ASSESSMENT OF SUCCESS FACTORS AND COMPARATIVE ANALYSIS OF PUBLIC PRIVATE PARTNERSHIP (P3) PROJECT PERFORMANCES AGAINST DESIGN-BUILD AND DESIGN-BID-BUILD PROJECT DELIVERY

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ABSTRACT

Assessment of Success Factors and Comparative Analysis of Public Private Partnership (P3) project performances against Design-Build and Design-Bid-Build project delivery

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Public-private partnerships (P3s) projects have gained widespread popularity in both developed and developing countries due to their ability to access new financing sources and shift specific project risks to the private sector. P3s has been an active area of research with a particular focus on the concept of Critical Success Factors (CSF). The growing interest and the diverse outcomes associated with P3s emphasize the need for a thorough investigation into the factors that contribute to successful P3 projects. This study focused on identifying the CSFs for P3 highway and building projects towards project objectives of achieving cost efficiency and schedule advantage using literature reviews and questionnaire survey. Additionally, the study aimed to conduct an empirical analysis by comparing cost and schedule performances of P3 projects with design-build (DB) and design-bid-build (DBB) highway and building projects. To collect data regarding critical success factors relevant to real projects in the United States, the research has employed a questionnaire survey. This survey was distributed to participants involved in P3 highway and building projects who provided ratings for the identified CSFs relevant to their respective projects. Furthermore, the study extended its data collection efforts to include DB and DBB highway and building projects of similar size and scope, to facilitate a comparative analysis enabling an assessment of cost and schedule effectiveness of these three project delivery methods. The study concluded that the P3 highway projects in the United States have better cost performance compared to DB and DBB projects. Similarly, P3 building projects exhibit better cost and schedule performance in comparison to DB and DBB projects while no statistically significant difference was found in schedule performances between P3 and DB projects. It is hoped that the research findings will assist the public owners to ensure the success of their future P3 endeavors, particularly in terms of cost and schedule performances. The study outcomes can hold potential in public and private sectors by providing insights into how specific critical factors can be applied to enhance the execution of P3 method in both highway and building construction projects.

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DEDICATION

I wish to dedicate this dissertation to my parents, Krishna Das Shrestha and Basanti Devi Shrestha. Despite the physical distance, their unwavering support, encouragement, and love have been constant companions throughout this journey. I am deeply grateful for their enduring motivation, especially during challenging times. I extend special appreciation to my husband, Rabin Shrestha and brother, Vivek Shrestha, for anchoring me and providing encouragement whenever needed. Much love to my son, Vivaan.

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CHAPTER 1 INTRODUCTION

1.1 Research Background

Successful completion of a construction project is typically measured by its cost efficiency and its ability to adhere to project schedules. This highlights the importance of cost-related factors and time- related factors in determining the success of the project (Albtoush et al., 2022). For a past decade, there has been a persistent issue of cost and time overruns in public highway construction industry(Bordat et al., 2004). The ability to complete projects within the originally estimated budget proposed time frame, and in line with the initial scope of work has become crucial project management function for every state Department of Transportation (DOTs) in United States (FHWA, 2007). Public-private partnerships (P3s) model have been often considered as a solution to this limitation to achieve efficiency and cost and time savings in the public projects.

In recent decades, there has been a significant rise in the popularity of Public-private partnerships (P3s) projects both in developed and developing countries (Cheung et al., 2012).This growth can be attributed to the advantages they offer in the delivery of public infrastructure projects (Muhammad et al., 2016). In contrast to design-bid-build (DBB) and design-build (DB) delivery method, P3 project delivery provides public agency a mechanism to procure contracts including design, construction and frequently long-term operations and maintenance of assets over a specified term that involves a component of private financing (DBIA, 2016). P3 contracts focus on implementation of performance-based contract requirements which are used to procure new-build facilities or upgrade an existing facility. There are different contracting approaches that are used in P3 projects. The contracting approaches are:

1. Design-Build-Operate (DBO) or Design-Build-Operate-Maintain DBOM

Under a DBO or DBOM approach, the design build is combined with the transfer of operations and maintenance responsibilities to the private partner, but it does not involve private financing in the project. Generally, in this contract approach, the project components are procured in a single contract.

2. Design-Build-Finance (DBF)

   DBF approach is a design build contract which is combined with financing of design and construction phase of project for short term. However, the public owner still retains responsibility for the long-term project operations and maintenance.

3. Design-Build-Finance-Operate (DBFO)

   Under this approach, the public owner retains responsibility only for long term maintenance whereas design, construction, financing, and operations responsibilities are transferred to the private partner.

4. Design-Build-Finance-Operate-Maintain (DBFOM)

   This contract approach essentially involves design, construction, financing, operations, and maintenance responsibilities that are transferred to private partners by public entities.

The interest in the P3 project delivery model is on the rise in the United States. The investment in the US P3 projects has reached an amount of US$ 83.3 billion from US$ 19.5 billion in 2018 and US$ 19.7 billion in 2017 (IMC, 2020). There were 94 ongoing P3 projects in the U.S. in total during 2018, whereas in 2020 there were 186 active P3 projects, increasing the figure by almost 135% from 2018 (Renner, 2021). Several states are developing P3 programs and most of the states have authorization to use P3 delivery method in their projects. Out of 50 states, 24 states have authorized P3 in their legislation which is broadly applicable to the number of agencies whereas

13 states have limited enabling statutes written for specific or eligible projects. The map in figure 1.1 shows the states that have authorized the use of P3s through enabling statutes.

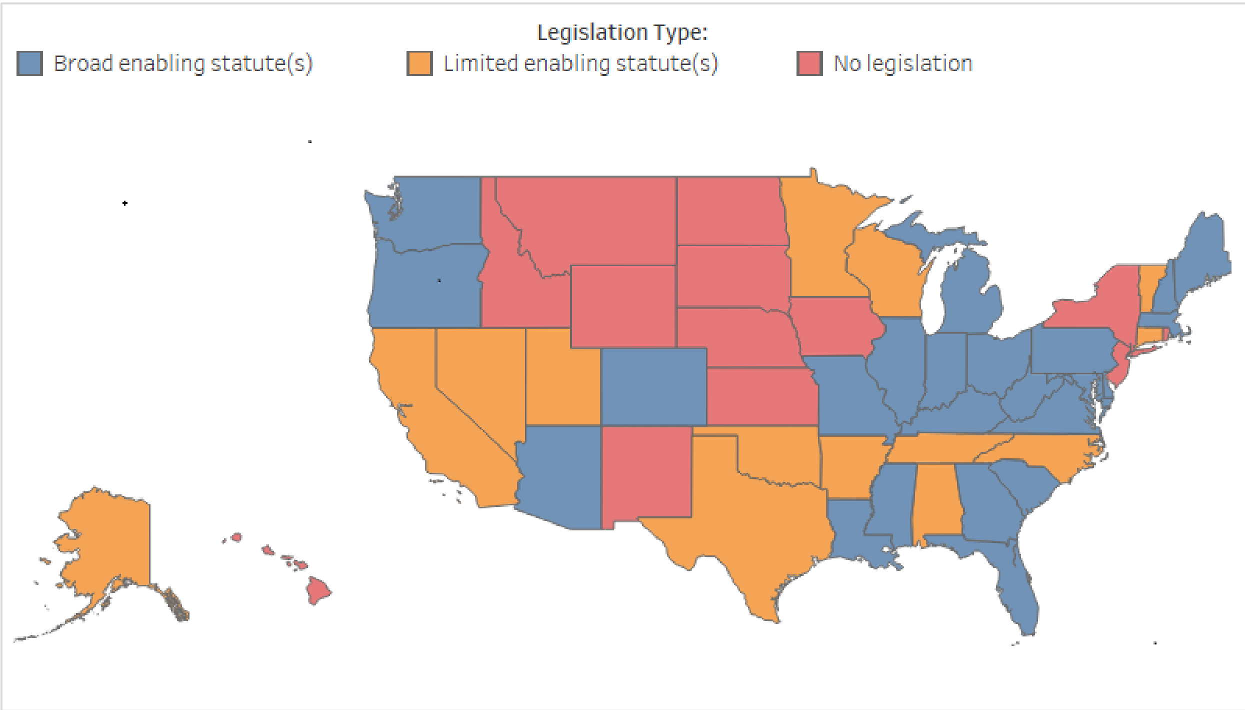

Figure 1.1 : Public private partnerships legislation by state (FHWA,2020)

P3 contracts have been used in a broad spectrum of infrastructure sectors over the past decade. The pre-dominant sector that has led the US P3 market both in number of projects and investment volume is the transportation sector. The second important part of the US P3 market is constituted by the social and health sector. The total number of P3 projects and their investment volumes (US$) in the United States until December 2019 is shown in Figure 1.2.

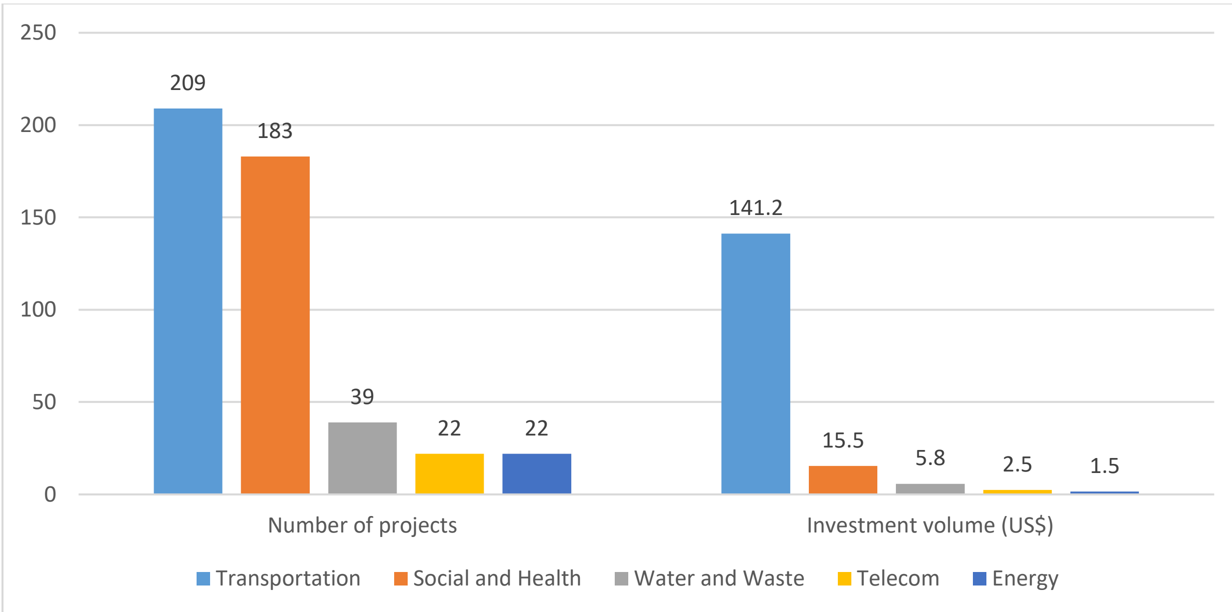

Figure 1.2. Sector wise P3 project portfolio in the US (IMC,2020)

Through P3 approach, government worldwide are leveraging private sector expertise and resources to address significant infrastructure gaps in public assets and services (Natalia et al., 2021). As P3 projects continue to gain substantial attention from governments, P3 has drawn interest of many researchers. The previous literatures extensively document the success and benefits associated with implementing P3 projects in various countries (Cheung et al., 2012).

The progress in implementation of P3 policies have been in slow pace with numerous P3 partnerships encountering failure or distress despite the enthusiasm shown by both public and private sectors (Kyei et al., 2017). The considerable size and complexity of these projects along with high initial costs have acted as barriers to wider adoption of this model (McGraw Hill, 2015). Given the substantial interest and mixed results over P3s (Muhammad et al., 2016) highlights that there is a pressing need for an investigation into the factors that contribute to the successful delivery of P3 projects, particularly in achieving cost efficiency and schedule advantages. Critical success factors (CSFs) are regarded as essential enablers for project success to achieve positive outcomes in a project (Sanvido et al., 1992). Extensive research has been conducted on critical factors in P3 projects that contribute to their successful implementation both in developed and developing countries. Furthermore, given the increasing number of P3s worldwide, there is a growing interest in exploring the key drivers of success for P3 projects (Ahmadabadi & Heravi, 2019).

Previous studies highlight that the identification of CSFs for P3 schemes has been applied across various infrastructure sectors. However, it is crucial to recognize that these factors are highly contextual with different types of projects necessitating different sets of CSFs for P3 arrangements (Alteneiji et al., 2020a). Each industry sector presents differing legal, regulatory and investment considerations leading to unique opportunities and challenges for P3 implementation. Therefore, to align with the government's investment priorities and give precedence to sectors where P3s are anticipated to be more successful (World Bank, 2017), a more comprehensive analysis of CSFs specific to the infrastructure sectors of the US is required. In addition, it is important to demonstrate how P3 projects compare in terms of cost and schedule compared to other project delivery methods to highlight the importance of evidence-based decision making in infrastructure development.

1.2 Need of the Study

The United States is currently facing a growing gap in total infrastructure investment. Over the span of 10 years, this investment gap has risen from $2.1trillion to a notable $2.59 trillion (ASCE, 2021). One primary motivation for undertaking P3 projects is the insufficient financial resources at both the state and federal government levels to cover the expenses of design, constructing, operating, and maintaining public infrastructure and building projects. Consequently, to fund infrastructure and building projects, opting for P3 becomes the preferred solution, as it allows private entities to contribute funds towards the design, build, operate, and maintain the public infrastructure projects. The involvement of private sector is sought to leverage scarce public resources, expedite project delivery, and improve cost effectiveness of project development(James et al., 2007). P3 project delivery with innovative methodologies, have been developed in recent years in North America and the number of P3 projects in this region has increased significantly since the early 1990s (Chasey et al., 2012).

Despite the enthusiasm from both public and private sectors, there has been a slow progress in implementation of P3 policies and many P3 partnerships have failed or have been distressed (Osei Kyei et al., 2017). The large size and complexity of the projects along with high project initiation investment such as conducting feasibility studies, hiring consultants or advisors and legal and financial advisory fees have acted as a barrier to greater adoption of this model (McGraw Hill, 2015). The substantial interest and mixed results over P3s (Muhammad et al., 2016) emphasizes the need for an investigation of the factors to deliver successful P3 projects to achieve cost efficiency and schedule advantage. Critical success factors (CSFs) are considered vital enablers for project success to achieve positive outcomes in a project (Sanvido et al., 1992). A significant amount of research has been carried out regarding critical factors in P3 projects that contribute to successful implementation of P3s in both developed and developing countries. Moreover, due to emerging number of P3s worldwide, the drivers of success for P3 projects have become a subject for investigation (Ahmadabadi & Heravi, 2019)The contribution of various factors to achieve project objectives such as attaining cost and schedule efficiency in P3 projects is highly contextual and vary from project to project which arises the need of investigation for distinct set of CSFs to enhance project performances.

Given the diverse applications of P3 across various sectors to acquire different types of public assets and services, it is equally important to investigate the success specific to each infrastructure sector. Despite the growing global trend in P3s implementation for social and economic infrastructure, it is essential to acknowledge the limited analysis of success factors within the building infrastructure sector (Alteneiji et al., 2020b). The existing body of research does not comprehensively address the unique dynamics and challenges specific to this infrastructure sector in the context of P3 implementation. An examination is necessary to guide government investment priorities by highlighting areas where P3 is more likely to achieve success and aligns with crucial policies (World Bank, 2017). This emphasizes the necessity for further exploration into the specific success factors influencing P3 projects in various infrastructure sectors like highways and buildings.

The emergence of P3s in the United States is a response to growing demands on the transportation system and limitations in public resources. This project delivery approach has the potential to significantly impact the performance of P3 projects when compared to design-build and traditional project delivery systems. Despite its growing appeal, conflicting accounts of both success and failure have surfaced in the literature (Muhammad & Johar, 2018). While P3s have long been advocated as an effective strategy for enhancing cost and schedule efficiency of public infrastructure projects in compared to traditional project delivery projects, there is a scarcity of empirical evidence that explore this assertion. Additionally, despite numerous studies examining project performance in the United States particularly comparing Design-Build (DB) and Design-Bid-Build (DBB) project delivery methods, there is a noticeable gap in research comparing cost and schedule performances between Public-Private Partnership (P3) and projects using traditional project delivery approaches in the US infrastructure market.

1.3 Research Objectives

This study primarily aims to identify CSFs that can enhance cost and schedule performances of P3 projects completed in the US. In addition, the study seeks to conduct a comparative analysis of the cost and schedule performances between P3 projects related to highway and building sectors with DB and DBB project delivery methods. The study is guided by the following objectives:

1. Identify critical success factors impacting cost and schedule performance of P3 highway and building projects.
2. Benchmark project performances of P3 highway and building projects against DB and DBB highway and building projects, respectively.

To fulfill the research objectives, the following activities will be carried out.

1. Distribute survey questionnaires to assess the significance of CSFs among project participants involved in P3 highway and building projects.
2. Gather cost and schedule data from recently completed P3, DB, and DBB highway and building projects with similar characteristics for empirical analysis aimed at benchmarking project performances.
3. Conduct statistical comparisons to evaluate project performances across P3, DB and DBB highway and building projects.

The comprehensive research process conducted for this study are elaborated in the following chapters.

CHAPTER 2 LITERATURE REVIEW

Various literature reviews were conducted closely relevant to the study. The literature was divided into four sections that were related to i) CSF studies for P3 projects, ii) Questionnaire survey and its applications, iii) Cost and schedule performance studies, iv) Project performance comparison studies.

2.1. CSFs identification studies for P3 projects

2.1.1 CSFs studies in General Infrastructure

Different research methods like literature review, questionnaire survey, interviews and case studies were used to investigate the success factors of P3 infrastructure projects in different countries. Critical examination of the previous journal articles from 2000 to 2019 revealed that the dominant research focuses on multi-sector type of infrastructure research, and irrespective of the infrastructure sector, the study identified the factors most significant in supporting P3 project's success as appropriate risk allocation and sharing (Natalia et al., 2021). Through in-depth interviews and questionnaire surveys, (Denolf et al., 2020) explored critical factors associated with P3 projects. The top five CSFs were timely land acquisition and appropriate compensation, financial capacity of the private sector, effective project management, favorable and complete legal framework and regulations, and financial feasibility and attraction.

While lists of CFSs for P3 projects vary from study to study, through exploratory factor analysis, (Sehgal & Dubey, 2019) determined the first and most significant success factors in P3 projects as managerial competence whereas project administration ranked second in the study. (Niazi & Painting, 2018) listed possible CSFs from questionnaire surveys while identifying six factors having greatest importance in successful implementation of P3 in Afghanistan construction industry. The six main identified CSFs are: favorable legal framework, political support, transparency in the procurement process, good governance, availability of financial market and lastly appropriate risk allocation and risk sharing. For Taiwan's P3 projects, (Hsueh & Chang, 2017) identified supportive legal frameworks and a favorable investment environment as its principal critical factors. In the context of UAE, (Al-Saadi & Abdou, 2016) explored critical factors for P3 projects using in-depth interviews. The study revealed that availability and effectiveness of proper regulatory and legal framework; proper risk allocation and sharing among project stakeholders; clear project brief and client outcomes; comprehensive and business viability of project feasibility study; and proper project value management systems during different project phases were the five most CSFs for P3 projects in UAE construction industry.

(Chan et al., 2010) explored 18 CSFs for adopting P3 projects in China and grouped them into five underlying CSFs groups using factor analysis technique. The five groups were: stable macroeconomic environment; shared responsibility between public and private sectors; transparent and efficient procurement process; stable political and social environment; and judicious government control. Similar study by (Hsueh & Chang, 2017) identified supportive legal frameworks, a favorable investment environment, selection of appropriate P3 projects and public support as four principal groups of CSFs for P3 infrastructure projects in Taiwan. With the case of Nigeria, good governance, protective policy against political risks, appropriate risk allocation and risk sharing, strong private consortium, political stability and favorable legal framework top the list of the most CSFs for realizing P3 projects (Dairu & Muhammad, 2016). (Osei Kyei et al., 2017) study results showed that effective risk management; meeting output specifications; reliable and quality service operations; adherence to time; satisfying the need for public facility/service; long-term relationship and partnership; and profitability are the seven critical criteria for P3 projects in Vietnam. (Hardcastle et al., 2005) examined the relative importance of eighteen CSFs for P3 in the UK and revealed that effective procurement, project implementability, government guarantee, favorable economic conditions and available financial market are the appropriate factor groupings relevant to UK construction projects using factor analysis.

2.1.2 CSFs studies in specific infrastructure sectors

CSFs studies on P3 have been performed in a wide range of infrastructure sectors. (Alteneiji et al., 2020b) identified the most CSFs for affordable housing as political support and stability, a favorable and efficient legal framework, appropriate risk allocation and sharing, and trust and openness. Commitment and responsibility of public and private sectors and government/political support and stability were identified as important CSFs by different studies for housing/building projects (Y. Ahmed & Sipan, 2019; Denolf et al., 2020; Kavishe & Chileshe, 2019). In addition, using questionnaire survey, (Patel et al., 2017) determined top critical factors for P3 projects in India as planning and design with approvals, operational cost over-run, formation of strong partnership (contracts), quality risk, selecting the right partner, safety consideration, assistance in P3, commitment and responsibility of public and private sectors, funding and its provisions and transparent procurement. A comparative analysis of CSFs of housing sector between Malaysia and Nigeria revealed that although the concept and key principles of housing P3s are identical, the relative importance of the CSFs for Nigeria differs from that of Malaysia due to their contextual peculiarities (Muhammad & Johar, 2018).

P3 highway projects has offered an opportunity to explore new financing sources and transfer risks from owners for most state transportation agencies in the US. Successful practices like value for money analysis, performance incentives, long term partnerships and clear legislative authority has resulted in successful P3 project delivery in the United States (USDOT, 2016). (Ahmadabadi & Heravi, 2019) identified the CSFs for highway projects in Iran by literature review and interviews.

The main identified CSFs were: reliable private consortium, appropriate risk allocation, reliable contractual arrangement, operation stage- government guarantee and experience, favorable legal and political support. (Prabhudesai & Sarode, 2018) established top five CSFs for P3 for road sector development in India as sufficient financial viability, appropriate dispute resolution mechanism, favorable government policy measures, long-term low interest rate finance and suitable adjustment formula for toll revenue. In the context of P3 highway projects in Malaysia, the most prioritized critical success factors were project implementability, judiciary government control and transparent procurement process (Sadullah et al., 2018).

(Surachman et al., 2020) performed a questionnaire survey to explore critical success factors of the water P3 projects in developing countries with evidence from Indonesia and found out that most important CSF in PPP water projects is the support and acceptance of the stakeholders from the community. Studies performed for water infrastructure assets in South Africa revealed that planning for project viability, high levels of transparency and accountability and a legal framework stipulating policy continuity are the CSFs for water infrastructure projects under the P3 initiative (Dithebe et al., 2019). However, the authors identified commitment of partners, strength of consortium, asset quality and social support, political environment, and national P3 unit as the most critical success factors for water supply projects in developing countries (Ameyaw et al., 2017; Ameyaw & P.C. Chan, 2016).

The list of critical success factors for P3 highway and building projects identified from literature surveys are summarized in Table 2.1 and Table 2.2 respectively.

Table 2.1 :List of CSFs identified for highway projects.

S. No.	Critical Success factors	References					
		(Endo et al., 2021)	(Ahmadabadi & Heravi, 2019)	(Prabhudesai & Sarode, 2018)	(Sadullah et al., 2018)	(USDOT, 2016)	(Fathi & Shrestha, 2023a)
1	Appropriate Risk allocation and sharing	✓	✓		✓		✓
2	Competitive and transparent procurement processes			✓	✓		
3	Favorable and efficient legal frameworks, and	✓	✓	✓		✓	
4	A robust and reliable private consortium.		✓				
5	Government/political support and stability			✓	✓	✓	✓
6	Timely land acquisition and appropriate compensation	✓					
7	Financial feasibility and attraction			✓			
8	Meeting output specifications				✓		
9	Reliable Contractual arrangement		✓	✓			✓

10	Dedicated PPP unit					✓	✓
11	Value for money			✓		✓	
12	Coordination among related stakeholders	✓					
13	Stable macroeconomic condition		✓		✓		
14	Available finance market		✓	✓	✓		
15	Favorable social support		✓	✓			
16	Economic viability		✓	✓			
17	Strong and good partnering		✓			✓	✓
18	Appropriate dispute resolution mechanism			✓			

Table 2.2: List of CSFs for P3 Building projects.

		References						
S.No.	Critical Success factors	(Alteneiji et al., 2020a)	(Alteneiji et al., 2020b)	(Kavishe & Chileshe, 2019)	(Y. Ahmed & Sipan, 2019)	(Patel et al., 2017)	(Muhammad & Johar, 2018)	(Abdul-Aziz & Jahn Kassim, 2011)
1	Appropriate Risk allocation and sharing	✔					✔	
2	Competitive and transparent					✔	✔	✔

	procurement processes							
3	Favorable and efficient legal frameworks, and	✓	✓				✓	
4	Commitment and responsibility of the public and private sectors,		✓		✓	✓	✓	
5	Government/political support and stability	✓	✓	✓			✓	✓
6	Financial feasibility and attraction				✓			
7	Long term relationship and partnership					✓		
8	Good governance		✓		✓		✓	
9	Economic environment				✓			
10	Trust and openness	✓		✓			✓	✓
11	Planning and design with approval						✓	
12	Stable macroeconomic conditions						✓	
13	Available finance market						✓	
14	Continuous project monitoring and control						✓	
15	Social support						✓	
16	Effective communication							✓
17	Profit assurance for the private sector							✓
18	Reliable private consortium							✓
19	Demand for project							✓
20	Robust and clear agreement							✓

2.2. Questionnaire survey and its applications on CSF studies

Interviews using questionnaire surveys has remained a popular technique to obtain worthwhile information due to its reliability, structure, and flexibility(Al-Saadi & Abdou, 2016). Among different research methods including case studies, literature reviews and interviews, Questionnaire survey is the most favored research method predominantly employed in construction engineering and management studies (Helmy et al., 2020; Hong & Chan, 2014). Questionnaire survey is applied in different CSF related researches such as CSFs identification(Al-Saadi & Abdou, 2016; Hsueh & Chang, 2017; Natalia et al., 2021; Osei Kyei et al., 2017; Sehgal & Dubey, 2019), CSF analysis(Alteneiji et al., 2020a; Dang et al., 2012; Hardcastle et al., 2005; Kavishe & Chileshe, 2019; Muhammad & Johar, 2018) and CSF ranking (Cheung et al., 2012; Hwang et al., 2013; Niazi & Painting, 2018) studies.

Due to limited number of studies on the critical success factors for P3 projects in Taiwan, (Hsueh & Chang, 2017) aimed to identify and prioritize the success factors by using formal questionnaire survey which was distributed to 200 experts experienced in P3 projects. The identified twenty-six CSFs of P3 projects in Taiwan were grouped into four principal factors using factor analysis. Similar study for UAE which has biggest market for P3s in gulf cooperation council countries, (Al-Saadi & Abdou, 2016) used questionnaires to identify key success factors of P3 in UAE infrastructure projects by interviewing public and private sector P3 experts from UAE construction industry. Another study (Osei Kyei et al., 2017) evaluated 15 success criteria for P3 projects by means of questionnaire survey on targeted international experts. Kendall's concordance analysis was used to determine agreement and consensus among the expert's response in the study.

(Niazi & Painting, 2018) explored critical success factors for P3 projects in the Afghanistan construction industry using structured questionnaires to determine ratings of the factors which have a significant contribution to success of P3 projects. In addition, study by (Cheung et al., 2012) used questionnaire survey to compare P3 CSFs between three countries, Hongkong, Australia and the United Kingdom.

2.3. CSF ranking studies

CSFs are the vital aspects that can help improve the effectiveness and success of any project (Badraddin et al., 2022). A study performed by (Kineber et al., 2022) identified the important factors for implementing value management (VM) through Relative Importance Index (RII) analysis and evaluated the most critical success factors for value management implementation in building projects. The study pointed out the level of importance for each identified success factor groups and ranked them according to their significance. RII analysis technique have also been applied to determine the significance of CSFs for construction project success (Badraddin et al., 2022). In this study, the authors ranked seven CSFs from factors identified from industry professionals in Jordan and ranked them based on their arithmetic mean scores. To identify critical success factors for construction projects in Lithuania, (Gudiene et al., 2014) used RII analysis and revealed highest ranking CSFs based on their mean values. In addition, using RII, studies have been able to explore CSFs in implementing knowledge management (KM)in consulting firms for construction industry (Othman et al., 2018). The authors focused on highlighting the CSFs leading the successful implementation of KM practice among consulting firms in Malaysia.

Attempts have been made to identify the relevance of critical success factors for diverse sectors in the construction industry. (Ghanbaripour et al., 2020) ranked critical success factors for subway construction projects based on the views of contractor's project managers in Iran. The study found a total of 39 success factors which were ranked based on their mean ratings. Similar study conducted by (Yang et al., 2010) analyzed the construction practitioner's perspective on relative importance of CSFs for stakeholder in Hongkong construction projects. The authors ranked the CSFs on the basis of their mean values and found 15 CSFs that can be regarded as critical for success of stakeholder management in construction projects. Studies have been able to shed light on critical success factors that are relevant to concrete waste recycling in construction projects. (Badraddin et al., 2022)conducted questionnaire survey to identify CSFs for concrete recycling from construction industry professionals and analyzed the responses using mean score ranking and normalization techniques. The authors were successful in exploring ten critical success factors in the study.

Using mean score technique, (Wuni & Shen, 2022) identified twenty-one significant success factors for implementing modular construction projects in Hong Kong. In this study, early design completion and freezing constituted the most significant CSF with the highest mean score of 4.31. (Shokri-Ghasabeh & Chileshe, 2016)conducted questionnaire survey and ranking analysis based on which highly ranked four factors were identified in the study to investigate and rank the critical factors influencing the bid/no bid decision making criteria in Australian construction projects.

Building information modelling (BIM) has been an emerging approach to improve productivity and quality in the construction industry. To develop a conceptual framework on BIM technology adoption and assess it in the context of architecture, engineering and construction industry

(Tsai et al., 2014) investigated 80 key factors, out of which, three factors were found to be most important based on their mean scores. The reviewed literature is presented in Table 2.3.

Table 2.3:Review of literatures related to ranking of CSFs

S. No.	Journal Article	Authors	Statistical method /analysis used	Findings
1	Identification and Evaluation of Success Criteria and Critical Success Factors in Project Success	Athanasios Lamprou, Dimitra G. Vagiona	RII analysis, Spearman correlation	Most important CSFs are identified. ranking of the SC and CSFs
2	Modelling the relationship between value management's activities and critical success factors for sustainable buildings	Ahmed Farouk Kineber and Idris Bin Othman,Ayodeji Emmanuel Oke,Nicholas Chileshe	Structural equation modelling, relative importance ranking analysis	Relationship between VM implementation activities and its CSFs
3	Critical Success Factors for Concrete Recycling in Construction Projects	Abdulmalek K. Badraddin , Afiqah R. Radzi , Saud Almutairi , and Rahimi A. Rahman	Mean score ranking, factor analysis techniques	Ten critical success factors for concrete recycling
4	Developing critical success factors for integrating circular economy into modular construction projects in Hong Kong	Ibrahim Yahaya Wuni, Geoffrey Qiping Shen	Mean score ranking, factor analysis, fuzzy synthetic evaluation	Top five significant success factors that significantly influence the success of circular modular construction
5	Critical success factors for subway construction projects – main contractors' perspectives	Amir Naser Ghanbaripour, Willy Sher & Ariyan Yousefi	Cronbach alpha,mean value ranking	Identified and ranked the CSFs for subway construction projects according to their importance
6	Ranking the Factors that Influence the Construction Project Success: the Jordanian Perspective	Ghanim A. Bakr	RII analysis, Cronbach alpha, and ranking by mean scores	Most important factors for success for various success criteria presented

7	Critical success factors in implementing knowledge management in consultant firms for Malaysian construction industry	Azlan Othmana, Syuhaida Ismailb, Khairulzan Yahyaa, Mohd. Hafis Ahmada	Cronbach alpha, RII analysis	Identified top five factors vital to effective execution of KM
8	Critical factors influencing the bid/no bid decision in the Australian construction industry	Morteza Shokri-Ghasabeh,Nicholas Chileshe	Cronbach alpha, spearman rank correlation, RII analysis	Ranking of the 26bid/no bid criteria factors
9	Developing critical success factors for the assessment of BIM technology adoption: part I. Methodology and survey	Meng-Han Tsai, Mony Mom & Shang-Hsien Hsieh	Cronbach alpha, Mean score ranking	Ranking analysis was employed to obtain 80 key factors (KFs) out of the 123 IFs
10	Identification and evaluation of the critical success factors for construction projects in Lithuania: AHP approach	Neringa Gudiene, Audrius Banaitis, Valentinas Podvezko and Nerija Banaitiene	RII analysis	Top ranking CSFs
11	Critical Success Factors for Stakeholder Management: Construction Practitioners' Perspectives	Jing Yang1; Geoffrey Qiping Shen; Derek S. Drew; and Manfong Ho	Mean score ranking	All 15 selected CSFs are regarded as critical by most respondents

After reviewing the literatures, it becomes evident that a significant portion of studies have used Relative Importance Index (RII)/ mean score analysis to prioritize CSFs across diverse research objectives. Given its prevalence and appropriateness, Relative Importance Index (RII) has been selected as a suitable analytical method to rank the CSFs for P3 highway and building projects in this study.

2.4. Project Performance comparison studies

Project performance comparison studies between P3s and traditional project deliveries have been carried out in experienced markets in P3 project delivery like Europe (Blanc-Brude et al., 2006) and Canada (J. Zhang et al., 2020). However, this kind of comparison study are lacking in North American P3 market (Chasey et al., 2012). Based on analysis of 200 European Investment Bank (EIB) financed road projects, (Blanc-Brude et al., 2006) found out that the unit construction cost of road to the public sector is 24% higher when constructed using P3 project delivery than in traditional project deliveries. The study concluded that the high-cost estimates originate from the transfer of construction risk which corresponds to cost overruns in traditionally procured road projects.

A Canadian study conducted for 39 traditional projects and 27 P3 projects showed that traditional projects experienced cost overruns of 28.8% than compared to P3 projects overruns of 1.22% (J. Zhang et al., 2020). Similar findings were found for schedule performance with an average delay of 4months for traditional projects while P3 projects were completed in time. For 12 completed P3 highway projects in North America, (Chasey et al., 2012) found out that P3 projects cost overruns averaged 0.81% compared with 1.49% overruns for design-build projects and 12.71% overruns for design-bid-build projects. In addition, schedule overruns for P3 highway projects averaged -0.30% compared with 11.04% schedule overruns for design-build projects and 4.34% overruns for design- bid-build projects.

(Ramsey & El Asmar, 2015) analyzed 25 completed P3 projects implemented in the United States to quantify their cost and schedule performances against traditional project deliveries. The study concluded the cost overruns for P3 projects averaging to 3.22% and schedule overruns averaging to -2.97% compared to DBB cost growth of 3.6% to 25% and schedule growth ranging from 4.34%

to 33.5%. P3 projects were completed 3.4% ahead of time than traditional projects which were completed 23.5% behind time which demonstrated superior schedule performance compared to traditional projects in Australia (Raisbeck et al., 2010).

Some studies have been performed showing the benefits of DB projects over DBB projects. (P. P. Shrestha & Fernane, 2017) conducted a research study for 38 DB and 39 DBB public university projects to find out cost and schedule performance of the projects. The cost growth for DB projects was found to be 3.8% against 7.4% for DBB projects. For DB and DBB projects, schedule growth was found to be -5.3% and 30.1% respectively. Study performed by (Molenaar & Franz, 2018) emphasized on the better project performance of DB projects with evidence showing that DB projects were delivered faster and with lower cost and schedule growth compared to DBB projects.

FHWA published a report in 2006 on effectiveness of design-build project delivery system which concluded that design-build projects had cost growth of 7.4% and schedule growth of -4.2% whereas design-bid-build projects experienced cost growth of 3.6% and schedule growth of 4.8%. Similar results were derived from study performed by (Gransberg et al., 2000) for DB and DBB projects concluding high-cost growth for DB projects compared to DBB projects. The results showed that DB projects experienced cost and schedule overruns of 4.20% and 3.99%. However, DBB projects showed cost overruns of 3.93% and schedule overruns of 28.25%.(P. P. Shrestha et al., 2012) performed statistical analysis on 16 DBB and 6 DB large highway project samples and found that mean cost growth for DB projects was 7.8% against 6.3% for DBB projects. The schedule growth for DB projects was 20.5% against 5.1% for DBB projects. It has to be noted that for DB and DBB projects change orders influence both cost and schedule efficiency of U.S. transportation projects, regardless of their scale or size (Shrestha et al., 2022a; Shrestha et al., 2022b; Shrestha & Shrestha, 2022). Government agencies and related stakeholders in the United

States have aimed to reduce the potential risks associated with projects using various project delivery methods (Brogan et al., 2022).

Previous literature related to comparative studies on cost and schedule performances conducted for different project deliveries are summarized in Table 2.4.

Table 2.4. Cost and schedule performance studies

References	Projects Considered	Project Types	Major findings	
			Cost Growth	**Schedule Growth**
(Fathi & Shrestha, 2022a)	25 DB	Transportation projects	-0.04%	No difference
	22 P3		2.84%	
(Blanc-Brude et al., 2006)	P3 vs DBB	Road projects	Unit construction cost for P3 road projects is 24% higher	
(J. Zhang et al., 2020)	P3	Mixed projects	1.22%	P3 projects were completed in time
	DBB		28.8%	average delay of 4months
(Chasey et al., 2012)	P3	Highway	0.81%	0.30%

References	Projects Considered	Project Types	Major findings	
			Cost Growth	Schedule Growth
	DB		1.49%	11.04%
	DBB		12.71%	4.34%
(Ramsey & El Asmar, 2015)	P3	Mixed projects	3.22%	1.2%
	DBB		3.6% to 25%	4.34% to 33.5%
(P. P. Shrestha & Fernane, 2017)	38 DB	Public university buildings	3.8%	-5.3%
	39 DBB		7.4%	30.1%
(FHWA, 2006)	11DB	Highway projects	7.4%	-4.2%
	11DBB		3.6%	+4.8%
(Gransberg et al., 2000)	DB	Highway projects	4.20%	3.99%
	DBB		3.93%	28.25%
(Shrestha et al., 2012	16 DBB	Highway projects	7.8%	20.5%
	6DB		6.3%	5.1%

2.4. Relationship between CSFs and project performance

Both CSFs and success criteria are important in achieving success for P3 projects implementation. Studies have been able to analyze relationships among CSFs of P3 projects with a purpose of improving P3 project performances and eventually contribute to sustainability and success of a P3 project (Chen et al., 2012; Shi et al., 2016).Some studies have characterized CSFs as independent variables necessary for project success whereas success criteria are the metrics used to evaluate project performances (Osei Kyei et al., 2017). A study conducted by (M. Ahmed & Garvin, 2022) identified the critical success factors and performance indicators for P3 transportation projects to evaluate P3 performance and found that CSFs reflect the effect of particular factors on P3 outcomes and they generally contribute towards the P3 success or performance.

(Ahmad et al., 2021) examined the relationship between the CSF categories and project success of P3 projects by using structural equation model and concluded that success factors such as commitment among the partners, strong private consortium, competitive and transparent procurement process, appropriate risk allocation and sharing, macroeconomic factors and clearly defined roles and responsibilities have significantly strong positive effect on P3 project success. Furthermore, during the construction period of P3 projects, private sector capability has a direct effect on project success whereas during the project operation stage, government capability is very effective on project success (Ahmadabadi & Heravi, 2019).

2.5. Summary of Literature Review and Gaps

The literature review revealed that the majority of studies have investigated the CSFs influencing P3 on both developed and developing countries. While a significant number of studies have concentrated on investigating CSFs have mainly centered on the infrastructure sector as a whole with studies focusing on general P3 projects (Ahmadabadi & Heravi, 2019; Cheung et al., 2012;

Chinomona et al., 2018; Dairu & Muhammad, 2016; Denolf et al., 2020; Hsueh & Chang, 2017; X. Zhang, 2005), there has been relatively few studies conducted that specifically focus on particular sectors such as highways and buildings.

Despite the growing global trend in P3s implementation for social and economic infrastructure, it is essential to recognize that the analysis of success factors in the building sectors remains limited (Alteneiji et al., 2020b). The existing body of research does not comprehensively cover the unique dynamics and challenges specific to the building sector in the context of P3 implementation in the United States. This rationale serves to emphasize on government investment priorities by shedding light on areas where P3 is more likely to achieve success, aligning with most important policies (World Bank, 2017). This highlights the need for further exploration and eventually this study attempts to fill this gap in the existing literature by delving into the success factors influencing P3 projects in two specific infrastructure sectors.

Emerging project delivery systems such as P3 with innovative methodologies, have been developed in recent years. These fresh approaches have potential to influence the performance of P3 projects in comparison to design-build and traditional project delivery systems. Despite several studies on P3, there are still gaps in identifying the essential critical success factors specific to P3 projects in the US (Fathi & Shrestha, 2023b). A comprehensive examination aimed at identifying CSFs for specific infrastructure project types like highway and building in the United States is limited. The success factors for P3 projects have been identified from past studies, however, they are mostly focused on developing countries and the European P3 market. Additionally, the contribution of various factors to project objectives, such as achieving cost and schedule efficiency, varies contextually in real projects (Chua et al., 1999). The contextual variability emphasizes the need for investigating a distinct list of CSFs to enhance project performance based on the types of projects. Therefore, it is essential to develop a new set of success factors based on the performances of P3 highway and building projects in the United States to address this limitation.

Moreover, while many comparative studies have scrutinized project performance in the United States between Design-Build (DB) and Design-Bid-Build (DBB) project delivery methods, there is a scarcity of research comparing the project performances between DB and traditional projects, including Public-Private Partnership (P3) projects in the US market (Fathi & Shrestha, 2022b). Furthermore, there is a notable absence of project performance comparisons specifically focusing on P3, DB, and DBB building projects in the United States. This study aims to address and fill these research gaps in this field.

CHAPTER 3 METHODOLOGY

The overview of methodology adopted for this study is presented in Figure 3.1.

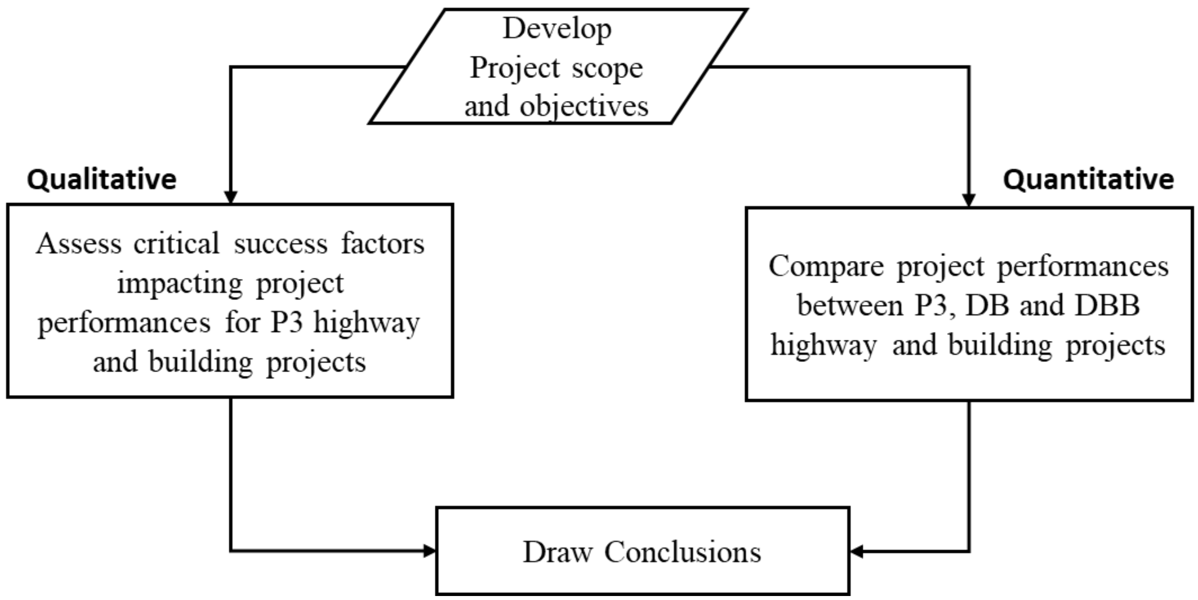

Figure 3.1: Overview of Methodology

Two major scopes have been developed in this study with an aim to assess the CSFs impacting cost and schedule performances of P3 highway and building projects as well as to compare the project performances of P3 projects with DB and DBB highway and building projects. Both Qualitative and Quantitative research methods have been used in the study to achieve the research objectives. The detailed methodology for the study is shown in Figure 3.2.

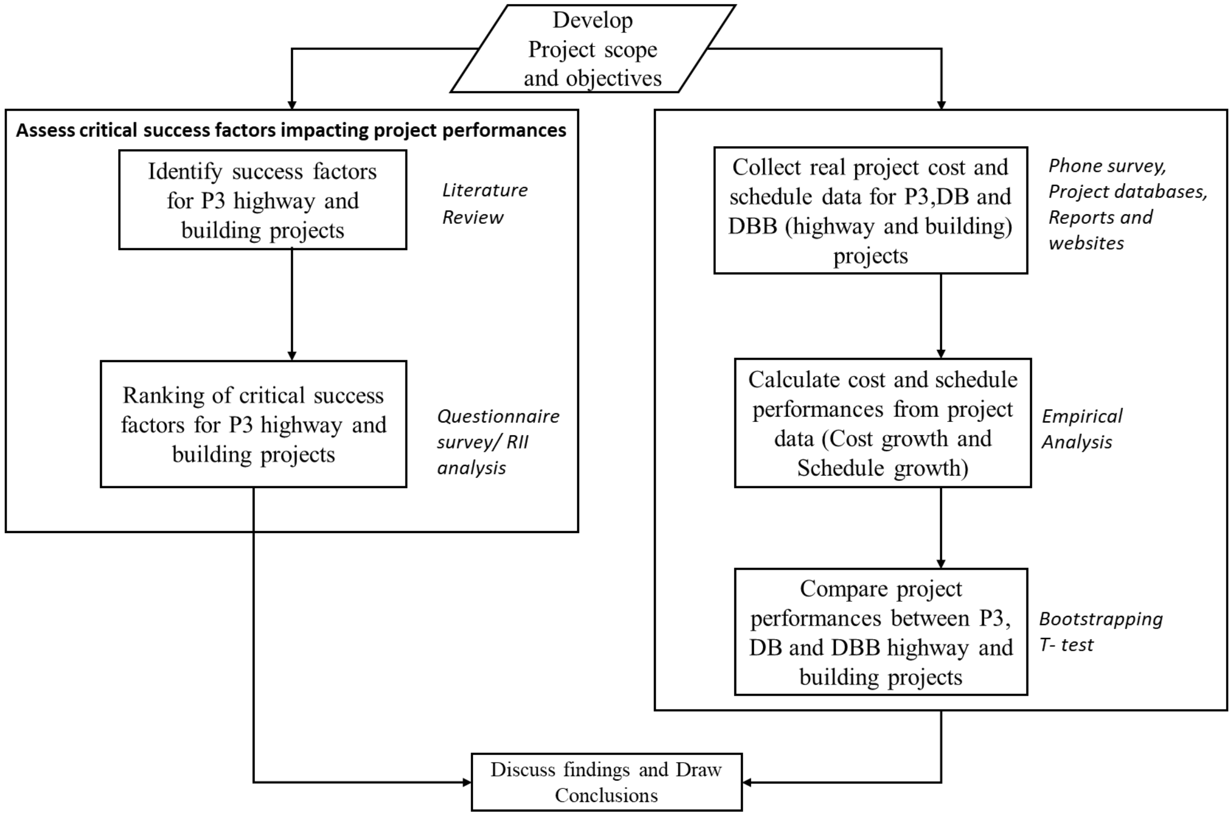

Figure 3.2:Breakdown of Methodology

Scope I: CSFs Ranking

The study initiated with an in-depth review of several literatures related to CSFs of P3 projects based on which a list of CSFs was identified for P3 highway projects and P3 building projects individually. After the literature review, separate questionnaires for P3 highway and P3 building projects were developed to get perspectives of P3 industry personnel on P3 success factors. The questionnaires were developed specifically for project personnel involved in P3 highway and building construction projects implemented in the US to rank the identified CSFs obtained from literature reviews based on their P3 experience.

Scope II: Project performance comparison

The study aims to benchmark the P3 project performance against DB and DBB highway and building projects. In order to achieve this objective, the cost and schedule data of P3, DB, and DBB highway and building projects was collected for the purpose of performance comparison. The cost and schedule performance metrics were calculated using empirical formulas for cost growth and schedule growth and are presented in percentages (%). The project performances for P3, DB and DBB highway and building projects were compared using bootstrapping t- test.

Scope I – CSFs Ranking

3.1 Data Collection

3.1.1 Data from literature review

Reviewing the literature showed that the majority of studies have been published related to CSFs for P3 in infrastructure sector whereas few studies have identified CSFs for P3 in specific sectors of infrastructure built in the US. The study emphasizes on two specific sectors of infrastructure i.e. "Highway" and "Building" which are listed under the focus areas in P3 project delivery (World Bank, 2021). A methodical analysis was conducted with reference to prior studies and research published in academic journals. The findings of other researchers regarding the CSFs identification for P3 projects in two different sectors will be collected and grouped.

After an in-depth literature review, a list of critical success factors for P3 highway and building projects were extracted from previous related studies. The differing names or descriptions of the CSFs identified were merged to facilitate the grouping of factors. Based on the literature review, a total of 18 critical factors were identified for P3 highway projects whereas a total of 20 critical factors were identified for P3 building projects. In addition, to review the sufficiency and appropriateness of the identified CSFs in the context of U.S construction industry which was as per the recommendation from dissertation committee during proposal defense, few P3 experts were contacted to check whether there are any CSFs applicable to P3 highway and building projects implemented in the United States that has been missing in the literature reviews. With the help of the P3 industry experts, two more CSFs were identified for P3 building projects whereas three CSFs were added in the P3 highway projects CSF list. The following CSFs were added to the P3 building project's CSF list:

1. Reasonable contract mechanisms to deal with unexpected events
2. Clear process around permitting

Similarly, the three CSFs that were added in the P3 highway projects CSF list are:

1. Clear contract clauses
2. Proper guidelines regarding p3 delivery
3. Experience of owners in p3 projects

3.1.2 Data from questionnaire survey

A questionnaire survey has been conducted to determine the success factors which are critical to P3 highway and building projects that have been implemented in the United States. The primary purpose of the questionnaire was to gather data concerning the importance of critical success factors that were relevant in the implementation of P3 highway and building projects. To create the interview questionnaire, the researchers referenced various literature sources as a basis for comparison and development. The questionnaire survey was adopted in this study as this approach allows respondents to take their time to reflect on their answers without any influence from the researcher, thus reducing potential biases and leading to a more objective outcome (Johnston & Faulkner, 2021).Therefore, a questionnaire survey was a best option to achieve the objectives of the study which requires statistical analysis.

As Likert scale has been widely adopted in questionnaires for identifying CSFs for PPP Projects (Hsueh & Chang, 2017),respondents were asked to assess the significance of success factors which helped to achieve cost and schedule efficiency in their projects in according to five-point Likert scale from 1 = “Not Significant” to 5 = “Highly Significant”. They were requested to rank the success factors as per their significance in achieving cost and schedule efficiency. Furthermore, project cost and schedule information were collected through a questionnaire to fill in the missing data which were not available during initial data collection. The data obtained from the questionnaire survey were analyzed using the Statistical Package for the Social Sciences (SPSS 29.0).

3.2 General information on survey respondents

The researcher first collected list of highways and building projects that were constructed in the United States using P3 project delivery using public websites and the research reports available online. The researcher intended to find the target participants involved in projects which were implemented using P3 project delivery. The questionnaires were sent to project personnel (Project Manager, Engineer, Contractors, Consultants) involved in the real P3 highway and building projects as provided in Appendix A and B. For each project, the people who perform the project functions will be different depending on the contract type, the phase of the project, local regulations and so on. Therefore, the same set of questions was also directed to more than one person in each project.

Two separate questionnaires were developed for distribution, one for P3 highway projects (Appendix G) and another for P3 building projects (Appendix H). The interview questionnaire comprised three sections aimed at gathering information from highway and building P3 projects. Section 1 is comprised of information of project characteristics. Section 2 focused on inquiries related to the importance of critical success factors and project performances. Specifically, this section contains questions that delve into the significance of these factors identified from literature review. Section 3 aimed to collect information on project cost and schedule performances in which these survey participants were involved. The questionnaire has been structured to collect information separately from participants who have experienced more than one P3 project.

The participants forming the research population were chosen through a non-random sampling approach primarily using Purposive sampling and snowball sampling method. Non-random sampling was opted for due to two main reasons: 1) Limited number of implemented P3 projects in the United States posed challenges for data collection and 2) The scarcity of subject matter experts involved in P3 projects construction. The researcher sought assistance and guidance from Association for the Improvement of American Infrastructure (AIAI) Infra to identify subject matter experts. Additionally, the researcher contacted P3 experts from P3 conference and Expo that was held from March 6-8,2023 at Dallas, Texas to find adequate respondents. The researcher made substantial efforts to ensure a comprehensive pool of respondents. The majority of the respondents received the survey through a Qualtrics link, while others were provided with a paper copy of the questionnaire for completion.

Before starting the survey process, it was ensured that the candidates met the minimum qualifications necessary to be deemed eligible for participation in this study. The outlined criteria for this research required the candidates to possess a minimum of five years of experience in P3 projects. Additionally, candidates were expected to have active engagement in a P3 project that is relevant to the study.

The survey questionnaire was distributed using two channels: in-person and email distribution. This outreach initiative extended from January 2023 to June 2023. Initially, emails were sent to potential project participants introducing the research's purpose and significance and inviting their voluntary participation. In these emails, the researcher assured participants of the confidentiality of sensitive information, emphasizing that no data would be disclosed publicly without their consent. To expedite the process, friendly reminders were sent every three weeks and follow-up calls were made if deemed necessary. Following multiple reminder emails and follow-up calls, 14 participants responded to the survey. These responses yielded information for 17 projects out of the 24 P3 building projects collected resulting in a response rate of 70%. There were multiple respondents who provided data for three P3 building projects in California and Indiana.

The researcher invested significant efforts in engaging more professionals from state DOTs and transportation agencies, however, some emails and calls went unanswered. Ultimately, sixteen individuals responded to the highway survey questionnaire generating a total of 20 responses by June 2023. These responses provided information for 14 projects out of 31 P3 highway projects collected resulting in a response rate of 45%. The details can be found in Table 3.1 and Table 3.2.

Table 3.1:Building questionnaire responses.

States	No. of projects	No. of participants
California	8	7
Maryland	1	1
Nevada	1	1
Texas	3	2
Kansas	1	1
Arizona	1	1
Indiana	2	1
Total	17	14

Table 3.2:Highway questionnaire responses

States	No. of projects	No. of participants
California	3	3
Virginia	3	4
Florida	3	4
Ohio	1	1
Indiana	1	1
Pennsylvania	1	1
Georgia	1	1
Colorado	1	1
Total	14	16

Figure3.3 and Figure 3.4 illustrate the distribution of survey questionnaire participants based on their roles in the P3 projects that they have been involved in. According to their responses, the survey participants are experienced industry professionals occupying roles such as project manager, project director, project finance manager, CEO, bid director and construction manager. Most of the highway project responses were collected from state DOTs including those of Texas, California, Florida, and Virginia. These state DOTs played a significant role in providing information related to CSFs of P3 highway projects. However, for the P3 building project questionnaire, the responses were collected predominantly from representatives working within the private sector.

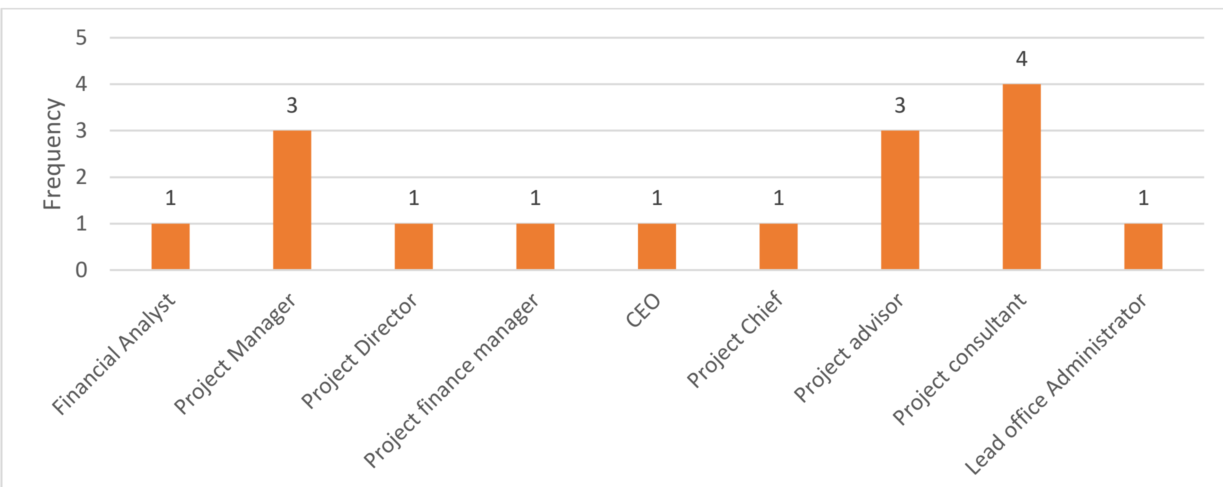

Figure 3.3: Role of participants in P3 highway projects.

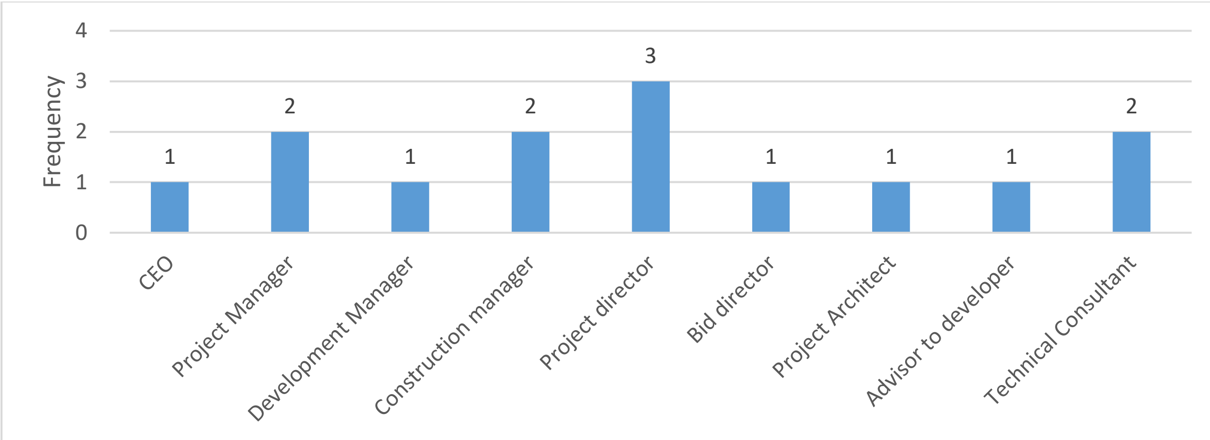

Figure 3.4: Role of participants in P3 building projects.

Figure3.5 and Figure 3.6 presents and analysis of participant's years of in the P3 projects they have been engaged with. The data shows that the majority of participants have experience exceeding 10 years working in P3 projects which emphasizes their extensive knowledge and depth of expertise in the overall understanding of P3 project dynamics.

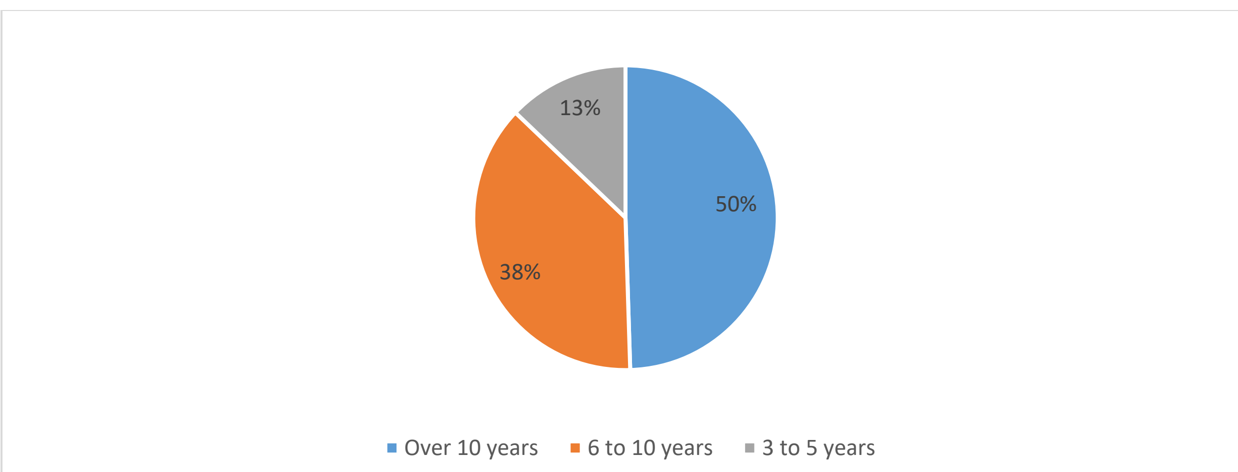

Figure 3.5:Years of experience of participants in P3 highway projects.

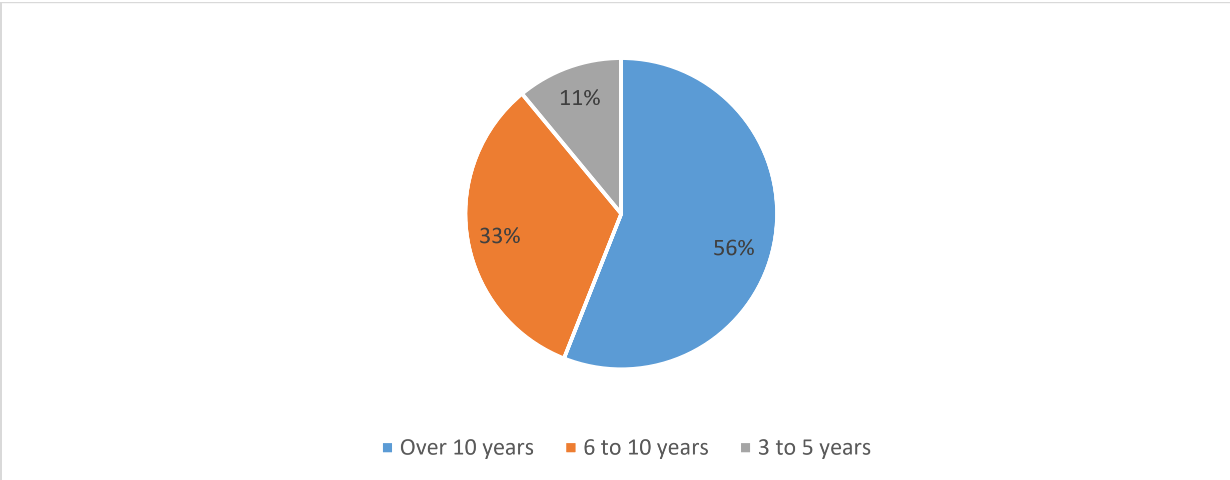

Figure 3.6:Years of experience of participants in P3 building projects.

Upon gathering the viewpoints of the respondents, it is necessary to assess whether their responses align or exhibit convergence. It may be deemed necessary to provide individuals with another opportunity to refine or adjust their responses through another round of data collection if any discrepancies or divergences persist. The agreement test process ensures a thorough exploration of perspectives and enhances the accuracy and coherence of the collected data.

3.3 Inter-Rate Reliability Agreement Test for CSF ratings

Inter-rater reliability agreement test is a type of reliability analysis used to test the level of agreement between different raters. This test will be conducted for evaluation of different ratings provided by the respondents for critical success factors of P3 highway and building projects. For evaluation of continuous measurements like Likert scale, a reliability statistic, intra-class correlation coefficient (ICC) is used to assess agreement which takes account into systematic bias in measurements that reduce reliability (Harvey, 2021). It is shown that low ICC may indicate low rater agreement whereas high ICC indicates high rater agreement.

(Cicchetti, 1994) states four common categories for intra-class correlation coefficient (ICC) values. It states that when the ICC value is below 0.40, the level of significance is poor, when ICC is between 0.40 to 0.59, the level of significance is fair, when the values are between 0.60 to 0.74, the level of significance is good and when the values are between 0.75 to 1.00, the level of significance is excellent. ICC can be calculated using following equation (Liljequist et al., 2019),

$$\text{ICC} = \frac{\text{variance of different ratings among the subjects in the population P}}{\text{total variation}}$$

3.4 <u>Relative Importance Index (RII) Test</u>

Relative importance index (RII) analysis has been used in different construction research to prioritize the significant factors by determining the level of significance of each factor (Sakhare & Patil, 2020). Relative Importance Index (RII) is one of the widely used technique used to identify and rank the critical success factors for different construction sectors (Kineber et al., 2022) . Therefore, in this study, Relative Importance Index (RII) has been selected as a suitable analytical method to rank the CSFs for P3 highway and building projects. In this study, RII will be used as a basis of analysis to determine ranking of the critical success factors according to their relative significance. RII is employed to rank criticality for each of the success factors that affect performance of P3 highway and building projects. The following five-point Likert scale of 1 to 5 is adopted for RII analysis.

1 = Not Significant

2= Less Significant

3= Neutral

4= Significant

5= Highly Significant

RII will be applied for each critical success factor using Equation as below.

$$RII = \frac{\sum W}{A \times N}$$

Where,

W: Weight given to each factor by the respondents and ranges from 1 to 5 (where 1 is Not Significant and 5 is Highly Significant)

A: Highest weight (i.e.5)

N: Total Number of Respondents

The RII value ranges from 0 to 1. It shows that the higher the value of RII, more important is the critical factor and vice versa.

Scope II- Project performance comparison

3.5 Data Collection

3.5.1 Data Collection from construction projects

Construction cost and schedule information for construction projects completed under three project deliveries (P3, DB and DBB) were collected for data analysis. This information related to the cost and schedule of any construction project is required to evaluate its performance in terms of completing the project within the proposed time and projected cost. Table 3.3 represents the states, completion size and completion year for the collected data information for highway and building projects under three project deliveries.

Table 3.3: Information on data collected.

Project Type	Project delivery	Number of projects	States	Project size	Completion year
Highway projects	P3	31	Texas, California, Florida	Greater than 100 million	2007-2020
	DB	40	Florida, Arizona, Maryland, Texas	Greater than 25 million	2009-2020
	DBB	50	Texas, Florida	Greater than 25 million	Texas- 2016-2020; Florida- 2018-2021
Building projects	P3	24	Texas, California, Florida, Virginia	Greater than 25 million	2012-2020
	DB	48	California, Texas	Greater than 25 million	2015-2020
	DBB	31	Texas, Florida, California	Greater than 25 million	2012-2018

3.5.2 P3 Projects

Information related to P3 highway and building projects including project location (state), type of agreement, construction completion year, estimated project cost, final completion project cost, estimated duration, and final duration for project completion were collected from various state DOTs, published reports and web databases. New data on P3 highway projects was incorporated alongside existing information gathered from prior research conducted by (Fathi & Shrestha, 2022c). The highway project data was collected for project size greater than 25 million and most of these projects were completed in the states of Texas, California, Florida, and Virginia whose data were collected from their corresponding states DOTs. However, for the P3 building projects, whose data are collected, were mostly provided by the public agencies.

Appendix A and B shows the list of completed P3 highway and building projects considered for the study.

3.5.3 DB and DBB Projects

DB and DBB projects data were collected to compare the project performances against P3 projects. Data related to general project information and information related to cost and schedule like Estimated duration, Actual duration, Contracted project cost, Estimated cost and Actual project cost were collected both for building and highway projects and for project size greater than 25 million. The majority of these projects were completed in states Texas, California and Florida. The project data collected for DB projects can be found in Appendix C and Appendix D. In Appendix E and Appendix F, the project data collected for DBB projects has been presented.

3.6 Project performance Analysis

3.6.1 Empirical analysis for project performances

The objective of the empirical analysis is to examine whether and by how much construction cost and schedule differs between P3s, DB and DBB project deliveries. For this purpose, metrics related to project cost and schedule were developed to compute project performances of different delivery methods considered in the study. For the performance comparison purpose of P3 projects with DB and DBB highway and building projects, the cost and schedule metrics will be used.

The cost performance metric is used to measure cost growth whereas schedule performance metric is used to measure schedule growth. To determine the project cost metrics of P3 and DBB projects, data was collected on the estimated completion (design and construction) cost and the actual completion cost of the projects under study whereas to determine the project schedule growth, estimated completion (design and construction) duration and the actual completion duration data was collected. The empirical formula to calculate these metrics is provided in Table 3.4.

Table 3.4. Project performance metrics for Cost and Schedule

No.	Metric	Equation to calculate the metric	Unit
1	Total Cost Growth	$\frac{\text{Total completion cost} - \text{Estimated cost}}{\text{Estimated cost}} \times 100$	%
2	Total Schedule Growth	$\frac{\text{Total completion duration} - \text{Estimated duration}}{\text{Estimated duration}} \times 100$	%

3.6.2 Research Hypothesis

The research hypothesis formulated for this study are outlined as follows:

Research Hypothesis 1: This hypothesis suggests that highway projects constructed using the P3 project delivery method will perform better in terms of both cost and schedule when compared to highway projects executed using DB approach.

Research Hypothesis 2: This hypothesis proposes that highway projects constructed using P3 project delivery are anticipated to have fewer cost overruns and schedule delays compared to DBB highway projects.

Research Hypothesis 3: This hypothesis suggests that highway projects constructed using DB project delivery will exhibit better cost and schedule performance when compared to highway projects executed using DBB approach.

These hypotheses are formulated with an aim to determine whether there are statistically significant differences in the cost and schedule performances between highway projects constructed using different project delivery methods: P3, DB and DBB.

Accordingly, null hypotheses were formulated based on the research hypotheses to conduct statistical tests. The following section outlines the null hypotheses corresponding to these research hypotheses:

Null Hypothesis 1.1: There are no significant differences in cost growth between highway projects constructed using P3 and DB project delivery. In mathematical terms, it can be expressed as:

$$\mu_{cost\ growth}\ (\text{P3 highway projects}) = \mu_{cost\ growth}\ (DB \text{highway}\ projects) = \ldots\ldots\ldots\ldots$$

Null Hypothesis 1.2: There are no significant differences in schedule growth between highway projects constructed using P3 and DB project delivery. In mathematical terms, it can be expressed as:

$$\mu_{schedule\ growth}\ (\text{P3 highway projects}) = \mu_{schedule\ growth}\ (DB\ \text{highway}\ projects) = \ldots\ldots\ldots\ldots$$

Null Hypothesis 2.1: There are no significant differences in cost growth between highway projects constructed using P3 and DBB project delivery. In mathematical terms, it can be expressed as:

$$\mu_{cost\ growth}\ (\text{P3 highway projects}) = \mu_{cost\ growth}\ (DBB\ \text{highway}\ projects) = \ldots\ldots\ldots\ldots$$

Null Hypothesis 2.2: There are no significant differences in schedule growth between highway projects constructed using P3 and DBB project delivery. In mathematical terms, it can be expressed as:

$$\mu_{schedule\ growth}\text{ (P3 highway projects)} = \mu_{schedule\ growth}\ (DBB\text{ highway } projects) = \text{.................................}$$

Null Hypothesis 3.1: There are no significant differences in cost growth between highway projects constructed using DB and DBB project delivery. In mathematical terms, it can be expressed as:

$$\mu_{cost\ growth}\text{ (DB highway projects)} = \mu_{cost\ growth}\ (DBB\text{ highway } projects) = \text{.................................}$$

Null Hypothesis 3.2: There are no significant differences in schedule growth between highway projects constructed using DB and DBB project delivery. In mathematical terms, it can be expressed as:

$$\mu_{schedule\ growth}\text{ (DB highway projects)} = \mu_{schedule\ growth}\ (DBB\text{ highway } projects) = \text{.................................}$$

3.6.3 Bootstrapping T -test

Bootstrapping methods have a long history of application in various types of research like construction research, medical research, and clinical trials. Bootstrapping is a statistical technique which involves resampling of a single dataset to create numerous simulated samples. This resampling technique is particularly useful in situations where the assumptions of traditional parametric tests are not met, such as when data is not normally distributed (Efron & Toshigami, 1994). When data deviate from normality assumption, bootstrapping t-test can be applied to compare the significant differences between the data groups.

The primary goal of bootstrapping is to generate a t-statistic distribution by repeatedly resampling the data under consideration allowing for replacement. Recent research as demonstrated by Zhao et al. (2021) has shown that the bootstrap t-test outperforms the traditional t-test in terms of different measures of the testing accuracy. This technique enables the calculation of the sampling distribution of the t-test statistic, even in cases when the data's distribution deviates from normality (Konietschke & Pauly, 2014; Zhao et al., 2021).

The results of bootstrapped t-test can offer understanding into whether there are statistically significant differences in performance between the groups and takes account for the distributional characteristics of the data and the limitations posed by the sample size (Nankervis & Savin, 1996).

The general bootstrapping process is presented in Figure 3.7.

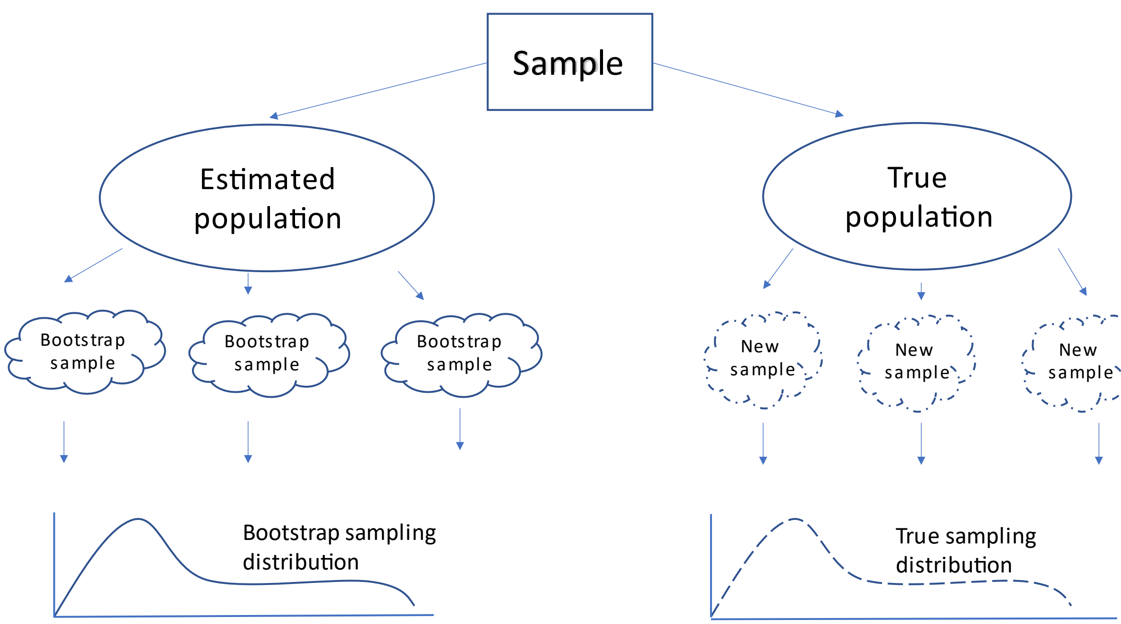

Figure 3.7: General bootstrapping process

When data deviates from normality assumption, non-parametric tests are used for data analysis, most common being the Mann-Whitney test(Johnston & Faulkner, 2021). Mann-Whitney U test is a non-parametric test, specifically used to compare the central tendencies of two independent groups. However, in this study, the goal was to compare means across the datasets while taking account the full dataset’s characteristics. Therefore, bootstrapping t-test was considered more appropriate for this study. Unlike traditional t-tests, which assume equal variances, the bootstrapping test does not adhere to the assumption of equal variances and does not necessitate an assessment of whether the variances of the considered groups of projects are statistically similar (Walters & Campbell, 2004). By using bootstrapping t-test this study aims to provide insights into the cost and schedule performance differences among projects executed under different delivery methods despite the non-normality of data and the limited sample sizes.

In this study, a bootstrapping t-test was employed to examine whether there exists a significant difference in cost and schedule growth for projects executed under P3, DB and DBB project delivery. This resampling technique is particularly useful in situations where the assumptions of traditional parametric tests are not met, such as when data is not normally distributed (Efron & Toshigami, 1994). When data deviate from normality assumption, bootstrapping t-test can be applied to compare the significant differences between the data groups.

The primary goal of bootstrapping is to generate a t-statistic distribution by repeatedly resampling the data under consideration allowing for replacement. Recent research as demonstrated by Zhao et al. (2021) has shown that the bootstrap t-test outperforms the traditional t-test in terms of different measures of the testing accuracy. This technique enables the calculation of the sampling distribution of the t-test statistic, even in cases when the data's distribution deviates from normality(Konietschke & Pauly, 2014; Zhao et al., 2021). The flowchart presented in Figure 3.8 shows the specific methodology adopted for bootstrapping in this research.

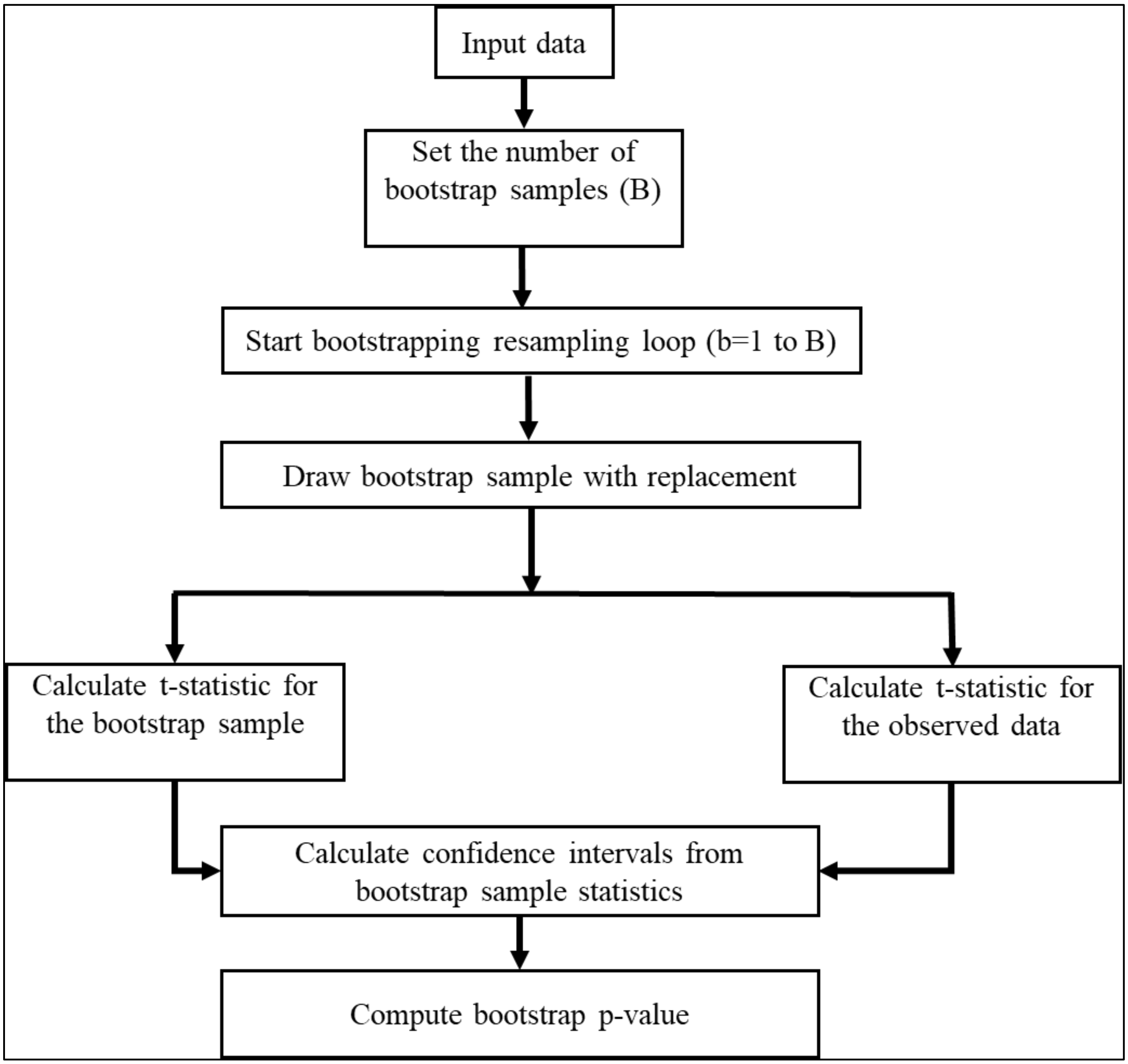

Figure 3.8: Bootstrapping methodology

CHAPTER 4 RESULTS

Scope I -CSFs Ranking

4.1 Questionnaire survey responses

There are two sub-sections following this section. The first subsection assesses the agreement test through ICC measure while the second involves ranking of the listed critical success factors based on their relative importance (RII).

4.2 Agreement Analysis- Intra-class coefficient (ICC)

To analyze the data, the initial step involves assessing its reliability. Reliability ensures the consistency for the test and gives the confidence to the researcher to determine whether the test yields consistent and dependable results (Aneesha & Haridharan, 2017). In this study, as discussed in the methodology section, the researcher used Inter-rater reliability agreement test to assess the reliability of the responses collected to rate the significance of critical success factors that influence the cost and schedule performance of projects.

The results of the ICC analysis conducted using SPSS are summarized in Table 4.1. For this analysis, a 95% confidence interval (i.e., the level of significance was 0.05) was established. This signifies that 95% of the ICC values in all instances fall within the confidence intervals outlined in Table 4.1.

Table 4.1: ICC analysis

Project type	Question	ICC value	Consensus status	95% confidence interval	
				Lower bound	Upper bound
Highway	Rate the significance of following critical success factors for completing your project under or on budget	0.744	Good	0.566	0.877
	Rate the significance of following critical success factors for completing your project ahead or behind schedule	0.606	Good	0.362	0.805
Building	Rate the significance of following critical success factors for completing your project under or on budget	0.621	Good	0.355	0.819
	Rate the significance of following critical success factors for completing your project ahead or behind schedule	0.641	Good	0.418	0.821

The obtained ICC value, which is greater than the 0.6 threshold (Cicchetti, 1994), signifies a strong and consistent level of agreement among the respondents. This level of agreement is categorized as "good agreement". The measurements indicate a high degree of consistency in the responses provided by the participants and this consistency strengthens the reliability of the data collected through the survey.

4.3 Ranking Results

Based on the relative importance, the relative weightage and subsequently obtained order for the critical success factors impacting cost and schedule performance of highway and building P3 projects are presented in this section.

The results of the RII analysis along with its respective RII values and the rankings for the critical success factors affecting cost performance of P3 highway projects are detailed in Table 4.2. “Appropriate Risk allocation and sharing” obtained the highest rank, sharing the same RII value as “A robust and reliable private consortium” which was placed the second position. Among all the critical factors, “Experience of owners in P3 projects” ranked the lowest in terms of its impact on the cost performance of P3 highway projects.

Table 4.2: Critical success factors based on their RII

Critical Success factors affecting cost performance	RII	Rank
Appropriate Risk allocation and sharing	0.89	1*
A robust and reliable private consortium	0.89	2*
Appropriate dispute resolution mechanism	0.88	3*
Financial feasibility and attraction	0.87	4*
Government/political support and stability	0.86	5*
Economic viability	0.86	6*
Strong and good partnering	0.85	7*
Clear contract clauses	0.85	8*
Competitive and transparent procurement processes	0.82	9
Reliable Contractual arrangement	0.82	10
Timely land acquisition and appropriate compensation	0.81	11

Favorable and efficient legal frameworks	0.8	12
Coordination among related stakeholders	0.78	13
Available finance market	0.74	14
Meeting output specifications	0.73	15
Stable macroeconomic condition	0.73	16
Favorable social support	0.71	17
Proper guidelines regarding p3 delivery	0.68	18
Value for money	0.63	19
Dedicated PPP unit	0.55	20
Experience of owners in P3 projects	0.53	21

Note: *Significant at alpha level 0.05.

The Mann-Whitney test results (Table 4.3) showed that the group of CSFs from rank 1 through 8 differ significantly from the group of CSFs ranked through 9 to 21; however, each CSFs did not differ significantly from one another.

Table 4.3:Results of Mann-Whitney U tests for critical success factors ranking significance

CSFs	Sample size	Mean rank	Significance
Clear contract clauses	20	18.38	0.214
Competitive and transparent procurement processes	20	22.63	

The results for the RII analysis which assesses the significance of critical success factors affecting schedule performance of P3 highway projects are presented in Table 4.4. The factors with the highest RII score were "Government/political support and stability" securing the first rank and "Appropriate dispute resolution mechanism" getting 2nd rank. In addition, "Value for money" was placed at the lowest end of the list in terms of RII values and its impact on schedule performance of P3 highway projects.

Table 4.4: Critical success factors based on their RII

Critical Success factors affecting schedule performance	RII	Rank
Government/political support and stability	0.93	1*
Appropriate dispute resolution mechanism	0.93	2*
A robust and reliable private consortium	0.92	3*
Timely land acquisition and appropriate compensation	0.88	4*
Strong and good partnering	0.88	5
Clear contract clauses	0.87	6
Reliable Contractual arrangement	0.86	7
Coordination among related stakeholders	0.84	8
Favorable and efficient legal frameworks	0.82	9
Appropriate Risk allocation and sharing	0.79	10
Meeting output specifications	0.77	11
Financial feasibility and attraction	0.76	12
Stable macroeconomic condition	0.72	13
Favorable social support	0.72	14
Competitive and transparent procurement processes	0.71	15
Economic viability	0.69	16
Experience of owners in p3 projects	0.69	17
Proper guidelines regarding p3 delivery	0.66	18
Available finance market	0.63	19
Dedicated PPP unit	0.59	20
Value for money	0.58	21

Note: *Significant at alpha level 0.05.

The Mann-Whitney test results (Table 4.5) showed that the group of CSFs from rank 1 through 4 differ significantly from the group of CSFs ranked through 5 to 21; however, each CSFs did not differ significantly from one another.

Table 4.5: Results of Mann-Whitney U tests for critical success factors ranking significance

CSFs	Sample size	Mean rank	Significance
Timely land acquisition and appropriate compensation	20	18.4	0.145
Strong and good partnering	20	22.6	

The results of the RII analysis including the corresponding RII values and rankings for the critical success factors affecting cost performance of P3 building projects are presented in Table 4.6. The factor "Appropriate Risk allocation and sharing" achieved the highest rank with RII value 0.89, while "Competitive and transparent procurement processes" was placed the second position with RII value 0.85. Among all the critical factors considered, "Favorable and efficient legal frameworks" had the lowest rank in terms of its impact on the cost performance of P3 building projects.

Table 4.6: Critical success factors based on their RII

Critical success factors affecting cost performance	RII	Rank
Appropriate Risk allocation and sharing	0.89	1*
Competitive and transparent procurement processes	0.85	2*
Profit assurance for the private sector	0.84	3*
Commitment and responsibility of the public and private sectors	0.83	4*
Economic environment	0.83	5*
Government/political support and stability	0.81	6*
Stable macroeconomic conditions	0.81	7*
Good governance	0.79	8*
Reliable private consortium	0.78	9*
Long term relationship and partnership	0.78	10*
Planning and design with approval	0.77	11
Effective communication	0.77	12
Favorable Social support	0.77	13
Continuous project monitoring and control	0.76	14
Reasonable contract mechanisms to deal with unexpected events	0.74	15
Robust and clear agreement	0.74	16
Clear process around permitting	0.71	17
Demand for project	0.7	18
Financial feasibility and attraction	0.69	19
Trust and openness	0.66	20
Available finance market	0.64	21
Favorable and efficient legal frameworks	0.58	22

Note: *Significant at alpha level 0.05.

The Mann-Whitney test results (Table 4.7) showed that the group of CSFs from rank 1 through 10 differ significantly from the group of CSFs ranked through 11 to 21; however, each CSFs did not differ significantly from one another.

Table 4.7: Results of Mann-Whitney U tests for critical success factors ranking significance

CSFs	Sample size	Mean rank	Significance
Reliable private consortium	20	16.55	0.02
Long term relationship and partnership	20	24.45	

The results for the RII analysis which evaluates the significance of critical success factors affecting schedule performance of P3 building projects are presented in Table 4.8. The factors with the highest RII score were “Continuous project monitoring and control” securing the first rank with RII value of 0.94 and “Competitive and transparent procurement processes” obtaining the second rank with RII value of 0.93. In addition, “Favorable and efficient legal frameworks” was placed at the lowest position in the list in terms of RII values and its impact on schedule performance of P3 building projects.

Table 4.8 : Critical success factors based on their RII

Critical success factors affecting schedule performance	RII	Rank
Continuous project monitoring and control	0.94	1*
Competitive and transparent procurement processes	0.93	2*
Profit assurance for the private sector	0.92	3*

Government/political support and stability	0.87	4*
Favorable Social support	0.87	5
Economic environment	0.83	6
Long term relationship and partnership	0.77	7
Good governance	0.76	8
Reliable private consortium	0.76	9
Appropriate Risk allocation and sharing	0.75	10
Commitment and responsibility of the public and private sectors	0.75	11
Robust and clear agreement	0.64	12
Planning and design with approval	0.63	13
Demand for project	0.61	14
Effective communication	0.6	15
Financial feasibility and attraction	0.6	16
Reasonable contract mechanisms to deal with unexpected events	0.59	17
Trust and openness	0.59	18
Available finance market	0.59	19
Stable macroeconomic conditions	0.59	20
Clear process around permitting	0.56	21
Favorable and efficient legal frameworks	0.51	22

Note: *Significant at alpha level 0.05.

The Mann-Whitney test results (Table 4.9) showed that the group of CSFs from rank 1 through 4 differ significantly from the group of CSFs ranked through 5 to 22; however, each CSFs did not differ significantly from one another.

Table 4.9: Results of Mann-Whitney U tests for critical success factors ranking significance

CSFs	Sample size	Mean rank	Significance
Government/political support and stability	20	23.5	0.092
Favorable Social support	20	17.5	

Scope II – Project performance comparison

This section is followed by two sub-sections. First, the descriptive statistics which provides an overview of the descriptive statistics related to the cost and schedule performances of the entire dataset for P3, DB and DBB projects. These statistics are presented for highway and building projects based on their respective project delivery methods. Following this, bootstrapping t-test was conducted to evaluate whether significant differences exist between cost growth or schedule growth within the considered groups of project deliveries (P3, DB and DBB) for highway and building projects.

4.4 Descriptive Statistics

Descriptive statistics were computed for cost and schedule growths in projects that were constructed using P3, DB and DBB project delivery. Given that the collected project data spanned different timeframes, data normalization was carried out employing cost indices shown in Table 4.10 from NHCCI (2022). This normalization process involved adjusting all cost data for equivalent costs as of December 2022 using the forementioned indices.

Table 4.10 : NHCCI Index for year 2022

Year Quarters	NHCCI Index
2022Q1	2.28
2022Q2	2.56
2022Q3	2.79
2022Q4	2.76

Figure 4.1 and Figure 4.2 illustrates the mean cost growth and schedule overrun across the entire data set for highway projects categorized by project delivery methods: P3, DB and DBB. Based on the descriptive statistics derived from the collected data, the cost growth for highway projects executed using P3 project delivery method amounted to 2.12%. The statistics revealed that, for DB and DBB projects, the cost increased by 8.95% and 5.65% respectively, relative to their initial project costs. Furthermore, regarding schedule growth, highway projects constructed through P3 project delivery method experienced a 0.59% increase in their schedules. However, the average schedule growth for DB and DBB projects were significantly higher, amounting to 37.94% and 31.395%, respectively.

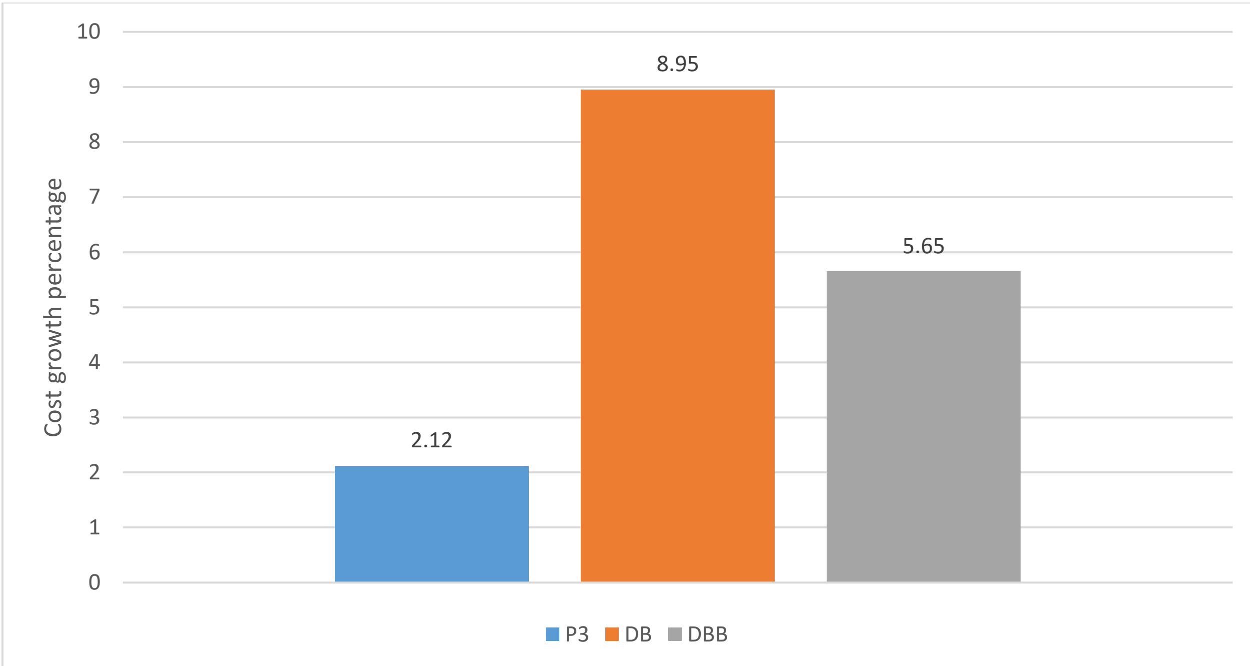

Figure 4.1: Average cost escalation for P3, DB and DBB highway projects

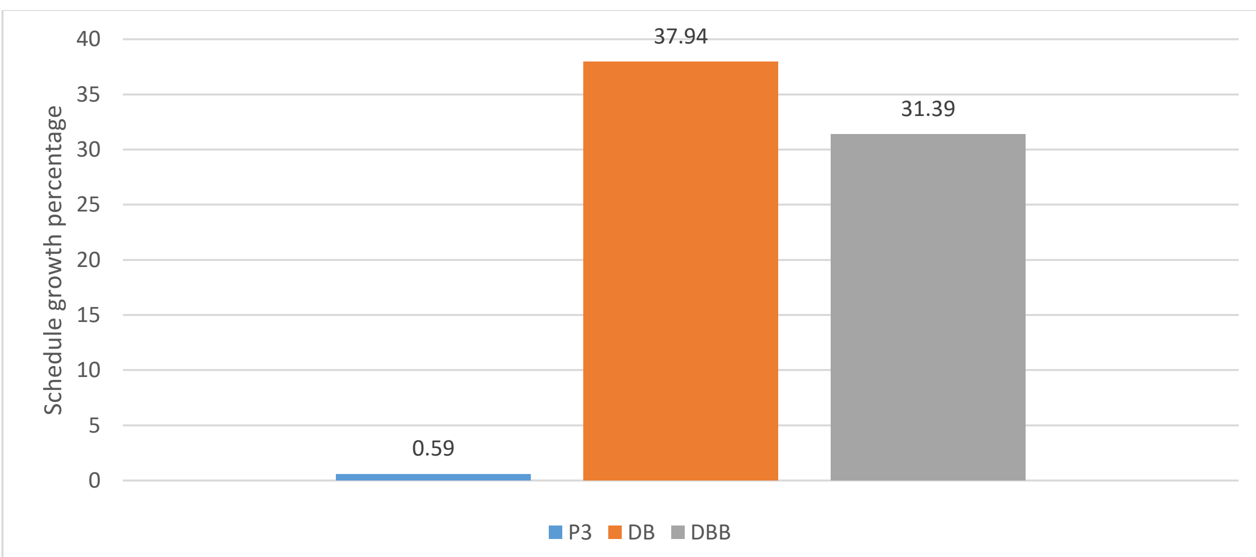

Figure 4.2: Average schedule overruns for P3, DB and DBB highway projects

Figure 4.3 and Figure 4.4 shows the mean cost growth and schedule overrun across the entire data set for building projects categorized by project delivery methods: P3, DB and DBB. Based on the descriptive statistics extracted from the gathered data, the cost growth for building projects executed using P3 project delivery method was -5.05%. The data indicated that, for DB and DBB projects, the costs increased by 7.95% and 33.10% respectively, in relation to their initial project costs. In addition, the schedule growth for building projects constructed through P3 and DB project delivery method experienced changes in their schedules, with a -2.39% and 2.65% increase, respectively. Notably, the average schedule growth for DB and DBB projects was substantially higher, amounting to 92.16%.

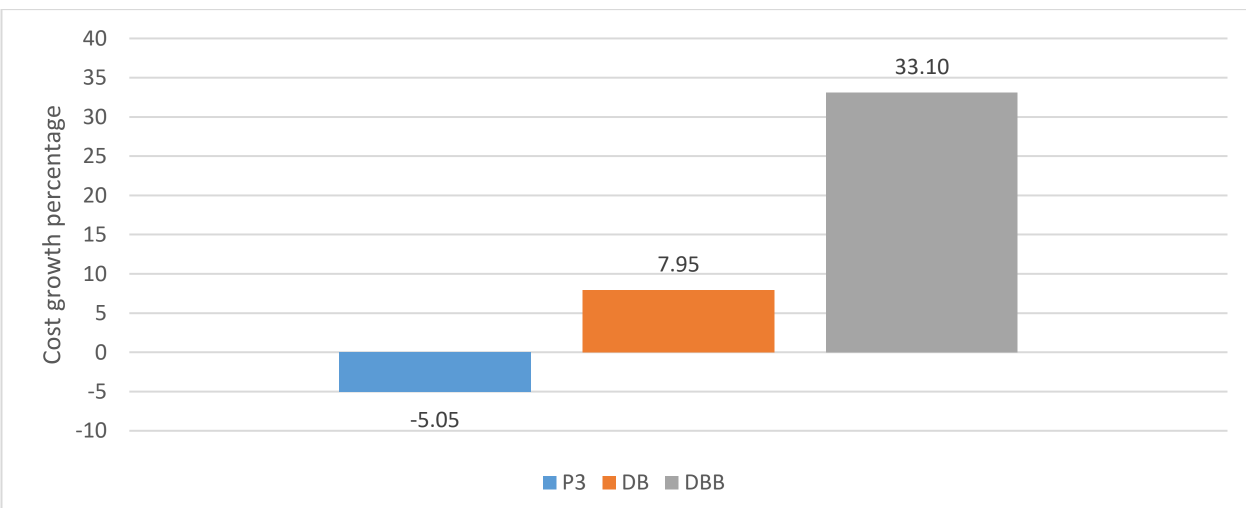

Figure 4.3: Average cost escalation for P3, DB and DBB building projects

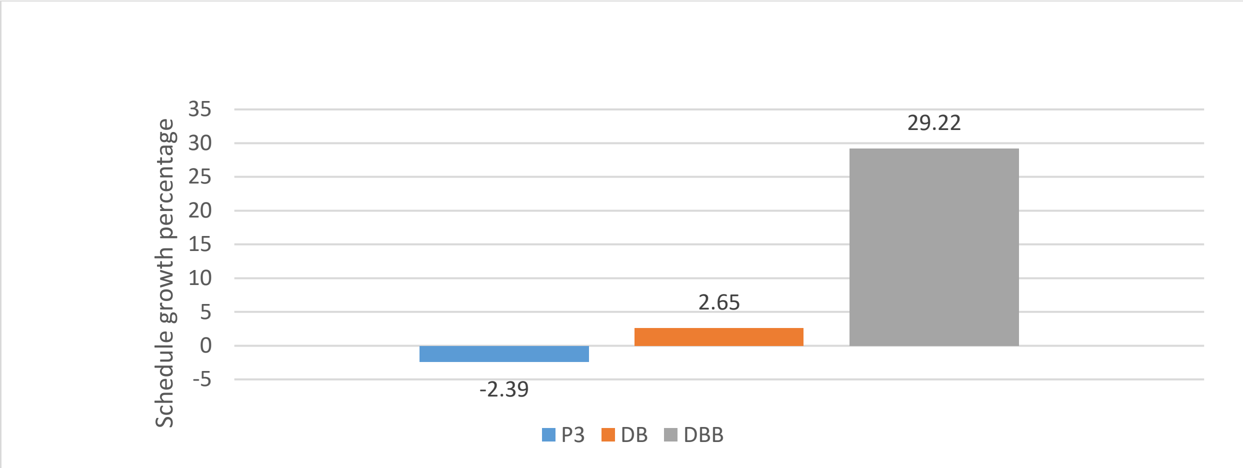

Figure 4.4: Average schedule overruns for P3, DB and DBB building projects

4.5 Statistical Analysis

To validate or refute the null hypothesis formulated for the research, it is necessary to conduct statistical tests. These tests often rely on assumptions to ensure the validity and reliability of their results. Since the objective of the study is to compare the project performances of P3 projects with DB and DBB projects, we need to examine whether there exists a significant difference between the datasets by comparing the group means. The t-test is often adopted for comparing the means of two groups, and thus, it is essential to assess the assumptions that apply to this statistical test. The three major assumptions associated with t-test are i) Dataset independence; ii) Normality assumption; iii) Homogeneity of variances between groups (Laerd Statistics, 2021).

i. Dataset independence

The project data has been sourced from various state agencies so it should be noted that the data are independent meaning that the observations are not related to one another.

To check the normality assumption, Kolmogorov-Smirnov normality tests were conducted to check whether the data for highway and building projects using P3, DB, and DBB delivery methods are normally distributed. The test results presented in the following sub sections revealed that cost growth and schedule growth data deviate from the standard normal curve and its distribution is non-normal.

ii. Normality Test

Normality test for cost growth of P3, DB and DBB highway projects

The test results from Kolmogorov-Smirnov normality tests indicate that the significance level (p-value) for cost growth data of highway projects is less than 0.001 for all data groups (less than significance level of 0.05). This result suggests that the data does not follow a normal distribution and the data deviates from the standard normal distribution curve. The normality test results for cost growth of P3, DB and DBB highway projects are presented in Table 4.11. Figure 4.9 presents the Q-Q plots related to this normality test.

Table 4.11 : Normality test results for highway cost growth

Cost Growth	Statistic	df	Significance
P3	0.280	31	<.001
DB	0.221	40	<.001
DBB	0.151	50	<.001

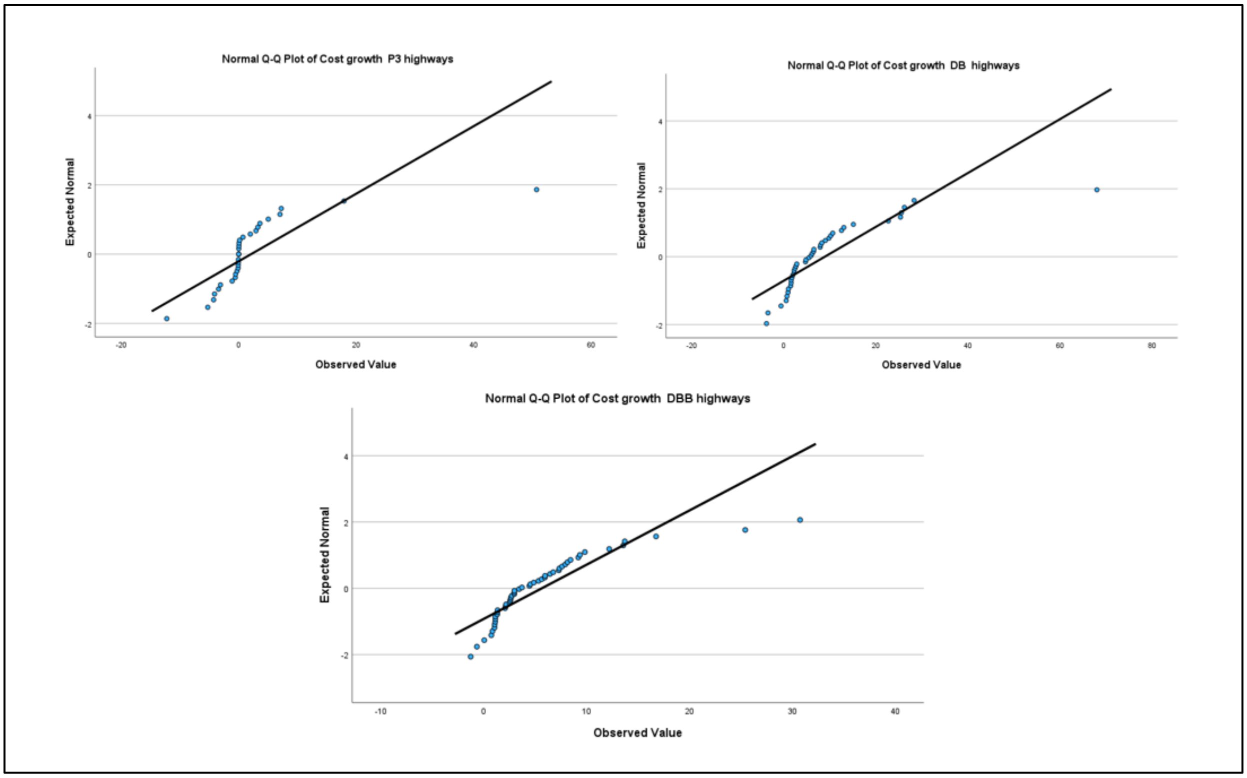

Figure 4.5:Q-Q plots for highway cost growth

<u>Normality test for schedule growth of P3,DB and DBB highway projects</u>

Results of the normality tests for the schedule growth data of highway projects constructed using P3, DB and DBB project delivery are presented in Table 4.12. Figure 4.5 shows the corresponding Q-Q plots associated with this normality test. The results of the Kolmogorov-Smirnov normality tests revealed that the significance level (p-value) associated with the schedule growth for P3 and DB highway projects is less than 0.001 and for DBB highway projects the p-value is 0.033(less than significance level of 0.05). This finding strongly indicates that the data does not adhere to a normal distribution and deviates from the standard normal distribution curve.

Table 4.12: Normality test results for highway schedule growth

Schedule Growth	Statistic	df	Significance
P3	0.286	31	<.001
DB	0.194	40	<.001
DBB	0.110	50	0.033

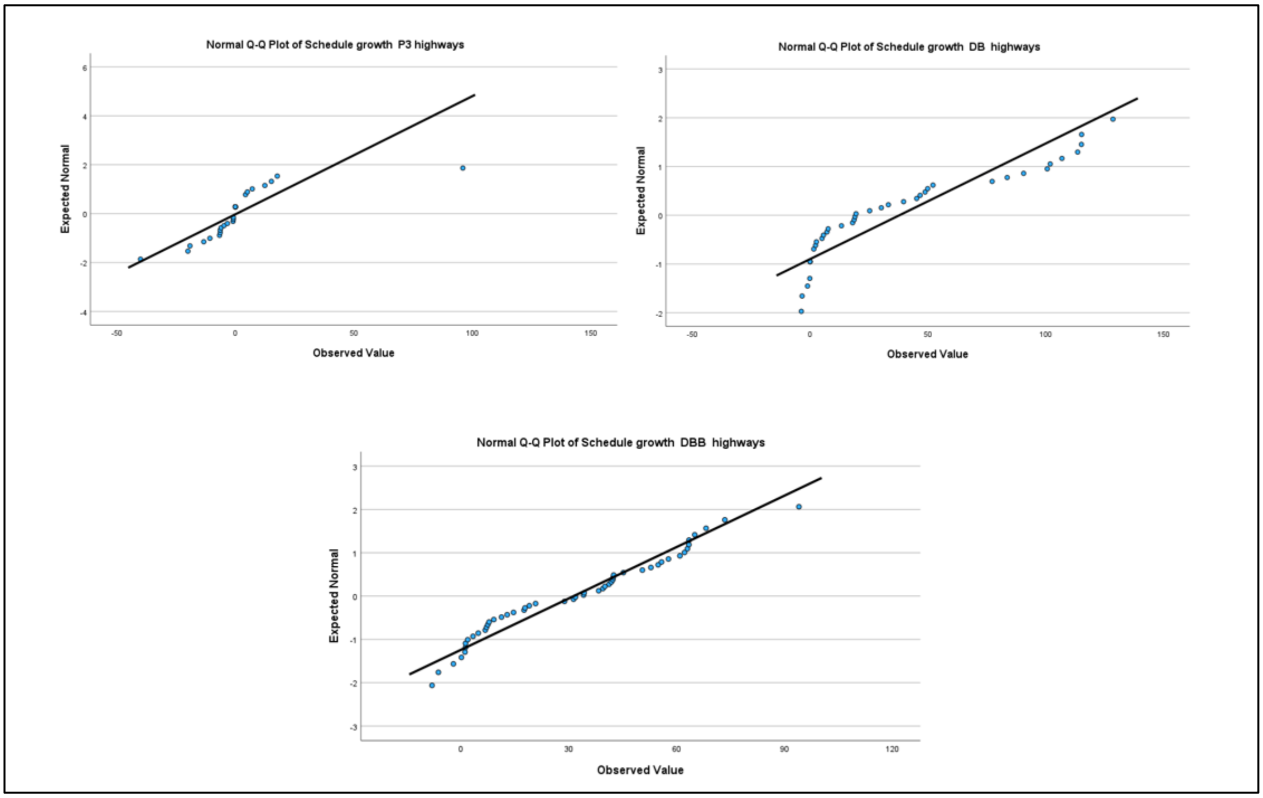

Figure 4.6 : Q-Q plots for highway schedule growth

Normality test for cost growth of P3,DB and DBB building projects

The test results from Kolmogorov-Smirnov normality tests indicate that the significance level (p-value) for cost growth data of building projects is less than 0.005 for all data groups (less than significance level of 0.05). This result indicates that the data does not follow a normal distribution and the data deviates from the standard normal distribution curve. The normality test results for building projects cost growth data are presented in Table 4.13. Figure 4.6shows the corresponding Q-Q plots associated with this normality test.

Table 4.13: Normality test results for building cost growth

Cost Growth	Statistic	df	Significance
P3	0.263	24	<.001
DB	0.287	48	<.001
DBB	0.192	31	0.005

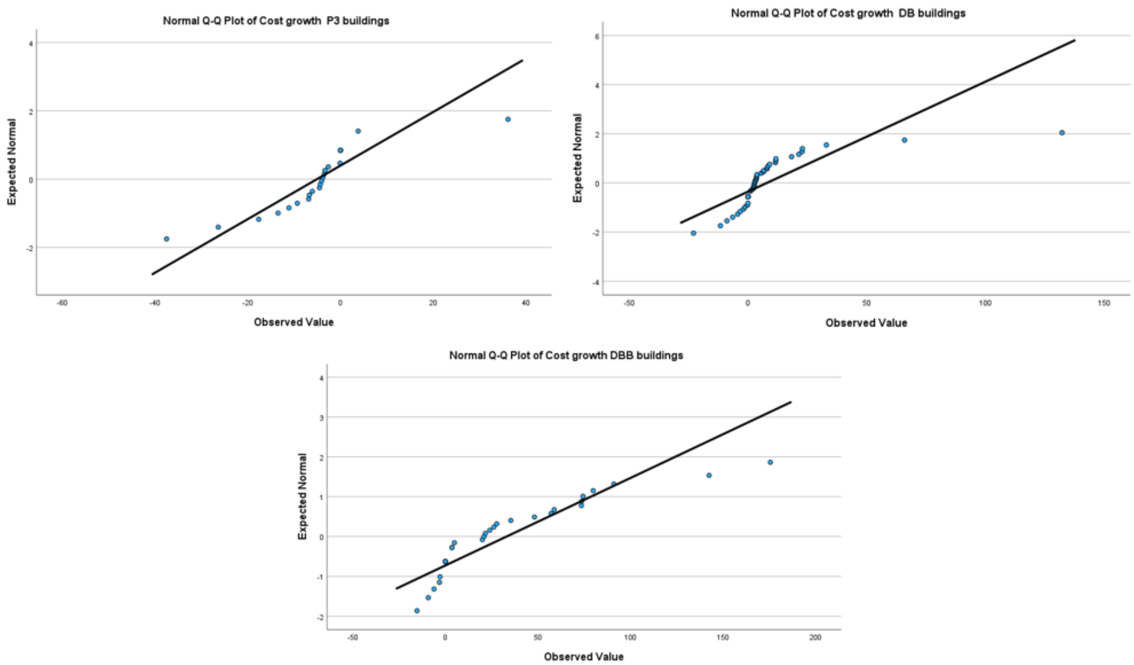

Figure 4.7: Q-Q plots for building cost growth

<u>Normality test for schedule growth of P3, DB and DBB building projects</u>

Results of the normality tests for the schedule growth data of highway projects constructed using P3, DB and DBB project delivery are presented in Table 4.14. Figure 4.7 shows the corresponding Q-Q plots associated with this normality test. Based on the findings, the significance level (p-value) obtained from the Kolmogorov-Smirnov normality tests is less than 0.009(below significance level of 0.05) for schedule growth data of building projects which indicates that the data does not follow a normal distribution.

Table 4.14: Normality test results for building schedule growth

Schedule Growth	Statistic	df	Significance
P3	0.207	24	0.009
DB	0.284	40	<.001
DBB	0.283	50	<.001

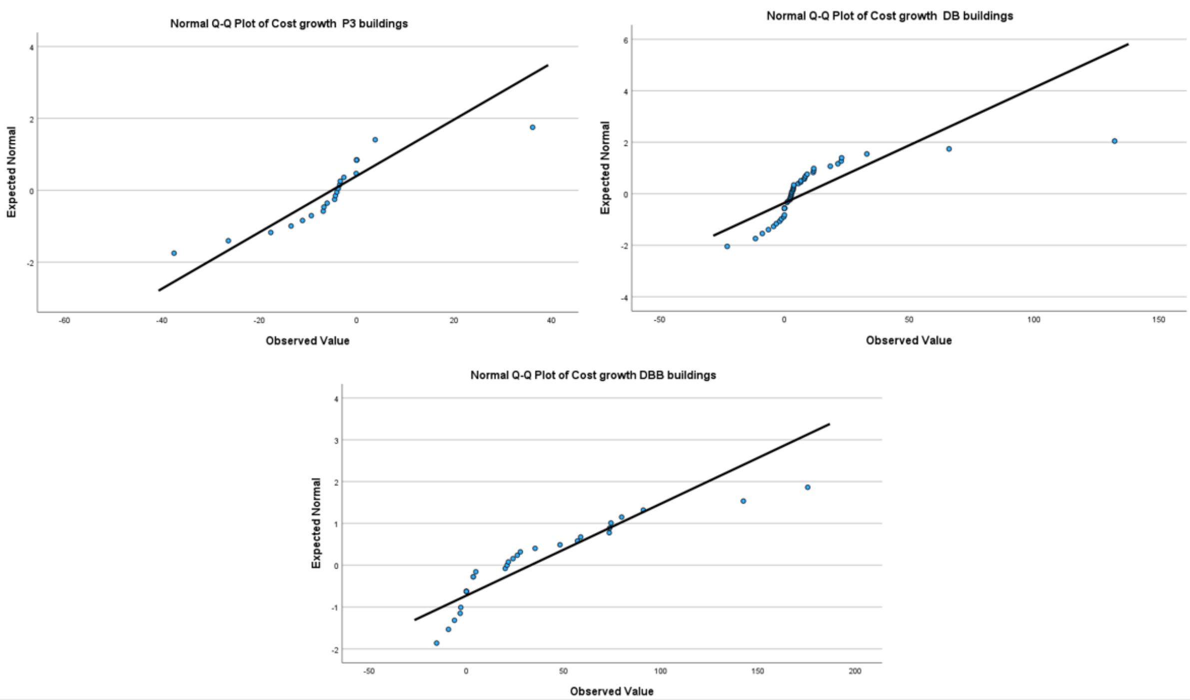

Figure 4.8: Q-Q plots for building schedule growth

iii. Homogeneity of variances between groups

To investigate the equality of variances among the groups for cost growth and schedule growth of P3, DB and DBB projects, Levene's test was employed. The results of the analysis for highway projects can be found in Table 4.8 which provides insights into the homogeneity of variances across these groups. The results of the Levene's test for the cost growth between P3 and DB highway projects reveal a p-value of 0.210 which is greater than the significance threshold of 0.05. This indicates that assumption of equal variances is satisfied which allows us to proceed with the t-test with equal variances. However, for schedule growth between P3 and DB highway projects the results of the Levene's test indicate a p-value of <0.001. In the case of cost growth between P3 and DBB project groups, the results of the Levene's test show a p-value of 0.853 which is greater than the significance threshold of 0.05. The schedule growth data between P3 and DBB highway projects indicate a p-value of 0.004. In this case, the p-values fall below the significance threshold of 0.05. Additionally, the Levene's test results for the cost growth between DB and DBB highway projects reveal a p-value of 0.098 suggesting no significant difference in variance of cost growth between these two delivery methods. However, for schedule growth between DB and DBB highway projects, the p-value is 0.001, falling below the significance threshold of 0.05. In cases where these p-values fall below the significance threshold of 0.05 the assumption of equal variances is not met which implies that we need to proceed with the t-test considering unequal variances for these datasets.

Table 4.15: Levene’s Test Results

Project Delivery	Performance metrics	Levene's statistic	Significance
P3 vs DB	Cost Growth	1.6	0.21
	Schedule Growth	27.18	<.001
P3 vs DBB	Cost Growth	0.035	0.853
	Schedule Growth	8.709	0.004
DB vs DBB	Cost Growth	2.805	0.098
	Schedule Growth	11.186	0.001

The results of the analysis for P3 building projects can be found in Table 4.16 which provides insights into the homogeneity of variances across these groups. The results of the Levene’s test for the cost growth between P3 and DB building projects reveal a p-value of 0.269 which is greater than the significance threshold of 0.05. This indicates that assumption of equal variances is satisfied which allows us to proceed with the t-test with equal variances. However, for schedule growth between P3 and DB building projects the results of the Levene’s test indicate a p-value of 0.042 which is less than significant level of 0.05. In the case of cost growth between P3 and DBB project groups, the results of the Levene’s test show a p-value of <0.001 which is less than the significance threshold of 0.05. The schedule growth data between P3 and DBB building projects indicates a p-value of <0.001. In this case, the p-values fall below the significance threshold of 0.05. Additionally, the Levene’s test results for the cost growth between DB and DBB building projects reveal a p-value of <0.001 suggesting significant difference in variance of cost growth between these two delivery methods. Similarly, for schedule growth between DB and DBB building projects, the p-value is <0.001, falling below the significance threshold of 0.05. In cases where these p-values fall below the significance threshold of 0.05 the assumption of equal variances is not met which implies that we need to proceed with the t-test considering unequal variances for these datasets.

Table 4.16: Levene’s Test Results

Project Delivery	Performance metrics	Levene's statistic	Significance
P3 vs DB	Cost Growth	1.24	0.269
	Schedule Growth	4.31	0.042
P3 vs DBB	Cost Growth	24.71	<0.001
	Schedule Growth	17.52	<0.001
DB vs DBB	Cost Growth	14.66	<0.001
	Schedule Growth	20.28	<0.001

4.6 T-test results

4.6.1 Highway projects

Detailed results of the bootstrapping t-test conducted for various project delivery groups are shown in Table 4.17 as presented in the subsequent section.

Table 4.17:Bootstrapping T-test results

Performance metrics	Project delivery		Statistic	Bootstrap t-test Significance p-value
Cost Growth	P3	N	31	0.017*
		Mean	2.12	
	DB	N	40	
		Mean	8.95	
	P3	N	31	0.023*
		Mean	2.12	
	DBB	N	32	
		Mean	7.27	
	DB	N	40	0.502
		Mean	8.95	
	DBB	N	32	
		Mean	7.27	
Schedule Growth	P3	N	31	<0.001*
		Mean	0.59	
	DBB	N	32	
		Mean	28.56	
	P3	N	31	<0.001*
		Mean	0.59	
	DB	N	40	
		Mean	37.94	
	DB	N	40	0.241
		Mean	37.94	
	DBB	N	32	
		Mean	28.56	
*Statistically significant at alpha level 0.05				

Cost performance comparison

P3 vs DB

Based on the bootstrapping results, it is seen that DB highway projects exhibit a mean cost growth of 8.94% while P3 highway projects have mean value of 2.11% for cost growth. The t-test results with the p-value of 0.017 (below significance level of 0.05) indicate that the difference between the groups means is statistically significant. This implies that the two compared groups (P3 and DB projects) have a meaningful difference in their cost performance.

P3 vs DBB

According to the results, DBB highway projects show a mean value of 7.27% for cost growth while P3 highway projects have a mean cost growth of 2.12%. From t-test results, the p-value of 0.023 (which is below significance level of 0.05) indicates that the difference between the groups means is statistically significant. This suggests a meaningful distinction in cost performance between the compared groups (P3 and DBB projects).

DB vs DBB

The results reveal that DB highway projects have a mean cost growth of 8.94% whereas DBB highway projects have a mean value of 7.27% for its cost growth. In the t-test, the p-value of 0.502 (greater than significance level of 0.05) suggests that the difference between the groups means is not statistically significant. This indicates that the compared groups (DB and DBB projects) do not exhibit meaningful distinction in their cost performance.

Schedule performance comparison

P3 vs DB

Based on the group statistics from bootstrapping t- test results, DB highway projects exhibit a mean schedule growth of 37.94% and P3 highway projects have mean schedule growth value of 0.59%. The resulting p-value of <0.001 (less than 0.05) means that there is very strong evidence supporting that the difference between the groups means is statistically significant. It means that the two groups being compared (i.e. P3 and DB projects) have meaningful distinction in their schedule performance.

P3 vs DBB

From the test results, DBB highway projects have a mean value of 28.56% for schedule growth while P3 highway projects exhibit a mean schedule growth of 0.59%. The t-test results with the p-value of <0.001 (significantly less than 0.05) strongly indicate that there's a statistically significant difference between the mean schedule growth of these two groups (P3 and DBB projects), highlighting a meaningful distinction in their schedule performance.

DB vs DBB

According to the group statistics derived from bootstrapping t- test results, DB highway projects demonstrate a mean schedule growth of 37.94% while DBB highway projects exhibit a mean value of 28.56% for schedule growth. The t-test results with the p-value of 0.008 (significantly less than 0.05) strongly suggest that there is statistically significant difference between the mean schedule growth of these two groups emphasizing meaningful distinction in their schedule performance.

4.6.2 Building projects

Detailed results of the bootstrapping t-test conducted for various project delivery groups for building projects are shown in Table 4.18 as presented in the subsequent section.

Table 4.18:Bootstrapping T-test results

Performance metrics	Project delivery	Statistic	Bootstrap t-test
			Significance
			p-value

Cost Growth	P3	N	31	0.037*
		Mean	-2.28	
	DB	N	40	
		Mean	7.98	
	P3	N	31	<0.001*
		Mean	-2.28	
	DBB	N	32	
		Mean	32.43	
	DB	N	40	0.008*
		Mean	7.98	
	DBB	N	32	
		Mean	32.43	
Schedule Growth	P3	N	31	0.271
		Mean	-0.59	
	DB	N	40	
		Mean	2.25	
	P3	N	31	0.004*
		Mean	-0.59	
	DBB	N	32	
		Mean	29.22	
	DB	N	40	0.005*
		Mean	2.25	
	DBB	N	32	
		Mean	29.22	
*Statistically significant at alpha level 0.05				

Cost performance comparison

<u>P3 vs DB</u>

Based on the bootstrapping results, it is seen that DB building projects exhibit a mean cost growth of 7.98% while P3 building projects have mean value of -2.27% for cost growth. The t-test results with the p-value of 0.037 (below significance level of 0.05) indicate that the difference between the groups means is statistically significant. This implies that the two compared groups (P3 and DB projects) have a meaningful difference in their cost performance.

<u>P3 vs DBB</u>

According to the results, DBB building projects show a mean value of 32.43% for cost growth while P3 building projects have a mean cost growth of -2.28%. From t-test results, the p-value of <0.001 (which is below significance level of 0.05) indicates that the difference between the groups means is statistically significant. This suggests a meaningful distinction in cost performance between the compared groups (P3 and DBB projects).

<u>DB vs DBB</u>

The results reveal that DB building projects have a mean cost growth of -7.98% whereas DBB building projects have a mean value of 32.43% for its cost growth. In the t-test, the p-value of 0.241 (greater than significance level of 0.05) suggests that the difference between the groups means is not statistically significant. This indicates that the compared groups (DB and DBB projects) do not exhibit meaningful distinction in their cost performance.

Schedule performance comparison

<u>P3 vs DB</u>

Based on the group statistics from bootstrapping t- test results, DB building projects exhibit a mean schedule growth of 2.24% and P3 building projects have mean schedule growth value of -0.59%. The resulting p-value of 0.271 (greater than 0.05) provides evidence indicating that the difference between the groups means is not statistically significant. It means that the two groups being compared (i.e. P3 and DB projects) have meaningful distinction in their schedule performance.

P3 vs DBB

From the test results, DBB building projects have a mean value of 29.22% for schedule growth while P3 building projects exhibit a mean schedule growth of -0.59%. The t-test results with the p-value of 0.004(significantly less than 0.05) strongly indicate that there's a statistically significant difference between the mean schedule growth of these two groups (P3 and DBB projects), highlighting a meaningful distinction in their schedule performance.

DB vs DBB

According to the group statistics derived from bootstrapping t- test results, DB building projects demonstrate a mean schedule growth of 2.25% while DBB building projects exhibit a mean value of 29.22% for schedule growth. The t-test results with the p-value of 0.005 (significantly less than 0.05) strongly suggest that there is statistically significant difference between the mean schedule growth of these two groups emphasizing meaningful distinction in their schedule performance.

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

The main research questions for this research have been as follows:

1. How does the cost and schedule performance of P3 highway and building projects in the United States compare to that of its DB and DBB counterparts? Is there any observable advantage in terms of project cost and duration savings?
2. What are the factors that significantly influence the cost and schedule performance of P3 highway and building projects in the United States?

The study provides strong evidence that P3 highway projects in the United States have shown better project performance in terms of its cost in the recent years compared to DB and DBB projects delivery methods. The mean cost growth value for P3 highway projects was found to be 2.12%, while for DB projects, it was 8.95% and for DBB projects it was 7.27%. In addition, P3 highway projects had a mean schedule growth value of 0.59% as compared to higher mean schedule growth of 37.94% for DB highway projects and 28.56% for DBB highway projects. Statistically significant differences were identified in both cost and schedule performances reinforcing the idea that the P3 project delivery that involved collaboration between public and private agencies, offers cost and schedule advantages in comparison to DB and DBB project delivery methods in the context of US highway construction projects. One significant finding in this study is the higher mean cost growth value observed for DB highway projects indicating that these projects tend to experience higher cost growth when compared to DBB highway projects. This finding could prompt further investigations into the factors contributing to observed cost differences between DB and DBB highway projects and project stakeholders should be aware of the potential cost implications associated with the DB approach.

The results of the study indicate that P3 building projects executed in the United States exhibit a mean cost growth value of -2.27%. In contrast, the mean cost growth is 7.98% for DB projects and significantly higher at 32.43% for DBB projects. The observed differences were determined to be statistically significant confirming the better cost and schedule performance of P3 building projects in comparison to DB and DBB building projects

Furthermore, the conventional D-B-B model entirely depends on the capabilities of the owner to manage the entire process involving various entities, each contributing a risk factor to their approach to the project affecting both cost and schedule. In contrast, the P3 delivery process shifts this responsibility onto the project delivery team who then has to organize and structure the entire project team to effectively deliver the project. The better cost performance in P3 highway and building projects as evident in this study means that public resources have been used more efficiently leading to increased public satisfaction and confidence in government infrastructure initiatives. Furthermore, it highlights the potential benefits of embracing innovative project delivery methods to enhance the efficiency and cost-effectiveness of public projects.

It was also evident from statistical analysis that P3 building projects have a mean schedule growth value of -0.59% as compared to mean schedule growth of 2.25% for DB building projects and substantially higher schedule growth of 29.22% for DBB building projects. The findings were statistically significant when schedule comparison was done between P3 and DBB projects while such significance was not observed in the comparison between P3 and DB project schedules. From the statistical viewpoint, the statistically insignificant differences between P3 and DB schedule growth suggests that there is not enough evidence to conclude that P3 and DB projects differ in terms of schedule performances.

In summary, the following conclusions have been developed through this study:

1. P3 highway projects in the United States have shown better project performance compared to DB and DBB projects delivery methods.
2. DB highway projects in the United States tend to experience higher cost growth when compared to DBB highway projects.
3. Better cost and schedule performance of P3 building projects in comparison to DB and DBB building projects
4. No significant difference in P3 and DB schedule performances

The identification of CSFs influencing the cost and schedule performance of P3 projects is significant as it can lead to better project planning and executing ultimately resulting in improved project outcomes, implement cost control measures, ensure timely project delivery, and allocate resource more efficiently by focusing on the critical success factors. The top-ranking CSF influencing cost performance of P3 highway projects “Appropriate Risk allocation and sharing” signifies the critical importance of effectively managing risks in P3 highway projects. It indicates that fairness in risk allocation between public and private partners is essential for cost control. In addition, second ranking CSF “A robust and reliable private consortium” highlights the significance of having a strong private partner that can contribute significantly to cost-effective project execution. Both these CSFs underscore the importance of balanced approach to risk allocation and importance of well structures partnerships in P3 projects. In addition, the shared top position of "Government/political support and stability" and "Appropriate dispute resolution mechanism" among the CSFs impacting the schedule performance of P3 highway projects highlights the importance of political stability, government support and effective dispute resolution in ensuring timely delivery of P3 projects.

Similarly, the top-ranking CSF “Appropriate Risk allocation and sharing” influencing cost performance of P3 building projects signifies the critical importance of effectively managing risks in P3 building projects. It indicates the importance of risk allocation between public and private partners in achieving successful cost outcomes in P3 building projects. In addition, second top ranking CSF “Competitive and transparent procurement processes” highlights the role of transparent procurement process in influencing cost performance for P3 building projects. The shared top position of " Continuous project monitoring and control " and " Competitive and transparent procurement processes " among the CSFs impacting the schedule performance of P3 building projects highlights the importance of continuous project monitoring and facilitation of competitive and transparent procurement practices in ensuring timely delivery of P3 projects. As continuous monitoring of the project can ensure adherence to schedules, it can reduce delays in the project. In addition, Competitive and transparent procurement processes ensure competitive and fair bidding that can help streamline selection of contractors and ensure that projects adhere to legal and regulatory requirements which contribute to successful adherence to project schedules in P3 building projects.

In summary, this study identified the following critical success factors influencing cost and schedule efficiency of P3 projects in the United States:

Table 5.1: Critical Success Factors identified from the study

	CSFs impacting cost performance	**CSFs impacting schedule performance**
Highway projects	Appropriate Risk allocation and sharing	Government/political support and stability
	A robust and reliable private consortium	Appropriate dispute resolution mechanism
	Appropriate dispute resolution mechanism	A robust and reliable private consortium
	Financial feasibility and attraction	Timely land acquisition and appropriate compensation
	Government/political support and stability	
	Economic viability	
	Strong and good partnering	
	Clear contract clause	
Building projects	Appropriate Risk allocation and sharing	Continuous project monitoring and control
	Competitive and transparent procurement processes	Competitive and transparent procurement processes
	Profit assurance for the private sector	Profit assurance for the private sector
	Commitment and responsibility of the public and private sectors	Government/political support and stability
	Economic environment	
	Government/political support and stability	
	Stable macroeconomic conditions	
	Good governance	
	Reliable private consortium	
	Long term relationship and partnership	

The distinction in critical success factors identified for P3 highway and building projects may originate from the predominant sources of the responses: public agencies for highway questionnaire and private sectors for building questionnaire. Critical success factors such as

Appropriate Risk allocation and sharing, Government/political support and stability, robust and reliable private consortium and Appropriate dispute resolution mechanism hold greater importance for public owners in highway projects and ensure the success of public infrastructure initiatives. On the other hand, the critical success factors specific to P3 building projects such as Appropriate Risk allocation and sharing, Continuous project monitoring and control, Competitive and transparent procurement processes, and Profit assurance for the private sector highlight priorities more pertinent to private sectors. These factors emphasize the significance of risk management tailored to the complexities of building projects, continuous project oversight, open procurement practices and ensuring profitability for private stakeholders.

5.1 Discussion

The study results revealed statistically significant differences when cost analysis was done between P3 and DB projects data. Specifically, the cost growth and schedule growth for P3 and DB highway projects slightly exceeded the findings of (Fathi & Shrestha, 2022a). However, the study findings for both highway and buildings project cost performance are in line with previous research such as (Chasey et al., 2012) and (Ramsey & El Asmar, 2015). (Chasey et al., 2012)found out that the P3 projects had cost overruns averaging only 0.81% while design-build projects experienced overruns of 1.49% and design-bid-build projects had substantial cost overruns of 12.71%. Similarly, (Ramsey & El Asmar, 2015) found that P3 projects had cost overruns averaging 3.22% which was considerably lower than DBB projects having cost growth ranging from 3.6% to 25%.

Moreover, when analysis was performed for highway project schedule performances, the findings closely align with the conclusions drawn in the study by (Ramsey & El Asmar, 2015) indicating that P3 projects have schedule overruns of -2.97%, while DBB projects experienced schedule growth ranging from 4.34% to 33.5%. Although statistically significant differences were observed in comparing P3 and DBB building project data regarding schedule performance, no such differences were found between P3 and DB data groups. These findings aligned with (Ramsey & El Asmar, 2015) study conclusions.

In the analysis comparing performances of DB and DBB highway projects, no statistically significant differences were found, suggesting that these two groups do not exhibit meaningful distinction in their cost performance. However, this contradicted (Chasey et al., 2012) findings which reported better cost performance of DB highway projects compared to DBB highway projects. Notably, DB projects showed a higher mean schedule growth of 37.94% while DBB projects had a lower mean schedule growth of 28.56% aligning with study by (Chasey et al., 2012). Regarding DB and DBB building projects, the findings are similar from those of (Shrestha & Fernane, 2017) and (Molenaar & Franz, 2018)which reported better cost performance of DB building projects compared to DBB building projects. Furthermore, the schedule analysis findings for building projects were consistent with (Shrestha & Fernane, 2017) results which found similar schedule performance patterns among DB and DBB building projects.

5.2 Significance of the Study

The significance of this research lies in key aspects such as:

1. **Improvement in Cost and Schedule Performance:** This study has helped to determine the most efficient project delivery method for large scale projects focusing on cost control and schedule advantages through an analysis and comparison of three project delivery methods. The information gained from this research has the potential to enhance project management strategies resulting in potential cost savings and decreased project delays.

2. **Successful project outcomes**: The findings derived from this study in identifying critical success factors can play an important role in strengthening the capabilities of the project teams. By prioritizing the identified critical success factors, project teams can enhance their planning and execution strategies, facilitate the implementation of cost control measures, and streamline their efforts towards timely project completion.
3. **Contribute to the Body of Knowledge:** By using literature review, empirical analysis and the application of statistical tests, this study provides findings and evidence that hold relevance for both researchers and industry practitioners. The use of statistical tests provides a quantitative basis for interpreting the data, enabling researchers and practitioners to draw sound conclusions and make informed decisions based on empirical evidence. By leveraging the study findings, stakeholders can navigate the complexities of project delivery with greater confidence eventually leading to more successful project outcomes.

5.3 Study Recommendations

Therefore, considering the study implications, it is necessary to optimize the benefits of P3 project delivery where a collaborative and competitive environment is built conducive to optimal cost and schedule outcomes. Addressing higher cost growth observed in DB highway projects requires thorough investigation to understand potential implications. Ensuring proper risk allocation and sharing mitigates potential losses, while securing strong governmental and political support encourages continuity and investor’s confidences is important to facilitate smooth implementation of P3 projects.

Future research is essential to explore how critical success factors identified for P3 highway and building projects can be effectively applied to improve cost and schedule performance. Deeper understanding of these factors can uncover specific mechanisms through which they influence project outcomes and can inform the development of targeted strategies and best practices for enhancing project efficiency. In addition, the initial investment cost associated with P3 projects represents a significant challenge that warrants thorough investigation which is crucial for devising effective strategies to manage costs and ensure viability of P3 projects in the long term.

APPENDIX A: LIST OF P3 HIGHWAY PROJECTS DATA

S.No.	Name of Project	Location
1	HP1	Virginia
2	HP2	Colorado
3	HP3	Florida
4	HP4	Florida
5	HP5	Arizona
6	HP6	Ohio
7	HP7	Texas
8	HP8	Texas
9	HP9	Texas
10	HP10	Texas
11	HP11	Virginia
12	HP12	California
13	HP13	California
14	HP14	Texas
15	HP15	California
16	HP16	Colorado
17	HP17	North Carolina
18	HP18	Virginia
19	HP19	Virginia
20	HP20	Virginia
21	HP21	Florida
22	HP22	Florida
23	HP23	Puerto Rico
24	HP24	Alabama
25	HP25	Pennsylvania
26	HP26	Indiana
27	HP27	Indiana
28	HP28	Indiana
29	HP29	New York/Jersey
30	HP30	Georgia
31	HP31	South Carolina

APPENDIX B: LIST OF P3 BUILDING PROJECTS DATA

S.No.	Name of Project	Location
1	BP1	Maryland
2	BP2	California
3	BP3	California
4	BP4	California
5	BP5	Nevada
6	BP6	California
7	BP7	California
8	BP8	California
9	BP9	California
10	BP10	Indiana
11	BP11	Indiana
12	BP12	Arizona
13	BP13	Arizona
14	BP14	Arizona
15	BP15	Texas
16	BP16	Pennsylvania
17	BP17	Pennsylvania
18	BP18	Indiana
19	BP19	Kansas
20	BP20	Indiana
21	BP21	Texas
22	BP22	Texas
23	BP23	California
24	BP24	California

APPENDIX C: LIST OF DB HIGHWAY PROJECTS DATA COLLECTED

S.No.	State	Project Id	Cost Growth (%)	Schedule Growth(%)
1	Florida	DB1	4.852	48.824
2		DB2	0.725	90.636
3		DB3	12.560	106.894
4		DB4	1.800	2.348
5		DB5	9.056	25.300
6		DB6	1.625	18.077
7		DB7	8.015	115.157
8		DB8	0.545	100.656
9		DB9	2.852	101.913
10		DB10	22.735	115.234
11		DB11	7.921	45.253
12		DB12	5.500	83.657
13	Arizona	DB13	6.565	5.699
14		DB14	25.370	77.273
15		DB15	1.041	52.167
16		DB16	1.970	30.245
17		DB17	1.533	39.695

18	Maryland	DB18	9.835	19.066
19		DB19	4.739	7.179
20		DB20	8.300	13.333
21		DB21	0.947	5.075
22		DB22	2.473	-3.695
23		DB23	6.198	-1.062
24		DB24	-3.410	2.703
25		DB25	2.269	-3.361
26		DB26	13.070	0.000
27		DB27	10.659	-0.097
28		DB28	6.493	19.515
29		DB29	2.657	49.920
30	Texas	DB30	68.032	113.553
31		DB31	25.569	0.000
32		DB32	28.331	0.000
33		DB33	-0.572	7.687
34		DB34	5.952	0.000
35		DB35	26.223	0.000
36		DB36	2.273	128.542
37		DB37	-3.725	1.590
38		DB38	10.227	33.242
39		DB39	15.141	46.713
40		DB40	1.618	18.727

APPENDIX D: LIST OF DB BUILDING PROJECTS DATA COLLECTED

S.No.	Project Id	Location	Cost Growth (%)	Schedule Growth (%)
1	DB1	Irvine, California	-0.001	0.000
2	DB2	Los Angeles, California	8.151	9.651
3	DB3	San Diego, California	22.904	-0.528
4	DB4	Valley Glen, California	2.829	0.000
5	DB5	Ventura, California	3.593	14.771
6	DB6	Dublin, California	11.733	15.275
7	DB7	Irvine, California	1.476	0.000
8	DB8	San Diego, California	5.533	0.000
9	DB9	Los Angeles, California	17.514	-0.104
10	DB10	Irvine, California	3.506	0.000
11	DB11	La Jolla, California	6.619	-4.654

S.No.	Project Id	Location	Cost Growth (%)	Schedule Growth (%)
12	DB12	Pasadena, California	2.327	0.000
13	DB13	La Jolla, California	9.118	16.722
14	DB14	San Diego, California	8.491	2.212
15	DB15	San Diego, California	21.402	-2.267
16	DB16	Colton, California	-4.348	0.000
17	DB17	San Francisco, California	33.008	-0.743
18	DB18	Lincoln City, Oregon	0.000	0.000
19	DB19	Fort knox,KY	0.000	0.000
20	DB20	Lansing,Michigan	2.267	0.000
21	DB21	Minneapolis, Minnesota	11.520	0.000
22	DB22	San Francisco, CA	22.758	12.186
23	DB23	Lancaster, California	3.830	-0.334
24	DB24	Alturas, CA	-6.425	-2.538
25	DB25	Las Vegas, NV	-1.249	-17.297

S.No.	Project Id	Location	Cost Growth (%)	Schedule Growth (%)
26	DB26	Anchorage, Alaska	132.261	2.586
27	DB27	Santee, CA	3.695	0.000
28	DB28	Valencia, California	18.374	1.116
29	DB29	Corona, California	3.376	-0.421
30	DB30	Chicago, IL	2.968	0.000
31	DB31	Bethlehem, PA	-1.904	0.000
32	DB32	La Jolla, California	2.658	-11.573
33	DB33	Denver,CO	2.767	5.061
34	DB34	Phoeniz,Arizona	-22.916	0.000
35	DB35	Lancaster,California	2.442	-0.101
36	DB36	Fullerton,CA	-11.610	-15.541
37	DB37	Mansfield,Texas	0.000	0.000
38	DB38	Sacramento,California	-0.275	21.619
39	DB39	San Francisco,CA	7.946	10.402
40	DB40	Golden,Colorado	0.000	0.000

S.No.	Project Id	Location	Cost Growth (%)	Schedule Growth (%)
41	DB41	Van Nuys,California	-8.860	0.000
42	DB42	Dallas,Texas	0.000	-3.217
43	DB43	Richmond,virginia	0.000	0.000
44	DB44	Sacramento,California	3.748	-3.580
45	DB45	San Diego,California	-3.262	-24.184
46	DB46	Riverside,California	6.489	24.459
47	DB47	Joliet,Illinois	1.016	20.041
48	DB48	Olathe,Kansas	0.000	-12.671
49	DB49	Githersburg,MD	65.936	72.364
50	DB50	San Antanio,Texas	11.755	-1.876

APPENDIX E: LIST OF DBB HIGHWAY PROJECTS DATA COLLECTED

S.No.	State	Project Id	Cost Growth (%)	Schedule Growth (%)
1	Texas	DBB1	7.938	68.194
2		DBB2	1.122	1.158
3		DBB3	2.975	1.923
4		DBB4	5.327	4.849
5		DBB5	-1.264	17.596
6		DBB6	5.941	19.048
7		DBB7	2.573	12.891
8		DBB8	8.143	34.142
9		DBB9	13.711	1.293
10		DBB10	4.448	31.868
11		DBB11	1.054	14.660
12		DBB12	1.067	7.500
13		DBB13	5.962	63.017
14		DBB14	9.835	7.143
15		DBB15	30.752	40.066
16		DBB16	0.056	31.343
17		DBB17	7.348	20.789
18		DBB18	9.197	73.413
19		DBB19	13.566	65.041
20		DBB20	9.352	1.295
21		DBB21	3.718	-2.062
22		DBB22	25.423	38.333

S.No.	State	Project Id	Cost Growth (%)	Schedule Growth (%)
23		DBB23	12.200	17.843
24		DBB24	2.530	62.212
25		DBB25	7.302	11.313
26	Florida	DBB26	6.441	63.422
27		DBB27	16.752	7.857
28		DBB28	8.444	39.504
29		DBB29	4.867	54.875
30		DBB30	1.133	42.360
31		DBB31	2.616	3.400
32		DBB32	2.136	57.739
33		DBB33	2.652	42.258
34		DBB34	-0.662	41.235
35		DBB35	1.137	9.182
36		DBB36	4.533	50.481
37		DBB37	5.635	60.917
38		DBB38	3.442	42.500
39		DBB39	0.739	52.857
40		DBB40	1.319	41.871

S.No.	State	Project Id	Cost Growth (%)	Schedule Growth (%)
41		DBB41	7.625	94.021
42		DBB42	2.978	6.803
43		DBB43	1.350	55.817
44		DBB44	2.740	28.824
45		DBB45	2.170	0.167
46		DBB46	0.855	63.455
47		DBB47	2.984	-8.000
48		DBB48	2.082	-6.234
49		DBB49	6.760	34.286
50		DBB50	1.314	45.208

APPENDIX F: LIST OF DBB BUILDING PROJECTS DATA COLLECTED

S.No.	State/Location	Project Name/description	Cost Growth (%)	Schedule Growth(%)
1	Orlando, FL	DBB1	142.52	45.34
2	Syracuse, NY	DBB2	27.78	25.98
3	Palo Alto, CA	DBB3	58.82	21.10
4	Lee County	DBB4	35.38	59.49
5	Gainesville, FL	DBB5	20.00	8.19
6	San Antonio, TX	DBB6	4.88	47.29
7	Tampa, FL	DBB7	3.57	8.73
8	Anchorage, AK	DBB8	0.00	9.42
9	American Lake, WA	DBB9	0.00	54.48
10	Biloxi, MS	DBB10	0.00	0.00
11	Indianapolis, IN	DBB11	0.00	8.99
12	Columbia, MO	DBB12	0.00	35.17
13	Cleveland, OH	DBB13	-2.86	28.62
14	Tampa, FL	DBB14	-6.12	5.54
15	Las Vegas	DBB15	79.89	82.38
16	Seattle	DBB16	-15.29	32.79
17	New Orleans	DBB17	73.52	43.11
18	Dallas	DBB18	74.38	21.70

APPENDIX G: SURVEY QUESTIONNAIRE FOR P3 HIGHWAY PROJECTS

Date of Response: …………

- Respondent's Name: ……………………………….
- Company/Organization: ………………………………
- Phone Number: ………………………………
- Email address: ………………………………
- Role/Title in this project: ………………………………
- Years of industry experience in P3 projects
    - ➢ 5years and below
    - ➢ 6 to 10 years
    - ➢ 11 to 15 years
    - ➢ Over 15 years

- Name of P3 Project involved in: ………………………………
- Location of the P3 project: ………………………………

Section I - Project Characteristics

1. Describe the type/nature of this P3 project.
    - ➢ New greenfield construction
    - ➢ Rehabilitation
    - ➢ Reconstruction
    - ➢ Maintenance
    - ➢ Expansion
    - ➢ Other: ………….

2. P3 Project scope:
    - ➢ Total length of road: ………miles
    - ➢ Total number of bridges: ………….
    - ➢ Total number of lanes: …………….

3. What type of P3 contractual agreement was used in the project?
    - ➢ Design-Build-Operate (DBO)
    - ➢ Design-Build-Operate-Maintenance (DBOM)
    - ➢ Design-Build-Finance (DBF)
    - ➢ Design-Build-Finance-Operate (DBFO)
    - ➢ Design-Build-Finance-Operate-Maintenance (DBFOM)

4. What is the source of funding for the P3 project?
   If funded by public sector:

- Bonds
- Bank loan
- Bank debt
- Tax Revenues
- State funds
- Federal funds
- Availability payment
- Other…………….

If funded by private sector:

- Private Equity
- Private Activity Bonds (PABs)
- Private Toll Revenue Bond
- Cash (Internal Revenues)
- Other………….

5. Was there any schedule performance bonus in this contract?
    - Yes
    - No
    - If yes, how much US$.................

6. Were there any disincentives for late completion?
    - Yes
    - No
    - If yes, how much in $/day or $/month………………

Section II – Critical Success Factors (CSF)

CSFs and Cost performance

1. Using a scale of 1=Not significant to 5=Highly significant, please indicate the significance of following critical success factors for completing your project under or on budget.

S.No.	Critical Success Factors	Degree of Significance				
		1-Not Significant	2-Less Significant	3-Neutral	4-Significant	5-Highly Significant
1	Appropriate Risk allocation and sharing					
2	Competitive and transparent					

	procurement processes					
3	Favorable and efficient legal frameworks					
4	A robust and reliable private consortium.					
5	Government/political support and stability					
6	Timely land acquisition and appropriate compensation					
7	Financial feasibility and attraction					
8	Meeting output specifications					
9	Reliable Contractual arrangement					
10	Dedicated PPP unit					
11	Value for money					
12	Coordination among related stakeholders					
13	Stable macroeconomic condition					
14	Available finance market					
15	Favorable social support					
16	Economic viability					
17	Strong and good partnering					
18	Appropriate dispute resolution mechanism					
19	Clear contract clauses					
20	Proper guidelines regarding p3 delivery					
21	Experience of owners in p3 projects					

CSFs and Schedule performance

1. Using a scale of 1=Not significant to 5=Highly significant, please indicate the significance of following critical success factors for completing your project under or on schedule.

S.No.	Critical Success Factors	Degree of Significance				
		1-Not Significant	2-Less Significant	3-Neutral	4-Significant	5-Highly Significant
1	Appropriate Risk allocation and sharing					
2	Competitive and transparent procurement processes					
3	Favorable and efficient legal frameworks					
4	A robust and reliable private consortium.					
5	Government/political support and stability					
6	Timely land acquisition and appropriate compensation					
7	Financial feasibility and attraction					
8	Meeting output specifications					
9	Reliable Contractual arrangement					
10	Dedicated PPP unit					
11	Value for money					
12	Coordination among related stakeholders					

13	Stable macroeconomic condition					
14	Available finance market					
15	Favorable social support					
16	Economic viability					
17	Strong and good partnering					
18	Appropriate dispute resolution mechanism					
19	Clear contract clauses					
20	Proper guidelines regarding p3 delivery					
21	Experience of owners in p3 projects					

Section III
<u>Project cost performance</u>

1. Owner estimated cost (US$): …………………………….
2. Contract amount (US$): …………………………….
3. Total project completion cost (US$): …………………………….

4. How was the cost performance of the project (overrun or underrun)? Did the project had cost savings/advantage (cost underruns) compared to estimated budget? If yes, by how much percentage?
   - The project was completed on budget
   - Cost underruns
     - 1% - 10%
     - 11%-20%
     - 21%-30%
     - 31%-40%
     - 41%-50%
     - Lower than 50%
   - Cost overruns
     - 1% - 10%
     - 11%-20%
     - 21%-30%

- 31%-40%
- 41%-50%
- Higher than 50%

<u>Project schedule performance</u>

5. Owner estimated duration (in days): …………………………….
6. Actual project completion duration (in days): …………………………….

7. How was the schedule performance of the project (ahead of schedule or behind the schedule) after adopting P3? Did the project had schedule advantage compared to proposed schedule? If yes, by how much percentage?

- ➢ Project was completed on schedule
- ➢ Schedule underrun-
  - 1% - 10%11%-20%
  - 21%-30%
  - 31%-40%
  - 41%-50%
  - Lower than 50%

- ➢ Schedule overrun-
  - 1% - 10%11%-20%
  - 21%-30%
  - 31%-40%
  - 41%-50%
  - Higher than 50%

APPENDIX H: SURVEY QUESTIONNAIRE FOR P3 BUILDING PROJECTS

Date of Response: …………

- Respondent's Name: ……………………………………
- Company/Organization: ………………………………
- Phone Number: ………………………………
- Email address: ………………………………
- Role/Title in this project: ………………………………
- Years of industry experience in P3 projects
    - ➢ 5years and below
    - ➢ 6 to 10 years
    - ➢ 11 to 15 years
    - ➢ Over 15 years

- Name of P3 Project involved in: ………………………………
- Location of the P3 project: ………………………………

Section I - Project Characteristics

7. Describe the type/nature of this P3 project.
    - ➢ University Building
    - ➢ University Student Housing
    - ➢ Courthouse Building
    - ➢ Public building
    - ➢ Other: ………….

8. P3 Project scope:
    - ➢ Total area of building: ………square feet
    - ➢ Part of project scope:
        - o Construction of New facility
        - o Expansion of existing facility
        - o Rehabilitation and renovation
        - o Other please specify.................

9. What type of P3 contractual agreement was used in the project?
    - ➢ Design-Build-Operate (DBO)
    - ➢ Design-Build-Operate-Maintenance (DBOM)
    - ➢ Design-Build-Finance (DBF)
    - ➢ Design-Build-Finance-Operate (DBFO)
    - ➢ Design-Build-Finance-Operate-Maintenance (DBFOM)

10. What is the source of funding for the P3 project?
If funded by public sector:
    - Bonds
    - Bank loan
    - Bank debt
    - Tax Revenues
    - State funds
    - Federal funds
    - Availability payment
    - Other…………….

If funded by private sector:
    - Private Equity
    - Private Activity Bonds (PABs)
    - Cash (Internal Revenues)
    - Other…………

11. Was there any schedule performance bonus in this contract?
    - Yes
    - No
    - If yes, how much US$.................

12. Were there any disincentives for late completion?
    - Yes
    - No
    - If yes, how much in $/day or $/month………………

Section II – Critical Success Factors (CSF)

CSFs and Cost performance

1. Using a scale of 1=Not significant to 5=Highly significant, please indicate the significance of following critical success factors for completing your project under or on budget.

	Critical Success Factors	Degree of Significance				
		1-Not Significant	2-Less Significant	3-Neutral	4-Significant	5-Highly Significant
1	Appropriate Risk allocation and sharing					
2	Competitive and transparent procurement processes					

3	Favorable and efficient legal frameworks					
4	Commitment and responsibility of the public and private sectors					
5	Government/political support and stability					
6	Financial feasibility and attraction					
7	Long term relationship and partnership					
8	Good governance					
9	Economic environment					
10	Trust and openness					
11	Planning and design with approval					
12	Stable macroeconomic conditions					
13	Available finance market					
14	Continuous project monitoring and control					
15	Social support					
16	Effective communication					
17	Profit assurance for the private sector					
18	Reliable private consortium					
19	Demand for project					
20	Robust and clear agreement					
21	Reasonable contract mechanisms to deal with unexpected events					
22	Clear process around permitting					

CSFs and Schedule performance

1. Using a scale of 1=Not significant to 5=Highly significant, please indicate the significance of following critical success factors for completing your project under or on schedule.

	Critical Success Factors	Degree of Significance				
		1-Not Significant	2-Less Significant	3-Neutral	4-Significant	5-Highly Significant
1	Appropriate Risk allocation and sharing					
2	Competitive and transparent procurement processes					
3	Favorable and efficient legal frameworks					
4	Commitment and responsibility of the public and private sectors					
5	Government/political support and stability					
6	Financial feasibility and attraction					
7	Long term relationship and partnership					
8	Good governance					
9	Economic environment					
10	Trust and openness					
11	Planning and design with approval					
12	Stable macroeconomic conditions					
13	Available finance market					

14	Continuous project monitoring and control					
15	Social support					
16	Effective communication					
17	Profit assurance for the private sector					
18	Reliable private consortium					
19	Demand for project					
20	Robust and clear agreement					
21	Reasonable contract mechanisms to deal with unexpected events					
22	Clear process around permitting					

Section III - Project performance

<u>Project cost performance</u>

8. Owner estimated cost (US$): …………………………….
9. Contract amount (US$): …………………………….
10. Total project completion cost (US$): …………………………….

11. How was the cost performance of the project (overrun or underrun)? Did the project had cost savings/advantage (cost underruns) compared to estimated budget? If yes, by how much percentage?
    - The project was completed on budget
    - Cost underruns
        - 1% - 10%
        - 11%-20%
        - 21%-30%
        - 31%-40%
        - 41%-50%
        - Lower than 50%
    - Cost overruns
        - 1% - 10%
        - 11%-20%
        - 21%-30%

- 31%-40%
- 41%-50%
- Higher than 50%

<u>Project schedule performance</u>

12. Owner estimated duration (in days): …………………………….
13. Actual project completion duration (in days): …………………………….

14. How was the schedule performance of the project (ahead of schedule or behind the schedule) after adopting P3? Did the project had schedule advantage compared to proposed schedule? If yes, by how much percentage?

   - ➢ Project was completed on schedule
   - ➢ Schedule underrun-
     - 1% - 10%
     - 11%-20%
     - 21%-30%
     - 31%-40%
     - 41%-50%
     - Lower than 50%

   - ➢ Schedule overrun-
     - 1% - 10%
     - 11%-20%
     - 21%-30%
     - 31%-40%
     - 41%-50%
     - Higher than 50%

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  Dissertation: Assessment of Success Factors and Comparative Analysis of Public Private Partnership (P3) project performances against Design-Build and Design-Bid-Build project delivery
- Master of Science in Civil Engineering, Nepal Engineering College-Center for Postgraduate studies, Pokhara university, Nepal
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Research Publications

- Shrestha B., Shrestha P.P., Maharjan R., Gransberg D., "Cost, Change Order, and Schedule Performance of Highway Projects: a Longitudinal Analysis", Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, DOI: 10.1061/(ASCE)LA.1943-4170.0000523

- Brogan E., Shrestha B., Clevenger C. C., Shrestha P. P., "State Transportation Agencies' Current Practices in Providing Design Information for Design-Build Projects during Procurement", Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, DOI: 10.1061/(ASCE)LA.1943-4170.0000521

- Shrestha B., Shrestha P.P, "Identification of Critical Success Factors (CSFs) for Public-Private Partnerships across infrastructure sectors" Proceedings of 9th International conference on Construction Engineering and Project Management

- Shrestha B., Shrestha P.P, "Cost and Schedule Analysis of highway projects based on project types" Proceedings of 9th International conference on Construction Engineering and Project Management

- Shrestha B., Park J., Shrestha P.P, "Factors that Impact Construction Workers' Hazard Recognition Ability and their Technological Solutions" Proceedings of 9th International conference on Construction Engineering and Project Management

Accomplishments

- Recipient of Advanced Doctoral Graduate Assistantship Completion (ADGAC) Fellowship awarded by Graduate College, University of Nevada, Las Vegas for Spring 2023
- Recipient of Graduate Differential Fees Scholarship awarded by Howard R. Hughes College of Engineering, University of Nevada, Las Vegas for academic years 2022 and 2023
- Recipient of Roy and Helen Kelsall Engineering Scholarship awarded by College of Engineering, University of Nevada, Las Vegas for academic year 2021-2022
- Recipient of the 2022/2023 "Building Hope Scholarship" awarded by Professional women in Building of Southern Nevada
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