Change Order Cost across all the projects due to variability in the scale and cost of projects. This metric was used to identify outliers in the dataset by calculating the upper and lower boundary using turkey method. Thirty-seven outliers were identified from the 239 change orders. These outliers were eliminated while analyzing data using ANOVAS.

Sr No	Building Type	Construction Type	Project Delivery Method	CO Source	CO Construction Phase	MT CO Cost/ Gross Area
1	Office	Not IV	No Integration	Owner	Construction	-0.24
2	Office	IV	Some Integration	Contractor	Closeout	0.00
3	Higher Education	Not IV	Some Integration	Designer	Pre Construction	0.07
4	Multi-Family	IV	Some Integration	Other	Construction	0.02

Table 4. 3: Sample Collation of All type of Change Order Data

4.3.2. Owner Driven Change Orders

Sample size for owner driven change orders level was 157 change orders. After the data cleaning, variables for “Owner Driven Change Orders” were building type, construction type, project delivery method, construction phase, and costs. This level for data collection was necessary due to the over representation of Owner as a source in the dataset. All the change orders have been considered independent observations in this level of analysis. Table 4.4 shows a sample data collection table for “Owner Driven Change Orders”. MT CO Cost/ Gross Area variable was developed in an attempt to normalize the Change Order Cost across all the projects due to variability in the scale and cost of projects. This metric was used to identify outliers in the dataset by calculating the upper and lower boundary using turkey method. Eighteen outliers were identified from the 157 change orders. These outliers were eliminated while analyzing data using ANOVAS.

Sr-No.	**Building Type**	**Construction Type**	**Project Delivery Method**	**CO Construction Phase**	**MT CO Cost/ Gross Area**
1	Multi-Family	IV	No Integration	Construction	0.16
2	Office	Not IV	Some Integration	Closeout	-0.20
3	Higher Education	Not IV	Some Integration	Pre Construction	5.29

Table 4. 4: Owner Driven Change Orders

CHAPTER 5 DATA ANALYSIS AND RESULTS

This chapter intends to discuss the data analysis and results incorporated to assess the variables established in chapter 4. This chapter further expands on the data analysis processes discussed earlier in chapter 3. As established in the data collection process, this data was analyzed on three levels – 1. Project level data, 2.a. all change order types data and, 2.b. owner driven change order data.

5.1. Project Level Data

5.1.1. Descriptive Statistics

While looking at the building type for all projects, 21% projects were Higher Education, 18% projects were Multi Family, 21% projects were Office, and 41% projects were Other types of buildings. For construction type variable, 18% of projects were classified as "type IV" and 82% of projects were classified as "not type IV." This metric shows that there are more projects exploring construction types varied from type IV which has been primarily used for heavy timber construction (IBC 2018). According to IBC (2018), type IV construction required the exterior walls of the project to be non-combustible. Similarly, IBC (2018) considered timber to be combustible and used only for the interior parts. More projects not classified under "type IV" indicate the growth of the mass timber construction industry. The project delivery method variable shows that 56% of projects used some level of integration method for project delivery. Whereas 44% of projects used no level of integration. There was no significant difference observed in the project delivery method.

These statistics do not show a quantifiable impact on the projects studied. To understand the impact of mass timber related Change orders on the entire project, the author studied the index values for expected Change Order costs for mass timber. The following formula was used to assess expected Change Order costs for mass timber when compared to the entire project:

$$\frac{\text{(Total cost of mass timber change orders/ Actual cost of mass timber scope)}}{\text{(Total cost of change orders/Actual cost of entire project)}}$$

Due to limitations of the data, the author was able to acquire total Change Order information for 17 projects for this index. Table 5.1 shows the results of this index for the 17 projects.

Sr No	**PR**	**Total cost of mass timber CO (a)**	**Actual Cost of mass timber scope (b)**	**Total cost of CO (c)**	**Actual Cost of entire project (d)**	**a/b (e)**	**c/d (f)**	**Index (e/f)**
1	6	$88,364	$1,750,112	$113,119	$13,655,135	0.05	0.01	6.09
2	7	$8,299	$3,599,890	$1,155,934	$30,637,641	0.00	0.04	0.06
3	12	$6,346	$11,828	$403,968	$104,854	0.54	3.85	0.14
4	13	$76,102	$9,543,360	$3,184,867	$107,032,427	0.01	0.03	0.27
5	14	$399,982	$3,999,206	$444,912	$45,350,596	0.10	0.01	10.19
6	18	-$84,769	$1,206,396	$50,537	$6,986,875	-0.07	0.01	-9.71
7	19	$96,123	$4,140,314	$695,334	$4,907,177	0.02	0.14	0.16
8	21	$156,012	$862,581	$52,337,609	$3,178,435	0.18	16.47	0.01
9	26	$854,020	$14,827,568	$12,808,545	$135,940,304	0.06	0.09	0.61
10	27	$864,406	$10,881,532	$2,346,330	$71,426,903	0.08	0.03	2.42
11	28	$0	$1,496,040	$343,648	$87,894,693	0.00	0.00	0.00
12	29	$88,848	$709,502	$546,135	$5,165,315	0.13	0.11	1.18
13	30	$280,724	$4,287,416	$1,071,854	$22,713,096	0.07	0.05	1.39
14	31	$7,489	$367,395	$584,110	$7,442,589	0.02	0.08	0.26
15	32	$267,952	$8,366,616	$4,796,782	$73,802,088	0.03	0.06	0.49

Table 5. 1: CO Index for expected Change Order costs for mass timber

Table 5.1 (cont'd)

16	33	$1,244,735	$9,988,915	$123,013,884	$130,363,083	0.12	0.94	0.13
17	34	$44,609	$2,538,819	$2,768,343	$33,108,484	0.02	0.08	0.21

To interpret the index value, the following rules were pursued.

1. When the index value for the above data is equal to one, the mass timber change orders costs are as expected.
2. When the index value is less than one, the project has less than expected mass timber Change Order costs.
3. When the index value is greater than one, the project has more than expected mass timber Change Order costs.

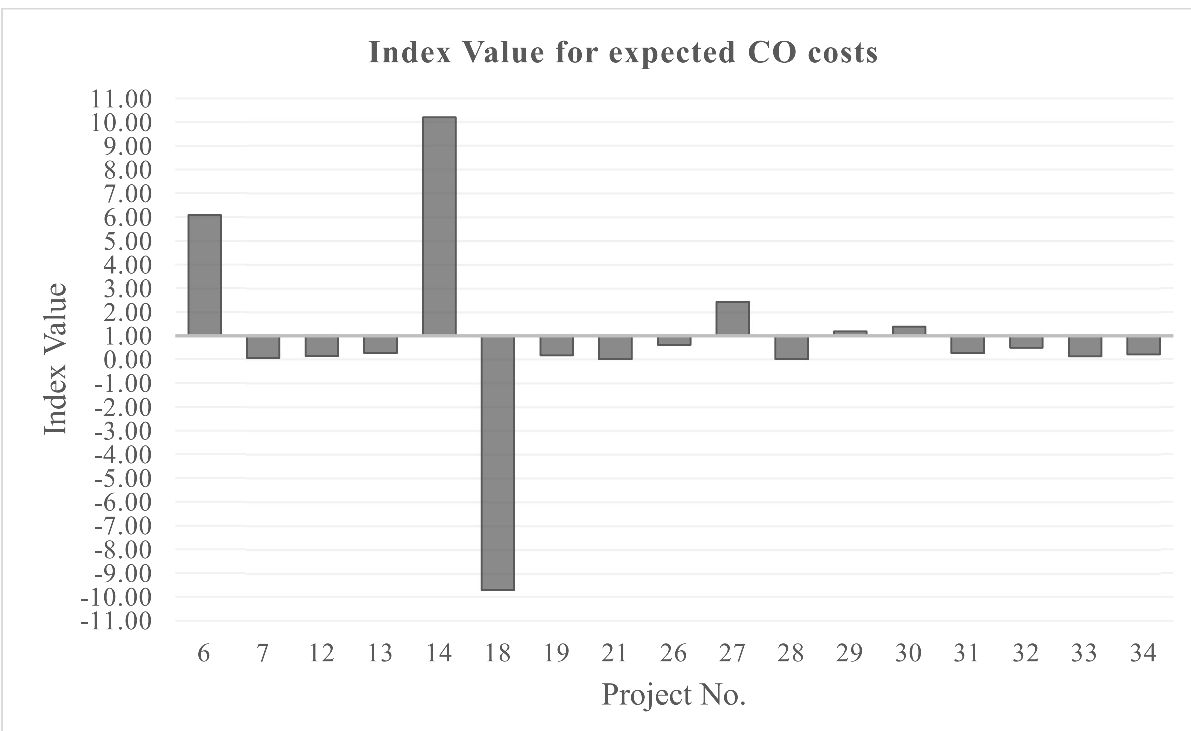

Figure 5.1: Comparing Index Value for 17 projects

It is observed in table 5.1 and figure 5.1 that 12 out of the 17 projects have an index value less than one. 71% of the projects observed show less than expected mass timber change order costs. Thus, it can be clearly observed that when compared to the change orders for the entire project, mass timber-related change orders show less than expected costs. Mass timber-related change order costs do not have a significant impact on the entire project. This proves that mass timber-related change orders have no effect on the actual project costs when compared to the scope of mass timber work. To strengthen this hypothesis, future studies can be carried out using a bigger sample size.

5.1.2. Pearson's Correlation

To determine the relationship between the actual costs for mass timber scope and total cost of mass timber related change orders, the author performed the Pearson's correlation test. Table 5.2 shows the results for the test.

		Actual Costs MT	Total MT CO Costs
Actual Costs MT	Pearson Correlation	1	0.940
	Sig. (2-tailed)		<.001
	N	34	34
Total MT CO Costs	Pearson Correlation	0.940	1
	Sig. (2-tailed)	<.001	
	N	34	34

Table 5. 2: Result for Pearson's correlation test

This data suggests that actual costs for mass timber scope (Actual Costs MT) and total cost of mass timber related change orders (Total MT CO Costs) have a statistically significant linear relationship. It is observed that $r = 0.940$ and $p < 0.001$. The value of p is significant when $p < 0.05$. Therefore, observation denotes a statistically significant linear relationship. The value of r also represents that actual costs MT and total MT CO costs have a positive direction to their relationship. Thus, actual costs MT and total MT CO costs tend to increase together as they are positively correlated. It can be inferred from this data that the cost for MT change orders increases when the actual costs for mass timber scope increases.

5.1.3. One-Way ANOVA

In order to understand the relationship between the independent variables and the dependent variable (total CO costs/ gross area), Analysis of Variances (ANOVA) was used. In this statistical analysis, the independent variables were identified as project delivery method, construction type, and building type. Whereas the dependent variable was the $/SF value of total CO costs/ Gross area. This dependent variable was chosen to normalize the variability observed in the Change Order costs across all projects. Outliers were also removed before the test was undertaken to reduce variability in the dependent variable. Table 5.3 depicts the result for the ANOVA test performed. Significance can be established when the value of $p < 0.05$.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Project Delivery Method	1	29.166	29.1662	4.1052	0.05355
Construction Type	1	14.178	14.1777	1.9956	0.17009
Building Type	3	26.135	8.7118	1.2262	0.32094
Residuals	25	177.617	7.1047		

Table 5. 3: Result for Project Level One-Way ANOVA

This test shows that project delivery method, construction type, and building type did not have a significant effect on the Total MT CO costs (As $p > 0.05$). This can be due to the small sample size (n=34) at the project level. To expand the study and increase the sample size, the author tested the change order level data.

5.2. Change Order Level Data

In order to achieve a larger sample size and a detailed statistical analysis, Change Order level data was observed. This data was further divided into two levels, a. all types of change orders and b. Owner driven change orders.

5.2.1. All Change Order Types

Descriptive Statistics

In order to understand change order sources, the author determined some descriptive statistics. When looking at the change order sources, overrepresentation of owner driven change orders can clearly be seen. In this dataset, projects with no level of integration represent 24% of all the change orders. Whereas projects with some level of integration represent 76% of the change orders. When we look at the construction type for all change orders, 75% of change orders represent not IV construction type. Construction type IV change orders represent 25% of the total change orders. When analyzing projects types higher education displays 23%, multifamily represents 15%, office represents 17%, and other displays the majority of the representation of 45% of all change orders. Owner driven change orders represent 66% of the total dataset. Whereas the next biggest group of designer driven change orders make up to 13% of the total dataset. For such variability in the data all the different groups can be analyzed with each other using ANOVAs. A one-way ANOVA has been discussed in the next paragraph. The construction phase for the change orders reveals 85% of the total change orders are created in the construction phase of the project. Although 11% of the total change orders are created during the preconstruction phase of the project. The remaining 4% of change orders are created during the closeout phase of the project. This indicates that a majority of change orders are created during the construction phase and needs more integration with all the stakeholders to reduce the frequency of change orders. When the variable CO cost/ gross area was studied for all types of change orders, some key data metrics were observed and shown in table 5.4 below.

	$/SF
Min	-0.373
Q1	0.027
Median	0.125
Mean	0.223
Q3	0.334
Max	1.796

Table 5. 4: CO cost/ Gross Area data metric

One-way ANOVA

As discussed in the above paragraph, the overrepresentation of owner change orders led us to use ANOVA to understand the data. All the outliers were removed prior to running the statistical test.

Table 5.5. represents the data obtained from the ANOVA test on the dataset. In this statistical analysis test, independent variables were CO source, building type, construction type, project delivery method, and CO construction phase. The CO cost/gross area was the dependent variable to test the data. This variable was used to normalize the huge variance observed in the raw data.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
CO Source	3	0.454	0.1512	1.798	0.149
Building Type	3	0.298	0.0992	1.180	0.319
Construction Type	1	1.536	1.5362	18.271	3.04E-05
Project Delivery Method	1	0.055	0.0546	0.650	0.421
CO Construction Phase	2	0.211	0.1053	1.253	0.288
Residuals	189	15.891	0.0841		

Table 5. 5: Result for “all types of Change Order” ANOVA

This test shows that co source, building type, project delivery method, and CO construction phase did not have a significant effect on the individual MT CO costs (As $p>0.05$). Although, Construction Type did have a significant effect on the individual MT CO costs ($p<0.05$). This insignificant data may stem from the availability and huge variability of data. Future studies can help expand this knowledge bank to find quantifiable results.

5.2.2. Owner Driven Change Orders

As discussed earlier, Owner driven change orders were a major part of the dataset. This led to investigating just the owner driven change orders to understand if they had an individual impact on the cost performance of the project. In an effort to understand their impact the author undertook statistical analysis tests like descriptive statistics and one-way ANOVA.

Descriptive Statistics

While studying the owner derived change orders, the author studied the CO construction phase variable. In this dataset, projects with no level of integration represent 36% of all the change orders. Whereas projects with some level of integration represent 64% of the change orders. When we look at the construction type for all change orders, 88% of change orders represent not IV construction type. Construction type IV change orders represent 12% of the total change orders. When analyzing project types higher education displays 15%, multifamily represents 10%, office represents 20%, and other displays the majority of the representation of 55% of all change orders. It is observed that construction phase takes up 81% of the total project change orders. While preconstruction and closeout have 15% and 4% respectively. The construction phase has the highest contribution to the owner driven change orders. This observation is consistent with both the datasets. This proves there is a need to implement better planning procedures to incorporate to reduce the change orders in the construction phase. When looking at the dependent variable, some key metrics were observed, shown below in table 5.6.

	$/SF
Min	-0.902
Q1	0.032
Median	0.222
Mean	0.367
Q3	0.502
Max	2.046

Table 5. 6: CO Cost/ Gross area metric

One-way ANOVA

ANOVA statistical test was also performed on this level of the dataset. The independent variables in this test were project delivery method, construction type, building type, and construction phase. The dependent variable was consistent with the previous data set as CO cost/ gross area. The outliers were removed before this test was performed. Table 5.7 represents the data obtained from the ANOVA test on the dataset.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Project Delivery Method	1	0.264	0.26412	0.9886	0.32193
Construction Type	1	0.379	0.37861	1.4171	0.23604
Building Type	3	1.188	0.39603	1.4823	0.22235
CO Construction Phase	2	1.333	0.66629	2.4938	0.08651
Residuals	131	35	0.26717		

Table 5. 7: Result for owner driven Change Order ANOVA

This test shows that project delivery method, construction type, building type, and CO construction phase did not have a significant effect on the individual MT CO costs ($P < 0.05$). No significant result was obtained from performing the statistical ANOVA tests on three different levels. This reiterates the fact that there is not enough information available. The data is obtained from the field and was not performed in any controlled environment. There is a need to study a larger sample size to obtain more significant results.

CHAPTER 6 DISCUSSION

Variability observed in the collected data in terms of costs, project delivery methods, change order sources, and building types. This was a direct result of collection of field data which is undertaken in uncontrolled environments. These real field projects can have a huge range for costs related to change orders as well as project costs. The Pearson's correlation test showed a strong positive relationship between actual costs of the mass timber scope in a project with mass timber change order costs. Thus, we can establish that the greater the scope of mass timber, greater the chance of mass timber related change orders. The project level data showed that mass timber related change orders showed less than expected costs. This confirmed the null hypothesis for RQ#2 H_0: Mass timber-related change orders have no effect on actual project costs when compared to the scope of mass timber work.

While analyzing the effects of project delivery methods, construction type, building type, CO source, and CO Construction phase did not have any effect on the costs of the project. This can be due two reasons,

1. Smaller sample size

   This can be attributed to the size of projects and change order data collected compared to the variables identified. A larger sample size may lead to a significant result and help understand the cost data better. This limitation is mainly due to the novel nature of mass timber construction projects and their wide adaptability may result in obtaining good quality data.

2. Variability in cost data

   The cost data had a lot of variability and the costs ranged from \$0 to \$42 million. The metric established for normalizing the data may not be the preferred method for further research. The metric CO costs/ gross area was developed in an attempt to normalize the available data. The availability of good quality data was a barrier to this study.

The null hypothesis for RQ#1 H_0: cost performance of mass timber projects is independent of the level of integration in project delivery methods is proven to be true. Although, through qualitative analysis, it is observed that 56% of projects use some level of integration within their projects. Mass timber as a structural material should always have some level of integration if not a higher level of integration. This is due to the prefabricated nature of this material. Prefabrication requires a lot of coordination between the design team, the construction team, and the manufacturing team. More coordination at the beginning of the project can ensure fewer change orders in the construction phase. Thus, some level of integration can play a major role in reducing mass timber-related change orders in a mass timber construction project.

6.1. Guidelines to Help Improve the Cost Performance of Mass Timber Construction Projects

Based on the data collected and analyzed, the author suggests a few guidelines to streamline the construction projects and reduce mass timber related change orders.

1. Some or higher level of project team integration: Early involvement provides teams to anticipate the project costs and forthcoming changes and can be well prepared for changes (Plugge 2007).
    - It is very rare for a given project to not have any change orders, but early involvement can reduce the impact of these change orders.

- Owing to its prefabricated nature, mass timber requires some level of integration and coordination between the project teams.
- When there is no or low integration within teams, the project team may have to make changes to this prefabricated material in the field. This leads to increasing construction time and labor hours.
- It is advised to utilize extra man hours in the pre-construction phase to coordinate the construction details to save material and labor costs in the construction phase of the project.
- The project team should work on clash detection and collaborate on expected challenges in terms of construction details, lead times and just in time delivery of mass timber.

2. A collaborative project delivery system like integrated project delivery (IPD) system can be utilized to enhance project value and improve owner satisfaction (Ashcraft 2022).
    - IPD intends to use the formal and informal knowledge of all major trades and translates it into a successful project. This aspect of IPD is beneficial to utilize in mass timber construction, similar to some level of integration.
    - IPD contributes to a higher level of integration and has potential to reduce change orders as well as clashes in a mass timber construction project. In IPD, mechanical, plumbing, and electrical trades are involved at the early stages of projects. This leads to coordination and collaboration with the manufacturer in terms of sleeves and penetrations. This leads to less scope for errors and reduced field changes to the mass timber material.

3. The quality of data collected should be accurate to help forecast or anticipate changes.
    - The database of project details should be of good quality and detailed. The project team should ensure all necessary details have been completed. It was observed during this study that data the obtained was incomplete. Bookkeeping is an important aspect of construction projects. Detailed bookkeeping can help project team refer the details of projects to assess challenges, project health or lessons learned.
4. Integration of BIM and VDC along with higher level of integration in projects will help reduce change orders in mass timber projects (Staub-French et al. 2021).
    - As previously discussed, higher level of integration has a lot of benefits. Although, use of BIM and VDC is an integral part of this process.
    - BIM and VDC help with clash detection and analyzing potential challenges before the start of the project.
    - BIM and VDC can also help with trades like mechanical, plumbing, and electrical to integrate with the manufacturing process and reduce field drilling or cutting of penetrations and sleeves.
    - The tolerances for mass timber a low due to the prefabricated nature. BIM and VDC can help with the precision and placement of connections and joinery.
5. Shifting from construction type IV for mass timber projects is a step further in advancement of mass timber that reduces restrictions and gives project teams more freedom in implementing the project.

- Construction type IV imposes some restrictions to the boundaries of the project. Thus, more projects classified under construction types not IV display the growth and acceptance of mass timber in the construction industry.
- Less restrictive construction types will help in widespread adoption of mass timber as a material and helps owners and contractors to explore this structural material to its full potential.
- Construction type not IV also allows the project to use mass timber in the building envelope and reduce oversized structural elements due to reduced fire restrictions. This will reduce material costs as correct sized structural elements are utilized.

6. An experienced project manager in the field of mass timber can be hired to reduce change orders in a mass timber construction project (Ahmed 2021).
    - It was observed that project teams with less or no experience tend to face challenges in installing or erecting mass timber elements. These challenges are not common in conventional construction structural elements like concrete or steel. This is owing to the mass and prolonged use of conventional construction elements.
    - An experienced project manager will be able to identify and take corrective actions based on the lessons learned from their previous mass timber projects. Translation of informal knowledge of previous mass timber projects will be beneficial for the project’s health in avoiding previously faced challenges.

6.2. Future Scope and Recommendations

Being a novel construction material, mass timber has shown a lot of potential in the last few years. The rapid growth can be observed in the number of projects this study was able to collect. The author believes, a larger sample size will be beneficial to take this study further and receive significant results. A different normalization technique might aid the cost analysis part. The normalization technique used for the index can prove beneficial for future scope of study. This was not done on this project due to unavailability of data. The index to be used is shown below:

$$\frac{\text{(Total cost of mass timber change orders/ Actual cost of mass timber scope)}}{\text{(Total cost of change orders/Actual cost of entire project)}}$$

More research is needed to reconcile the non-significant findings in this research. The above-mentioned techniques might aid in getting the desired result for a future study.

Apart from this, to understand the impact of individual change orders, analysis techniques like failure mode and effect analysis (FMEA) can be utilized. A change order can show lesser impact in terms of dollar value, although it is important to see the impact of the change order on the entire project. FMEA as tool will prove effective to understand this impact.

6.3. Contributions to Knowledge

As previously established, the cost-competitiveness of mass timber construction projects needs to be improved to help aid its widespread adoption. The United States has been reluctant to accept Mass Timber as a new technology owing to the higher initial costs. There are multiple gaps in the cost knowledge base of mass timber construction projects. This study is an attempt to fill these gaps by understanding the causes of change orders on Mass timber construction projects.

This study hopes to contribute to the vast body of knowledge related to change orders with studies on mass timber construction.

6.3.1. Expected Outputs

1. This study intends to identify and reduce common factors causing changes in mass timber construction projects.
2. The developed guideline can be used by construction companies for more integrated pre-planning techniques.

6.3.2. Expected Outcomes

1. This study will help fill the gap in cost unpredictability in the construction phase of projects.
2. This study intends to help decision-makers understand construction costs better and reduce the cost uncertainty of mass timber construction projects.
3. The study hopes to provide critical knowledge related to project delivery methods that have not been extensively studied before.
4. This study intends to overcome the barrier of construction cost uncertainty and promote the widespread adoption of mass timber construction.

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APPENDIX A: ALL TYPES OF CHANGE ORDERS

Sr No.	Pr No.	Actual Cost	Actual Cost MT	Gross Area	Building Type	Construction Type	Project Delivery Method	CO Source	CO Cost/ Gross Area	CO Construction Phase
1	1	$75,757,653.93	$566,404	260000	Office	Not IV	Design - Bid- Build	Owner	-0.24	Construction
2	2	$16,204,676.38	$1,934,062	18,180	Other	Not IV	Design - Bid- Build	Owner	1.20	Construction
3	2	$16,204,676.38	$1,934,062	18,180	Other	Not IV	Design - Bid- Build	Owner	2.12	Construction
4	2	$16,204,676.38	$1,934,062	18,180	Other	Not IV	Design - Bid- Build	Owner	1.09	Construction
5	3	$167,158,118.61	$14,746,460	310,000	Multi-Family	IV	Design - Bid- Build	Owner	0.16	Construction
6	3	$167,158,118.61	$14,746,460	310,000	Multi-Family	IV	Design - Bid- Build	Owner	0.16	Construction
7	3	$167,158,118.61	$14,746,460	310,000	Multi-Family	IV	Design - Bid- Build	Owner	0.29	Construction
8	3	$167,158,118.61	$14,746,460	310,000	Multi-Family	IV	Design - Bid- Build	Owner	0.50	Construction
9	4	$60,395,128.55	$2,464,942	81,000	Other	Not IV	Design - Bid- Build	Owner	0.30	Construction
10	4	$60,395,128.55	$2,464,942	81,000	Other	Not IV	Design - Bid- Build	Owner	1.36	Construction
11	4	$60,395,128.55	$2,464,942	81,000	Other	Not IV	Design - Bid- Build	Owner	0.15	Construction
12	4	$60,395,128.55	$2,464,942	81,000	Other	Not IV	Design - Bid- Build	Owner	0.03	Construction
13	4	$60,395,128.55	$2,464,942	81,000	Other	Not IV	Design - Bid- Build	Owner	0.11	Construction
14	4	$60,395,128.55	$2,464,942	81,000	Other	Not IV	Design - Bid- Build	Owner	0.02	Construction
15	4	$60,395,128.55	$2,464,942	81,000	Other	Not IV	Design - Bid- Build	Owner	0.03	Construction
16	4	$60,395,128.55	$2,464,942	81,000	Other	Not IV	Design - Bid- Build	Owner	0.02	Construction

Table A.1: All types of change orders

Table A.1 (cont'd)

17	5	$15,134,038.81	$1,303,360	21,816	Higher Education	Not IV	Design - Bid- Build	Owner	0.10	Construction
18	5	$15,134,038.81	$1,303,360	21,817	Higher Education	Not IV	Design - Bid- Build	Owner	0.34	Construction
19	5	$15,134,038.81	$1,303,360	21,818	Higher Education	Not IV	Design - Bid- Build	Owner	-0.02	Construction
20	5	$15,134,038.81	$1,303,360	21,818	Higher Education	Not IV	Design - Bid- Build	Owner	1.22	Construction
21	6	$13,655,134.77	$1,750,112	24,500	Office	Not IV	Design - Bid- Build	Owner	1.50	Construction
22	6	$13,655,134.77	$1,750,112	24,500	Office	Not IV	Design - Bid- Build	Owner	0.26	Construction
23	6	$13,655,134.77	$1,750,112	24,500	Office	Not IV	Design - Bid- Build	Owner	0.50	Construction
24	6	$13,655,134.77	$1,750,112	24,500	Office	Not IV	Design - Bid- Build	Owner	0.63	Construction
25	6	$13,655,134.77	$1,750,112	24,500	Office	Not IV	Design - Bid- Build	Owner	0.48	Construction
26	6	$13,655,134.77	$1,750,112	24,500	Office	Not IV	Design - Bid- Build	Owner	0.25	Construction
27	7	$30,637,641.48	$3,599,890	68,000	Multi-Family	IV	Design Assist	Owner	0.03	Construction
28	7	$30,637,641.48	$3,599,890	68,000	Multi-Family	IV	Design Assist	Owner	0.01	Construction
29	7	$30,637,641.48	$3,599,890	68,000	Multi-Family	IV	Design Assist	Owner	0.08	Construction
30	8	$41,791,650.18	$4,640,224	51,000	Other	Not IV	Design Assist	Owner	4.22	Construction
31	8	$41,791,650.18	$4,640,224	51,000	Other	Not IV	Design Assist	Owner	0.83	Construction
32	8	$41,791,650.18	$4,640,224	51,000	Other	Not IV	Design Assist	Owner	1.86	Construction
33	8	$41,791,650.18	$4,640,224	51,000	Other	Not IV	Design Assist	Owner	0.50	Construction
34	8	$41,791,650.18	$4,640,224	51,000	Other	Not IV	Design Assist	Owner	0.40	Construction
35	8	$41,791,650.18	$4,640,224	51,000	Other	Not IV	Design Assist	Owner	0.37	Construction
36	8	$41,791,650.18	$4,640,224	51,000	Other	Not IV	Design Assist	Owner	0.03	Construction

Table A.1 (cont'd)

37	9	$1,840,0 56.38	$1,84 0,056	51,0 00	Office	Not IV	Design Assist	Ow ner	1.00	Constru ction
38	9	$1,840,0 56.38	$1,84 0,056	51,0 00	Office	Not IV	Design Assist	Ow ner	0.88	Constru ction
39	9	$1,840,0 56.38	$1,84 0,056	51,0 00	Office	Not IV	Design Assist	Ow ner	-0.31	Constru ction
40	9	$1,840,0 56.38	$1,84 0,056	51,0 00	Office	Not IV	Design Assist	Ow ner	-0.19	Closeo ut
41	9	$1,840,0 56.38	$1,84 0,056	51,0 00	Office	Not IV	Design Assist	Ow ner	-0.17	Constru ction
42	9	$1,840,0 56.38	$1,84 0,056	51,0 00	Office	Not IV	Design Assist	Ow ner	0.24	Constru ction
43	9	$1,840,0 56.38	$1,84 0,056	51,0 00	Office	Not IV	Design Assist	Ow ner	0.06	Constru ction
44	9	$1,840,0 56.38	$1,84 0,056	51,0 00	Office	Not IV	Design Assist	Ow ner	0.21	Constru ction
45	10	$12,105, 585.19	$733, 767	18,0 00	Other	Not IV	Design Assist	Ow ner	0.00	
46	11	$1,684,1 67.05	$1,68 4,167	18,5 00	Other	Not IV	Design - Bid- Build	Ow ner	1.99	Constru ction
47	11	$1,684,1 67.05	$1,68 4,167	18,5 00	Other	Not IV	Design - Bid- Build	Ow ner	0.39	Constru ction
48	11	$1,684,1 67.05	$1,68 4,167	18,5 00	Other	Not IV	Design - Bid- Build	Ow ner	0.40	Constru ction
49	11	$1,684,1 67.05	$1,68 4,167	18,5 00	Other	Not IV	Design - Bid- Build	Ow ner	0.05	Constru ction
50	11	$1,684,1 67.05	$1,68 4,167	18,5 00	Other	Not IV	Design - Bid- Build	Ow ner	0.13	Constru ction
51	12	$104,854 .26	$11,8 28	2,50 0	Other	Not IV	Design - Bid- Build	Ow ner	2.54	Constru ction
52	13	$107,032 ,427.12	$9,54 3,360	107, 000	Office	Not IV	Design - Bid- Build	Ow ner	0.31	Constru ction
53	13	$107,032 ,427.12	$9,54 3,360	107, 000	Office	Not IV	Design - Bid- Build	Ow ner	0.00	Constru ction
54	13	$107,032 ,427.12	$9,54 3,360	107, 000	Office	Not IV	Design - Bid- Build	Ow ner	0.02	Constru ction
55	13	$107,032 ,427.12	$9,54 3,360	107, 000	Office	Not IV	Design - Bid- Build	Ow ner	0.38	Constru ction
56	14	$45,350, 595.80	$3,99 9,206	48,3 95	Higher Educati on	Not IV	Design Assist	Ow ner	5.29	Pre Constru ction
57	14	$45,350, 595.80	$3,99 9,206	48,3 95	Higher Educati on	Not IV	Design Assist	Ow ner	3.16	Constru ction

Table A.1 (cont'd)

58	14	$45,350,595.80	$3,999,206	48,395	Higher Education	Not IV	Design Assist	Owner	0.29	Construction
59	14	$45,350,595.80	$3,999,206	48,395	Higher Education	Not IV	Design Assist	Owner	0.18	Construction
60	14	$45,350,595.80	$3,999,206	48,395	Higher Education	Not IV	Design Assist	Owner	0.24	Construction
61	14	$45,350,595.80	$3,999,206	48,395	Higher Education	Not IV	Design Assist	Owner	1.19	Construction
62	14	$45,350,595.80	$3,999,206	48,395	Higher Education	Not IV	Design Assist	Owner	-2.08	Construction
63	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.03	Pre Construction
64	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.40	Pre Construction
65	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.04	Pre Construction
66	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.00	Pre Construction
67	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	9.11	Pre Construction
68	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.04	Pre Construction
69	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	38.41	Pre Construction
70	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.12	Pre Construction
71	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.22	Pre Construction

Table A.1 (cont'd)

72	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	1.52	Pre Construction
73	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	45.14	Pre Construction
74	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.91	Pre Construction
75	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	-0.09	Pre Construction
76	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	3.76	Pre Construction
77	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	2.05	Construction
78	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.94	Construction
79	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.00	Construction
80	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.10	Construction
81	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.00	Construction
82	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.08	Construction
83	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.00	Construction
84	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.51	Construction
85	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.13	Construction

Table A.1 (cont'd)

86	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.12	Construction
87	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.00	Construction
88	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.00	Construction
89	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.36	Construction
90	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	1.20	Construction
91	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.05	Construction
92	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.13	Construction
93	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.01	Pre Construction
94	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.41	Construction
95	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.03	Construction
96	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.01	Pre Construction
97	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.06	Construction
98	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.01	Construction
99	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.01	Construction

Table A.1 (cont'd)

100	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.22	Closeout
101	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	-0.11	Construction
102	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.00	Construction
103	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	Owner	0.01	Construction
104	16	$1,668,046.76	$168,005	2,000	Office	Not IV	Design Assist	Owner	43.68	Pre Construction
105	16	$1,668,046.76	$168,005	2,000	Office	Not IV	Design Assist	Owner	1.23	Closeout
106	17	$2,107,090.83	$2,107,091	81,696	Other	Not IV	Design - Bid- Build	Owner	-0.90	Pre Construction
107	17	$2,107,090.83	$2,107,091	81,696	Other	Not IV	Design - Bid- Build	Owner	0.84	Construction
108	17	$2,107,090.83	$2,107,091	81,696	Other	Not IV	Design - Bid- Build	Owner	0.52	Construction
109	18	$6,986,874.63	$1,206,396	22,000	Office	Not IV	Design - Bid- Build	Owner	-0.70	Pre Construction
110	18	$6,986,874.63	$1,206,396	22,000	Office	Not IV	Design - Bid- Build	Owner	-4.74	Construction
111	18	$6,986,874.63	$1,206,396	22,000	Office	Not IV	Design - Bid- Build	Owner	1.32	Construction
112	18	$6,986,874.63	$1,206,396	22,000	Office	Not IV	Design - Bid- Build	Owner	-0.12	Construction
113	18	$6,986,874.63	$1,206,396	22,000	Office	Not IV	Design - Bid- Build	Owner	0.26	Construction
114	18	$6,986,874.63	$1,206,396	22,000	Office	Not IV	Design - Bid- Build	Owner	0.13	Construction
115	19	$4,907,177.16	$4,140,314	94,000	Multi-Family	Not IV	Design - Bid- Build	Owner	0.21	Construction
116	19	$4,907,177.16	$4,140,314	94,000	Multi-Family	Not IV	Design - Bid- Build	Owner	0.07	Construction
117	19	$4,907,177.16	$4,140,314	94,000	Multi-Family	Not IV	Design - Bid- Build	Owner	0.04	Construction

Table A.1 (cont'd)

118	19	$4,907,177.16	$4,140,314	94,000	Multi-Family	Not IV	Design - Bid- Build	Owner	0.70	Construction
119	20	$13,060,221.22	$2,938,545	16,100	Other	Not IV	Design - Bid- Build	Owner	14.24	Construction
120	20	$13,060,221.22	$2,938,545	16,100	Other	Not IV	Design - Bid- Build	Owner	11.74	Construction
121	21	$3,178,434.84	$862,581	30,000	Higher Education	Not IV	Design - Bid- Build	Owner	1.37	Construction
122	21	$3,178,434.84	$862,581	30,000	Higher Education	Not IV	Design - Bid- Build	Owner	1.96	Construction
123	21	$3,178,434.84	$862,581	30,000	Higher Education	Not IV	Design - Bid- Build	Owner	0.67	Construction
124	21	$3,178,434.84	$862,581	30,000	Higher Education	Not IV	Design - Bid- Build	Owner	0.47	Construction
125	21	$3,178,434.84	$862,581	30,000	Higher Education	Not IV	Design - Bid- Build	Owner	0.72	Construction
126	22	$271,088,435.37	$2,847,549	22,000	Higher Education	Not IV	Design Assist	Owner	3.45	Construction
127	22	$271,088,435.37	$2,847,549	22,000	Higher Education	Not IV	Design Assist	Owner	0.12	Construction
128	22	$271,088,435.37	$2,847,549	22,000	Higher Education	Not IV	Design Assist	Owner	0.42	Closeout
129	22	$271,088,435.37	$2,847,549	22,000	Higher Education	Not IV	Design Assist	Owner	1.52	Closeout
130	23	$1,115,077.78	$1,115,078	40,953	Higher Education	IV	Design Assist	Owner	0.42	Pre Construction
131	23	$1,115,077.78	$1,115,078	40,953	Higher Education	IV	Design Assist	Owner	2.38	Construction
132	23	$1,115,077.78	$1,115,078	40,953	Higher Education	IV	Design Assist	Owner	0.05	Construction
133	24	$46,050,350.80	$1,977,673	60,400	Other	Not IV	Design Assist	Owner	0.90	Construction

Table A.1 (cont'd)

134	24	$46,050,350.80	$1,977,673	60,400	Other	Not IV	Design Assist	Owner	2.13	Construction
135	24	$46,050,350.80	$1,977,673	60,400	Other	Not IV	Design Assist	Owner	2.62	Construction
136	24	$46,050,350.80	$1,977,673	60,400	Other	Not IV	Design Assist	Owner	0.59	Construction
137	24	$46,050,350.80	$1,977,673	60,400	Other	Not IV	Design Assist	Owner	0.24	Construction
138	24	$46,050,350.80	$1,977,673	60,400	Other	Not IV	Design Assist	Owner	0.29	Construction
139	24	$46,050,350.80	$1,977,673	60,400	Other	Not IV	Design Assist	Owner	0.38	Construction
140	24	$46,050,350.80	$1,977,673	60,400	Other	Not IV	Design Assist	Owner	0.59	Construction
141	24	$46,050,350.80	$1,977,673	60,400	Other	Not IV	Design Assist	Owner	0.43	Construction
142	24	$46,050,350.80	$1,977,673	60,400	Other	Not IV	Design Assist	Owner	0.51	Construction
143	25	$43,139,377.54	$1,699,415	56,500	Other	Not IV	Design Assist	Owner	0.11	Construction
144	25	$43,139,377.54	$1,699,415	56,500	Other	Not IV	Design Assist	Owner	0.30	Construction
145	25	$43,139,377.54	$1,699,415	56,500	Other	Not IV	Design Assist	Owner	0.49	Construction
146	25	$43,139,377.54	$1,699,415	56,500	Other	Not IV	Design Assist	Owner	0.25	Construction
147	25	$43,139,377.54	$1,699,415	56,500	Other	Not IV	Design Assist	Owner	0.05	Construction
148	25	$43,139,377.54	$1,699,415	56,500	Other	Not IV	Design Assist	Owner	0.19	Construction
149	26	$135,940,304	$14,827,568	482,862.00	Multi-Family	IV	Design Assist	Owner	-0.25	Pre Construction
150	26	$135,940,304	$14,827,568	482,862.00	Multi-Family	IV	Design Assist	Owner	0.13	Construction
151	26	$135,940,304	$14,827,568	482,862.00	Multi-Family	IV	Design Assist	Contractor	0.64	Construction
152	26	$135,940,304	$14,827,568	482,862.00	Multi-Family	IV	Design Assist	Contractor	0.13	Construction

Table A.1 (cont'd)

153	26	$135,940,304	$14,827,568	482,862.00	Multi-Family	IV	Design Assist	Contractor	0.03	Construction
154	26	$135,940,304	$14,827,568	482,862.00	Multi-Family	IV	Design Assist	Contractor	0.05	Construction
155	26	$135,940,304	$14,827,568	482,862.00	Multi-Family	IV	Design Assist	Contractor	0.32	Construction
156	26	$135,940,304	$14,827,568	482,862.00	Multi-Family	IV	Design Assist	Contractor	0.03	Construction
157	26	$135,940,304	$14,827,568	482,862.00	Multi-Family	IV	Design Assist	Contractor	0.04	Construction
158	26	$135,940,304	$14,827,568	482,862.00	Multi-Family	IV	Design Assist	Subcontractor	0.02	Construction
159	26	$135,940,304	$14,827,568	482,862.00	Multi-Family	IV	Design Assist	Subcontractor	0.03	Construction
160	26	$135,940,304	$14,827,568	482,862.00	Multi-Family	IV	Design Assist	Subcontractor	0.14	Construction
161	26	$135,940,304	$14,827,568	482,862.00	Multi-Family	IV	Design Assist	Contractor	0.33	Construction
162	26	$135,940,304	$14,827,568	482,862.00	Multi-Family	IV	Design Assist	Unforeseen Problems	0.07	Construction
163	26	$135,940,304	$14,827,568	482,862.00	Multi-Family	IV	Design Assist	Unforeseen Problems	0.08	Construction

Table A.1 (cont'd)

164	26	$135,940,304	$14,827,568	482,862.00	Multi-Family	IV	Design Assist	Designer	0.04	Construction
165	26	$135,940,304	$14,827,568	482,862.00	Multi-Family	IV	Design Assist	Unforeseen Problems	0.05	Construction
166	26	$135,940,304	$14,827,568	482,862.00	Multi-Family	IV	Design Assist	Unforeseen Problems	0.25	Construction
167	26	$135,940,304	$14,827,568	482,862.00	Multi-Family	IV	Design Assist	Owner	-0.37	Closeout
168	27	$71,426,903	$10,881,532	200,000.00	Office	IV	Design Assist	Contractor	1.31	Pre Construction
169	27	$71,426,903	$10,881,532	200,000.00	Office	IV	Design Assist	Owner	0.07	Pre Construction
170	27	$71,426,903	$10,881,532	200,000.00	Office	IV	Design Assist	Owner	0.06	Construction
171	27	$71,426,903	$10,881,532	200,000.00	Office	IV	Design Assist	Contractor	0.02	Construction
172	27	$71,426,903	$10,881,532	200,000.00	Office	IV	Design Assist	Subcontractor	0.09	Construction
173	27	$71,426,903	$10,881,532	200,000.00	Office	IV	Design Assist	Contractor	0.18	Construction
174	27	$71,426,903	$10,881,532	200,000.00	Office	IV	Design Assist	Contractor	0.01	Construction
175	27	$71,426,903	$10,881,532	200,000.00	Office	IV	Design Assist	Subcontractor	0.05	Construction

Table A.1 (cont'd)

176	27	$71,426,903	$10,881,532	200,000.00	Office	IV	Design Assist	Owner	0.03	Construction
177	27	$71,426,903	$10,881,532	200,000.00	Office	IV	Design Assist	Contractor	0.19	Construction
178	27	$71,426,903	$10,881,532	200,000.00	Office	IV	Design Assist	Contractor	0.02	Construction
179	27	$71,426,903	$10,881,532	200,000.00	Office	IV	Design Assist	Contractor	0.00	Closeout
180	27	$71,426,903	$10,881,532	200,000.00	Office	IV	Design Assist	Owner	1.87	Construction
181	27	$71,426,903	$10,881,532	200,000.00	Office	IV	Design Assist	Owner	0.43	Construction
182	28	$87,894,693	$1,496,040	170,431.00	Other	Not IV	Design Assist		0.00	
183	29	$5,165,315	$709,502	20,300.00	Multi-Family	Not IV	Design Assist	Unforeseen Problems	0.38	Construction
184	29	$5,165,315	$709,502	20,300.00	Multi-Family	Not IV	Design Assist	Subcontractor	0.31	Construction
185	29	$5,165,315	$709,502	20,300.00	Multi-Family	Not IV	Design Assist	Subcontractor	1.80	Construction
186	29	$5,165,315	$709,502	20,300.00	Multi-Family	Not IV	Design Assist	Owner	0.95	Construction
187	29	$5,165,315	$709,502	20,300.00	Multi-Family	Not IV	Design Assist	Unforeseen Problems	0.93	Construction

Table A.1 (cont'd)

188	30	$22,713,096	$4,287,416	87,000.00	Multi-Family	Not IV	Design Assist	Subcontractor	3.23	Construction
189	31	$7,442,589	$367,395	8,116.00	Other	Not IV	Design - Bid- Build	Unforeseen Problems	0.26	Construction
190	31	$7,442,589	$367,395	8,116.00	Other	Not IV	Design - Bid- Build	Unforeseen Problems	0.66	Construction
191	32	$73,802,088	$8,366,616	212,000.00	Other	IV	Design Assist	Subcontractor	0.03	Construction
192	32	$73,802,088	$8,366,616	212,000.00	Other	IV	Design Assist	Contractor	0.03	Construction
193	32	$73,802,088	$8,366,616	212,000.00	Other	IV	Design Assist	Contractor	0.14	Construction
194	32	$73,802,088	$8,366,616	212,000.00	Other	IV	Design Assist	Subcontractor	0.01	Construction
195	32	$73,802,088	$8,366,616	212,000.00	Other	IV	Design Assist	Contractor	0.02	Construction
196	32	$73,802,088	$8,366,616	212,000.00	Other	IV	Design Assist	Subcontractor	0.01	Construction
197	32	$73,802,088	$8,366,616	212,000.00	Other	IV	Design Assist	Subcontractor	0.05	Construction

Table A.1 (cont'd)

198	32	$73,802,088	$8,366,616	212,000.00	Other	IV	Design Assist	Subcontractor	0.19	Construction
199	32	$73,802,088	$8,366,616	212,000.00	Other	IV	Design Assist	Subcontractor	0.19	Construction
200	32	$73,802,088	$8,366,616	212,000.00	Other	IV	Design Assist	Contractor	0.19	Construction
201	32	$73,802,088	$8,366,616	212,000.00	Other	IV	Design Assist	Subcontractor	0.00	Construction
202	32	$73,802,088	$8,366,616	212,000.00	Other	IV	Design Assist	Designer	0.03	Construction
203	32	$73,802,088	$8,366,616	212,000.00	Other	IV	Design Assist	Unforeseen Problems	0.22	Closeout
204	32	$73,802,088	$8,366,616	212,000.00	Other	IV	Design Assist	Subcontractor	0.02	Construction
205	32	$73,802,088	$8,366,616	212,000.00	Other	IV	Design Assist	Designer	0.02	Construction
206	32	$73,802,088	$8,366,616	212,000.00	Other	IV	Design Assist	Unforeseen Problems	0.00	Construction
207	32	$73,802,088	$8,366,616	212,000.00	Other	IV	Design Assist	Contractor	0.13	Construction
208	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	0.11	Construction

Table A.1 (cont'd)

209	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	0.26	Construction
210	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	0.30	Construction
211	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Other	0.06	Construction
212	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	0.07	Pre Construction
213	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	0.47	Closeout
214	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	2.15	Pre Construction
215	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Owner	0.00	Pre Construction
216	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	0.28	Construction
217	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	1.93	Construction
218	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	0.47	Construction
219	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	0.08	Construction
220	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	0.03	Construction
221	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	0.40	Construction
222	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	0.17	Construction

Table A.1 (cont'd)

223	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	-0.14	Construction
224	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	0.09	Construction
225	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	0.02	Construction
226	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	0.18	Construction
227	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	0.10	Construction
228	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	0.04	Construction
229	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	0.28	Construction
230	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	0.14	Construction
231	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	0.05	Construction
232	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	-0.04	Construction
233	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	0.04	Construction
234	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	0.10	Construction
235	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	0.15	Construction
236	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	0.01	Construction

Table A.1 (cont'd)

237	33	$130,363,083	$9,988,915	160,000.00	Higher Education	Not IV	Design Assist	Designer	0.02	Construction
238	34	$33,108,484	$2,538,819	47,000.00	Higher Education	Not IV	Design Assist	Designer	0.61	Construction
239	34	$33,108,484	$2,538,819	47,000.00	Higher Education	Not IV	Design Assist	Contractor	0.33	Construction

APPENDIX B: OWNER DRIVEN CHANGE ORDERS

Sr No.	PROJECT	Actual Cost	Actual Cost MT	Gross Area	Building Type	Construction Type	Project Delivery Method	CO Cost/ Gross Area	CO Construction Phase
1	1	$75,757,653.93	$566,404	260000	Office	Not IV	Design - Bid- Build	-0.24	Construction
2	2	$16,204,676.38	$1,934,062	18,180	Other	Not IV	Design - Bid- Build	1.20	Construction
3	2	$16,204,676.38	$1,934,062	18,180	Other	Not IV	Design - Bid- Build	2.12	Construction
4	2	$16,204,676.38	$1,934,062	18,180	Other	Not IV	Design - Bid- Build	1.09	Construction
5	3	$167,158,118.61	$14,746,460	310,000	Multi-Family	IV	Design - Bid- Build	0.16	Construction
6	3	$167,158,118.61	$14,746,460	310,000	Multi-Family	IV	Design - Bid- Build	0.16	Construction
7	3	$167,158,118.61	$14,746,460	310,000	Multi-Family	IV	Design - Bid- Build	0.29	Construction
8	3	$167,158,118.61	$14,746,460	310,000	Multi-Family	IV	Design - Bid- Build	0.50	Construction
9	4	$60,395,128.55	$2,464,942	81,000	Other	Not IV	Design - Bid- Build	0.30	Construction
10	4	$60,395,128.55	$2,464,942	81,000	Other	Not IV	Design - Bid- Build	1.36	Construction
11	4	$60,395,128.55	$2,464,942	81,000	Other	Not IV	Design - Bid- Build	0.15	Construction
12	4	$60,395,128.55	$2,464,942	81,000	Other	Not IV	Design - Bid- Build	0.03	Construction
13	4	$60,395,128.55	$2,464,942	81,000	Other	Not IV	Design - Bid- Build	0.11	Construction
14	4	$60,395,128.55	$2,464,942	81,000	Other	Not IV	Design - Bid- Build	0.02	Construction
15	4	$60,395,128.55	$2,464,942	81,000	Other	Not IV	Design - Bid- Build	0.03	Construction
16	4	$60,395,128.55	$2,464,942	81,000	Other	Not IV	Design - Bid- Build	0.02	Construction
17	5	$15,134,038.81	$1,303,360	21,816	Higher Education	Not IV	Design - Bid- Build	0.10	Construction

Table B.1: Owner driven change orders

Table B.1 (cont'd)

18	5	$15,134,038.81	$1,303,360	21,817	Higher Education	Not IV	Design - Bid- Build	0.34	Construction
19	5	$15,134,038.81	$1,303,360	21,818	Higher Education	Not IV	Design - Bid- Build	-0.02	Construction
20	5	$15,134,038.81	$1,303,360	21,818	Higher Education	Not IV	Design - Bid- Build	1.22	Construction
21	6	$13,655,134.77	$1,750,112	24,500	Office	Not IV	Design - Bid- Build	1.50	Construction
22	6	$13,655,134.77	$1,750,112	24,500	Office	Not IV	Design - Bid- Build	0.26	Construction
23	6	$13,655,134.77	$1,750,112	24,500	Office	Not IV	Design - Bid- Build	0.50	Construction
24	6	$13,655,134.77	$1,750,112	24,500	Office	Not IV	Design - Bid- Build	0.63	Construction
25	6	$13,655,134.77	$1,750,112	24,500	Office	Not IV	Design - Bid- Build	0.48	Construction
26	6	$13,655,134.77	$1,750,112	24,500	Office	Not IV	Design - Bid- Build	0.25	Construction
27	7	$30,637,641.48	$3,599,890	68,000	Multi-Family	IV	Design Assist	0.03	Construction
28	7	$30,637,641.48	$3,599,890	68,000	Multi-Family	IV	Design Assist	0.01	Construction
29	7	$30,637,641.48	$3,599,890	68,000	Multi-Family	IV	Design Assist	0.08	Construction
30	8	$41,791,650.18	$4,640,224	51,000	Other	Not IV	Design Assist	4.22	Construction
31	8	$41,791,650.18	$4,640,224	51,000	Other	Not IV	Design Assist	0.83	Construction
32	8	$41,791,650.18	$4,640,224	51,000	Other	Not IV	Design Assist	1.86	Construction
33	8	$41,791,650.18	$4,640,224	51,000	Other	Not IV	Design Assist	0.50	Construction
34	8	$41,791,650.18	$4,640,224	51,000	Other	Not IV	Design Assist	0.40	Construction
35	8	$41,791,650.18	$4,640,224	51,000	Other	Not IV	Design Assist	0.37	Construction
36	8	$41,791,650.18	$4,640,224	51,000	Other	Not IV	Design Assist	0.03	Construction
37	9	$1,840,056.38	$1,840,056	51,000	Office	Not IV	Design Assist	1.07	Construction

Table B.1 (cont'd)

38	9	$1,840,056.38	$1,840,056	51,000	Office	Not IV	Design Assist	0.95	Construction
39	9	$1,840,056.38	$1,840,056	51,000	Office	Not IV	Design Assist	-0.33	Construction
40	9	$1,840,056.38	$1,840,056	51,000	Office	Not IV	Design Assist	-0.20	Closeout
41	9	$1,840,056.38	$1,840,056	51,000	Office	Not IV	Design Assist	-0.18	Construction
42	9	$1,840,056.38	$1,840,056	51,000	Office	Not IV	Design Assist	0.26	Construction
43	9	$1,840,056.38	$1,840,056	51,000	Office	Not IV	Design Assist	0.06	Construction
44	9	$1,840,056.38	$1,840,056	51,000	Office	Not IV	Design Assist	0.22	Construction
46	11	$1,684,167.05	$1,684,167	18,500	Other	Not IV	Design - Bid- Build	1.99	Construction
47	11	$1,684,167.05	$1,684,167	18,500	Other	Not IV	Design - Bid- Build	0.39	Construction
48	11	$1,684,167.05	$1,684,167	18,500	Other	Not IV	Design - Bid- Build	0.40	Construction
49	11	$1,684,167.05	$1,684,167	18,500	Other	Not IV	Design - Bid- Build	0.05	Construction
50	11	$1,684,167.05	$1,684,167	18,500	Other	Not IV	Design - Bid- Build	0.13	Construction
51	12	$104,854.26	$11,828	2,500	Other	Not IV	Design - Bid- Build	2.54	Construction
52	13	$107,032,427.12	$9,543,360	107,000	Office	Not IV	Design - Bid- Build	0.31	Construction
53	13	$107,032,427.12	$9,543,360	107,000	Office	Not IV	Design - Bid- Build	0.00	Construction
54	13	$107,032,427.12	$9,543,360	107,000	Office	Not IV	Design - Bid- Build	0.02	Construction
55	13	$107,032,427.12	$9,543,360	107,000	Office	Not IV	Design - Bid- Build	0.38	Construction
56	14	$45,350,595.80	$3,999,206	48,395	Higher Education	Not IV	Design Assist	5.29	Pre Construction
57	14	$45,350,595.80	$3,999,206	48,395	Higher Education	Not IV	Design Assist	3.16	Construction

Table B.1 (cont'd)

58	14	$45,350,595.80	$3,999,206	48,395	Higher Education	Not IV	Design Assist	0.29	Construction
59	14	$45,350,595.80	$3,999,206	48,395	Higher Education	Not IV	Design Assist	0.18	Construction
60	14	$45,350,595.80	$3,999,206	48,395	Higher Education	Not IV	Design Assist	0.24	Construction
61	14	$45,350,595.80	$3,999,206	48,395	Higher Education	Not IV	Design Assist	1.19	Construction
62	14	$45,350,595.80	$3,999,206	48,395	Higher Education	Not IV	Design Assist	-2.08	Construction
63	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	0.03	Pre Construction
64	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	0.40	Pre Construction
65	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	0.04	Pre Construction
66	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	0.00	Pre Construction
67	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	9.11	Pre Construction
68	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	0.04	Pre Construction
69	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	38.41	Pre Construction
70	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	0.12	Pre Construction
71	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	0.22	Pre Construction

Table B.1 (cont'd)

72	15	$62,236, 840.22	$62,23 6,840	400 ,00 0	Other	Not IV	Design Assist	1.52	Pre Constru ction
73	15	$62,236, 840.22	$62,23 6,840	400 ,00 0	Other	Not IV	Design Assist	45.14	Pre Constru ction
74	15	$62,236, 840.22	$62,23 6,840	400 ,00 0	Other	Not IV	Design Assist	0.91	Pre Constru ction
75	15	$62,236, 840.22	$62,23 6,840	400 ,00 0	Other	Not IV	Design Assist	-0.09	Pre Constru ction
76	15	$62,236, 840.22	$62,23 6,840	400 ,00 0	Other	Not IV	Design Assist	3.76	Pre Constru ction
77	15	$62,236, 840.22	$62,23 6,840	400 ,00 0	Other	Not IV	Design Assist	2.05	Constru ction
78	15	$62,236, 840.22	$62,23 6,840	400 ,00 0	Other	Not IV	Design Assist	0.94	Constru ction
79	15	$62,236, 840.22	$62,23 6,840	400 ,00 0	Other	Not IV	Design Assist	0.00	Constru ction
80	15	$62,236, 840.22	$62,23 6,840	400 ,00 0	Other	Not IV	Design Assist	0.10	Constru ction
81	15	$62,236, 840.22	$62,23 6,840	400 ,00 0	Other	Not IV	Design Assist	0.00	Constru ction
82	15	$62,236, 840.22	$62,23 6,840	400 ,00 0	Other	Not IV	Design Assist	0.08	Constru ction
83	15	$62,236, 840.22	$62,23 6,840	400 ,00 0	Other	Not IV	Design Assist	0.00	Constru ction
84	15	$62,236, 840.22	$62,23 6,840	400 ,00 0	Other	Not IV	Design Assist	0.51	Constru ction
85	15	$62,236, 840.22	$62,23 6,840	400 ,00 0	Other	Not IV	Design Assist	0.13	Constru ction

Table B.1 (cont'd)

86	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	0.12	Construction
87	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	0.00	Construction
88	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	0.00	Construction
89	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	0.36	Construction
90	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	1.20	Construction
91	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	0.05	Construction
92	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	0.13	Construction
93	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	0.01	Pre Construction
94	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	0.41	Construction
95	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	0.03	Construction
96	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	0.01	Pre Construction
97	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	0.06	Construction
98	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	0.01	Construction
99	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	0.01	Construction

Table B.1 (cont'd)

100	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	0.22	Closeout
101	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	-0.11	Construction
102	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	0.00	Construction
103	15	$62,236,840.22	$62,236,840	400,000	Other	Not IV	Design Assist	0.01	Construction
104	16	$1,668,046.76	$168,005	2,000	Office	Not IV	Design Assist	43.68	Pre Construction
105	16	$1,668,046.76	$168,005	2,000	Office	Not IV	Design Assist	1.23	Closeout
106	17	$2,107,090.83	$2,107,091	81,696	Other	Not IV	Design - Bid- Build	-0.90	Pre Construction
107	17	$2,107,090.83	$2,107,091	81,696	Other	Not IV	Design - Bid- Build	0.84	Construction
108	17	$2,107,090.83	$2,107,091	81,696	Other	Not IV	Design - Bid- Build	0.52	Construction
109	18	$6,986,874.63	$1,206,396	22,000	Office	Not IV	Design - Bid- Build	-0.70	Pre Construction
110	18	$6,986,874.63	$1,206,396	22,000	Office	Not IV	Design - Bid- Build	-4.74	Construction
111	18	$6,986,874.63	$1,206,396	22,000	Office	Not IV	Design - Bid- Build	1.32	Construction
112	18	$6,986,874.63	$1,206,396	22,000	Office	Not IV	Design - Bid- Build	-0.12	Construction
113	18	$6,986,874.63	$1,206,396	22,000	Office	Not IV	Design - Bid- Build	0.26	Construction
114	18	$6,986,874.63	$1,206,396	22,000	Office	Not IV	Design - Bid- Build	0.13	Construction
115	19	$4,907,177.16	$4,140,314	94,000	Multi-Family	Not IV	Design - Bid- Build	0.21	Construction
116	19	$4,907,177.16	$4,140,314	94,000	Multi-Family	Not IV	Design - Bid- Build	0.07	Construction
117	19	$4,907,177.16	$4,140,314	94,000	Multi-Family	Not IV	Design - Bid- Build	0.04	Construction

Table B.1 (cont'd)

118	19	$4,907,177.16	$4,140,314	94,000	Multi-Family	Not IV	Design - Bid- Build	0.70	Construction
119	20	$13,060,221.22	$2,938,545	16,100	Other	Not IV	Design - Bid- Build	14.24	Construction
120	20	$13,060,221.22	$2,938,545	16,100	Other	Not IV	Design - Bid- Build	11.74	Construction
121	21	$3,178,434.84	$862,581	30,000	Higher Education	Not IV	Design - Bid- Build	1.37	Construction
122	21	$3,178,434.84	$862,581	30,000	Higher Education	Not IV	Design - Bid- Build	1.96	Construction
123	21	$3,178,434.84	$862,581	30,000	Higher Education	Not IV	Design - Bid- Build	0.67	Construction
124	21	$3,178,434.84	$862,581	30,000	Higher Education	Not IV	Design - Bid- Build	0.47	Construction
125	21	$3,178,434.84	$862,581	30,000	Higher Education	Not IV	Design - Bid- Build	0.72	Construction
126	22	$271,088,435.37	$2,847,549	22,000	Higher Education	Not IV	Design Assist	3.45	Construction
127	22	$271,088,435.37	$2,847,549	22,000	Higher Education	Not IV	Design Assist	0.12	Construction
128	22	$271,088,435.37	$2,847,549	22,000	Higher Education	Not IV	Design Assist	0.42	Closeout
129	22	$271,088,435.37	$2,847,549	22,000	Higher Education	Not IV	Design Assist	1.52	Closeout
130	23	$1,115,077.78	$1,115,078	40,953	Higher Education	IV	Design Assist	0.42	Pre Construction
131	23	$1,115,077.78	$1,115,078	40,953	Higher Education	IV	Design Assist	2.38	Construction
132	23	$1,115,077.78	$1,115,078	40,953	Higher Education	IV	Design Assist	0.05	Construction
133	24	$46,050,350.80	$1,977,673	60,400	Other	Not IV	Design Assist	0.90	Construction

Table B.1 (cont'd)

134	24	$46,050,350.80	$1,977,673	60,400	Other	Not IV	Design Assist	2.13	Construction
135	24	$46,050,350.80	$1,977,673	60,400	Other	Not IV	Design Assist	2.62	Construction
136	24	$46,050,350.80	$1,977,673	60,400	Other	Not IV	Design Assist	0.59	Construction
137	24	$46,050,350.80	$1,977,673	60,400	Other	Not IV	Design Assist	0.24	Construction
138	24	$46,050,350.80	$1,977,673	60,400	Other	Not IV	Design Assist	0.29	Construction
139	24	$46,050,350.80	$1,977,673	60,400	Other	Not IV	Design Assist	0.38	Construction
140	24	$46,050,350.80	$1,977,673	60,400	Other	Not IV	Design Assist	0.59	Construction
141	24	$46,050,350.80	$1,977,673	60,400	Other	Not IV	Design Assist	0.43	Construction
142	24	$46,050,350.80	$1,977,673	60,400	Other	Not IV	Design Assist	0.51	Construction
143	25	$43,139,377.54	$1,699,415	56,500	Other	Not IV	Design Assist	0.11	Construction
144	25	$43,139,377.54	$1,699,415	56,500	Other	Not IV	Design Assist	0.30	Construction
145	25	$43,139,377.54	$1,699,415	56,500	Other	Not IV	Design Assist	0.49	Construction
146	25	$43,139,377.54	$1,699,415	56,500	Other	Not IV	Design Assist	0.25	Construction
147	25	$43,139,377.54	$1,699,415	56,500	Other	Not IV	Design Assist	0.05	Construction
148	25	$43,139,377.54	$1,699,415	56,500	Other	Not IV	Design Assist	0.19	Construction
149	26	$135,940,304.40	$12,269,487.00	482862	Multi-Family	IV	Design Assist	-0.25	Pre Construction
150	26	$135,940,304.40	$12,269,487.00	482862	Multi-Family	IV	Design Assist	0.13	Construction
151	26	$135,940,304.40	$12,269,487.00	482862	Multi-Family	IV	Design Assist	-0.36	Closeout
152	27	$71,426,902.56	7195191	200000	Office	IV	Design Assist	0.07	Pre Construction
153	27	$71,426,902.56	7195191	200000	Office	IV	Design Assist	0.06	Construction

Table B.1 (cont'd)

154	27	$71,426,902.56	7195191	200000	Office	IV	Design Assist	0.03	Construction
155	27	$71,426,902.56	7195191	200000	Office	IV	Design Assist	1.87	Construction
156	27	$71,426,902.56	7195191	200000	Office	IV	Design Assist	0.43	Construction
157	29	$5,165,315.40	695036	20300	Multi-Family	Not IV	Design Assist	0.95	Construction
158	33	$130,363,082.81	7037360	160000	Higher Education	Not IV	Design Assist	0.00	Pre Construction