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Identifying Perceived Factors to Complete Progressive Design-Build (PDB) Project Successfully: An Exploratory Factor Analysis

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Abstract

Progressive Design-Build (PDB) has gained increasing attention as an alternative project delivery method that promotes early collaboration between owners and design-builders. However, limited empirical research has systematically identified the factors that are perceived to be critical to complete PDB projects successfully. This study identifies and evaluates perceived important success indicators (SIs) and groups them into broader success factors (SFs) that affect PDB projects during procurement and implementation. A narrative literature review and preliminary expert screening identified and finalized the procurement- and implementation-related SIs, followed by a questionnaire survey of industry professionals and academicians. Fifty-five valid responses from respondents who had worked on PDB projects across multiple projects were analyzed using statistical analyses. Exploratory Factor Analysis (Principal Axis Factoring) grouped the procurement-related success indicators into four SFs: owner competencies, owner and design-builder working relationships, design-builder competencies, and independent third parties' experience. Four implementation SFs were identified: owner and design-builder working relationships, owner's project management processes, owner's and design-builder's competencies, and owner's design and change-management processes. The findings provide practical guidance for owners and design-build teams on prioritizing organizational, relational, and managerial practices perceived as important for successful PDB project delivery.

Keywords: progressive design-build; project delivery methods; procurement-related success factors; implementation-related success factors; principal axis factoring analysis

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1. Introduction

One major alternative delivery method for designing and constructing building and infrastructure projects is lump-sum Design-Build. In this delivery method, the design-builder bids on design and construction costs during procurement, when about 15% of the design is complete. Because detailed design information is lacking during procurement, the design-builder has difficulty estimating construction costs. Therefore, the design-builder must accept the risk of a cost overrun. To reduce cost-overrun risks, the revised lump-sum DB method was introduced, in which the design-builder is selected based on qualifications. After 50–90% of the design is completed, the design-builder sets the Guaranteed Maximum Price (GMP) for the construction portion of the project. This method is called Progressive Design-Build (PDB). PDB has been successfully imple-

mented across building and infrastructure sectors, including water, wastewater, aviation, and building projects, and is increasingly adopted in highway projects [1]. This success stems from PDB's advantages over the lump-sum DB method, including greater owner control over scope, cost, and schedule; improved quality, flexibility, and innovation; and risk allocation [2–4].

Another notable feature of PDB is the off-ramp option, which allows the owner to terminate the contract and pursue an alternative contracting strategy if the parties cannot agree on the final project terms [5]. PDB is also characterized by open-book negotiation processes, in which the project team collaboratively develops a work plan with full cost transparency, promoting a trust-based decision-making environment and alignment with the owner's budget goals [4]. To support cost transparency and ensure that the price aligns with fair market value, the owner typically hires an Independent Cost Estimator (ICE) [1].

The American Council of Engineering Companies of New York has recommended that owners consider design-builders' experience, project implementation approach, risk identification method, and collaboration with third parties [6]. They have also emphasized owner and design-builder team engagement, including the composition of the owner's and design-builder's teams. The owner representative should have decision-making authority and relevant experience. They should also hire experienced ICE, an independent scheduler, and subject matter experts to provide unique expertise and perspective. The design-builder team should include experienced design and construction management professionals with relevant qualifications and experience. The system should include an open-book accounting system to ensure transparency.

Research on PDB remains relatively limited but has attracted increasing attention in recent years, as the method is adopted more widely across building and infrastructure sectors. However, few studies have evaluated the procurement- and implementation-related success factors that influence PDB project success. Recent studies have examined the cost and schedule benefits of PDB across infrastructure projects, suggesting that PDB is particularly valuable for complex projects with tight schedules. Adamtey and Onsarigo [7] conducted a comprehensive literature review and case study analysis to identify effective tools for successful PDB implementation. Among these, project packaging was especially effective at improving cost and schedule certainty by enabling progressive estimates and better cost control. However, the study relied primarily on the literature and recommended further validation through interviews and surveys with project stakeholders.

To compare the time and cost performance of PDB and lump-sum DB projects, Adamtey [8] analyzed data from 75 PDB and 92 lump-sum DB projects across sectors. The study concluded that PDB consistently had fewer schedule overruns than lump-sum DB, though it found no significant differences in cost performance. Further supporting these findings, Jeong et al. [9] proposed the "Four Pillars of Project Success," which are predictability, risk, schedule, and cost; they emphasized that PDB enhances schedule performance and project predictability through early party integration and collaborative planning. While PDB may not always reduce costs, it can maximize project value.

Alameri and Esmaeili [10] further explored the main factors influencing owners' decisions to select PDB and identified eight critical selection criteria. Their research outlined that scope flexibility and early procurement of long-lead materials can support budget control and schedule performance. Building on this, Alameri and Esmaeili [11] statistically analyzed 19 completed PDB projects. They recommended best practices, including early design-builder involvement, formal partnering agreements, risk identification and allocation, setting the GMP after 60% design completion, verifying costs

through independent estimators, and prioritizing team qualifications. Their findings highlighted that early collaboration, transparent cost processes, and stakeholder trust are essential to successful project outcomes. However, both studies were limited by sample size and sector focus, indicating the need for broader research using a more diverse dataset and more advanced statistical analysis techniques.

In recent years, researchers have also explored implementing PDB in specific sectors. Gad et al. [12] investigated PDB in airport projects. They found that owners primarily choose this approach to accelerate schedules, transfer design risks to the design-builder, and maintain input in design decisions. Their case study of a California terminal expansion highlighted the importance of continuous owner engagement, strong upper-management buy-in, efficient change-order processing, and clear procurement documents to ensure project quality and minimize delays.

Nguyen et al. [13] investigated the success factors and lessons learned from the PDB airport capital construction projects. The authors reviewed PDB guidance and manuals, surveyed 39 US airports, and interviewed 12 airport representatives to meet the objectives. The study found that owners are using PDB for their projects because it is flexible in handling complexity, reduces claims and constructability issues, and improves cost control. The major benefits owners reported from using PDB include improved project schedules, enhanced design control mechanisms, and effective management of project risks and complexity.

Similarly, Shang and Migliaccio [14] conducted a case study of the University of Washington's West Campus Utility Plant and presented lessons learned for PDB implementation in the building sector. Their research proposed early collaboration, real-time cost feedback, and workforce continuity and targeted PDB training for new team members as essential to project success. The study also stressed that owners must remain actively engaged throughout all project phases, and not just design, to achieve intended outcomes.

Salih et al. [15] analyzed 21 water and wastewater PDB projects from the DBIA database, including their cost and schedule performance. Their study found that most projects were completed on or ahead of schedule and under budget. The authors emphasize that strong planning, early risk management, and team collaboration are essential for PDB success. Nevertheless, the authors caution that these findings should not be generalized to other sectors, as project type can significantly influence delivery-method performance.

To address challenges in PDB implementation in highway projects, Alleman and Tran [1] identified legislative barriers, limited owner education and resources, and low industry interest. Their study emphasized that early contractor involvement improves risk allocation, project quality, and schedule performance when teams are well-coordinated. To explore alternatives for states where PDB legislation is restrictive or unclear, Gransberg [4] has demonstrated through case studies and legislative content analysis that many DOTs can implement PDB under existing lump-sum DB statutes, even without specific PDB legislation. The study further reinforces that PDB can accelerate procurement and improve cost and schedule certainty through early contractor engagement and open-book pricing practices.

Molenaar et al. [16] conducted a literature review and survey with 581 practitioners to determine how the PDB is adopted, perceived, and practiced. The survey results showed that 75% of respondents were either satisfied or very satisfied with using the PDB method in their projects. Respondents said the key drivers behind PDB's position perception are collaboration, team dynamics between the owner and the design-builder, the level of owner involvement in design and construction phases, transparency, and

trust. Respondents also stated that in PDB, risk identification and allocation are more effective because PDB promotes a shared-risk philosophy, raises awareness of design risk, and clarifies project scope, cost, and timeline.

Recently, the authors conducted a literature review on PDB opportunities and challenges by reviewing scholarly articles [17]. They identified 32 articles to achieve the objectives. The major challenges in implementing PDB included legislative restrictions, a lack of owner education and a collaborative mindset, limited industry interest, complexity in dealing with third parties, and unfairness in ramp-off to the design-builder. Opportunities in the PDB method include increased project innovation, greater control and scope flexibility, more flexible price negotiation, more equitable risk allocation, early contractor involvement, owner involvement in the design process, open-book pricing, etc.

Tavares & Shrestha [18] conducted a questionnaire survey of transportation officials who have used PDB methods in their projects to rank procurement- and implementation-related success indicators. The literature review identified 19 procurement-related and 18 implementation-related indicators that affect PDB projects, which the authors sent to transportation officials to rank. A total of 10 respondents who have worked on transportation PDB projects rated the indicators. Descriptive statistics showed that early involvement of the design-builder during the design phase, effective communication between the owner and design-builder, and the owner communicating their end needs to the design-builder were the most important procurement-related indicators. The top three implementation-related indicators identified were the level of trust between the owner and the design-builder, the owner communicating project requirements to the design-builder, and effective communication among project participants during the implementation phase. In this study, respondents were transportation officials only. However, the authors recommended expanding this survey and collecting data from personnel involved in buildings, water/wastewater, and aviation.

In summary, studies on PDB across building and infrastructure sectors have highlighted several practices that improve schedule and cost performance in complex projects. However, the literature reveals a few gaps. First, many studies are limited by small sample sizes or sector-specific analyses, which restricts the generalizability of their findings. Second, while previous research has identified important practices and selection criteria, no prior research has comprehensively identified and analyzed success indicators across procurement and implementation phases and grouped them into success factors using exploratory factor analysis. Therefore, this study aims to fill these gaps by identifying the top five procurement- and implementation-related SIs through a literature review, evaluating their relative importance using industry survey data, and grouping them into SFs using statistical analysis techniques.

2. Materials and Methods

This study adopts a mixed-methods approach, following the methodology proposed by Shrestha et al. [19], to identify and evaluate the procurement- and implementation-related SFs perceived as important for PDB project success. The study consisted of three main phases: 1. identification of potential SIs through a narrative literature review; 2. preliminary expert screening and prioritization of the identified SIs through a questionnaire survey; and 3. analysis of the collected data using the Relative Importance Index to identify the important SIs and principal axis factoring analysis to group them into various SFs. These steps are described in the following sections. Figure 1 shows the flowchart depicting the research methodology.

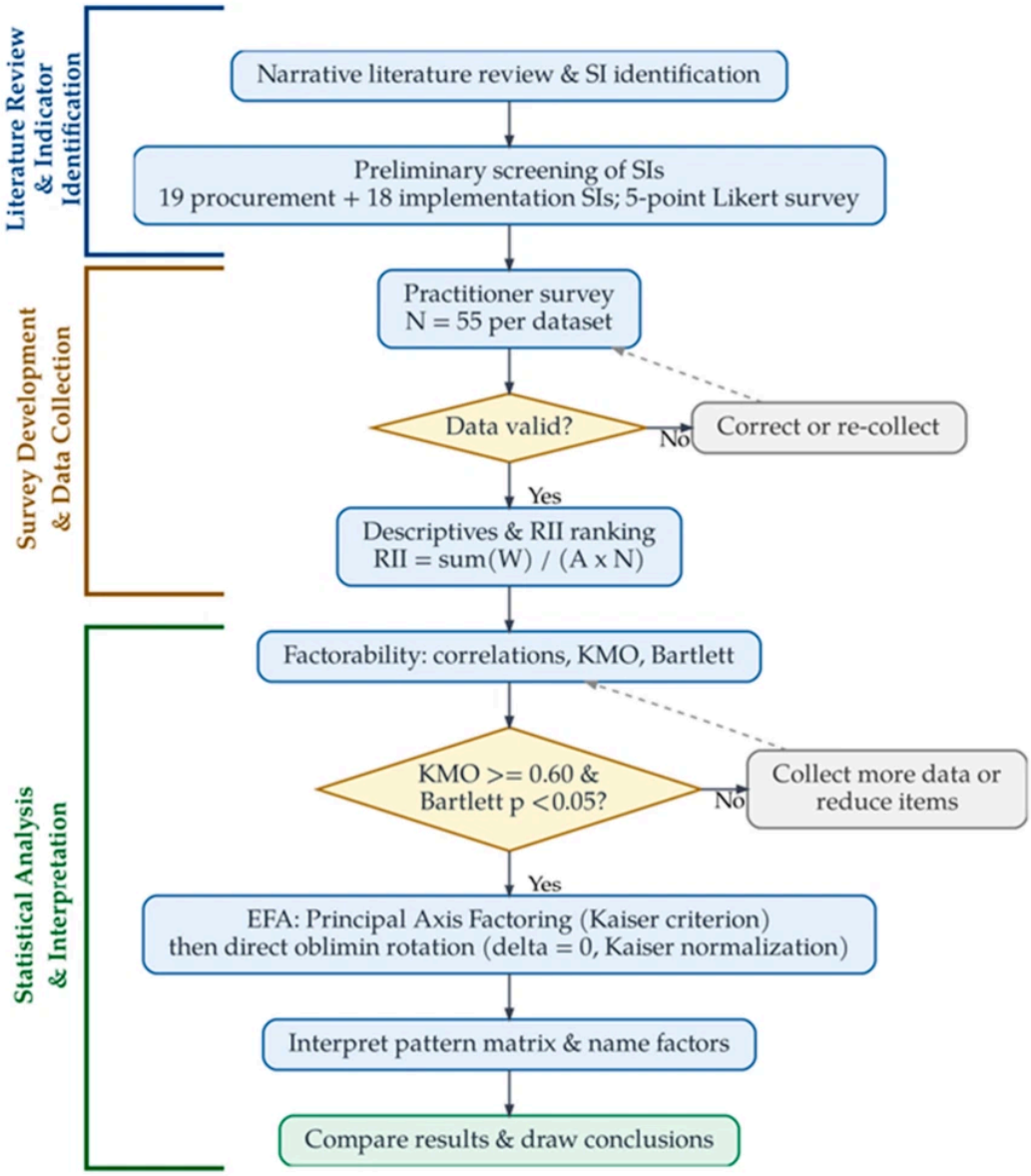


Figure 1. Research methodology flowchart.

2.1. Literature Review

The authors initially conducted a narrative literature review to identify and synthesize the main success indicators associated with successful lump-sum DB and PDB projects. Relevant publications were retrieved from the DBIA bookstore and Google Scholar using the keywords "progressive design-build," "design-build," "success indicators," "project performance," "buildings," and "infrastructure." Sources included peer-reviewed journal articles, conference papers, industry white papers, and DBIA publications. Studies were included if they examined PDB procurement or implementation practices, selection factors, or success practices for implementing PDB. Because research specifically addressing success indicators in PDB projects is limited, we have also included influential studies on success indicators in lump-sum DB projects.

The authors extracted the success indicators based on their relevance to successful completion of PDB projects, as discussed in the studies, and on their repeated mention. The authors evaluated these indicators for their potential positive influence on PDB project outcomes and then organized them by contract phase (procurement and implementation).

This literature review initially identified 63 individual success indicators that are perceived to positively influence DB project outcomes. After synthesizing the concepts and removing duplicates, the authors consolidated them into an initial list of 35 distinct indicators (17 for the procurement phase and 18 for the implementation phase). Appendi x A (Tables A1 and A2) lists the success indicators for both the procurement and implementation phases of most DB projects and their corresponding literature sources.

2.2. Questionnaire Development and Data Collection

2.2.1. Preliminary Expert Screening Stage

Before the main survey, a preliminary expert screening was conducted on Qualtrics with two senior engineers with extensive project delivery experience to check the relevance of the extracted success indicators that positively impact PDB project success. One expert is a faculty member who has researched alternative delivery methods for the last 30 years, and the other has more than 20 years of professional experience in alternative delivery methods, including PDB. Participants reviewed the initial list of 35 success indicators and rated their relevance as "Not at all important," "Moderately Important," or "Extremely Important." They were also invited to suggest additional indicators not included in the initial list.

The preliminary expert screening results helped refine the final list of success indicators for the procurement and implementation phases to successfully complete PDB projects. Respondents rated all indicators as either "Moderately Important" or "Extremely Important," and none were rated "Not at all important." Each respondent also suggested one additional success indicator, both rated as "Extremely Important" for the procurement phase only. They are as follows:

- Consistent communication of the owner's procurement plan and expectations from project initiation through procurement.
- Design-builder's participation in the procurement phase, through competitive bidding and selection of subcontractors' packages.

These experts stated that both procurement-related SIs are "Extremely Important" for the PDB project success. The authors incorporated both indicators into the final list of procurement-phase SIs in the questionnaire survey. Therefore, the final list includes 19 SIs for the procurement phase and 18 SIs for the implementation phase, as presented in the study.

2.2.2. Questionnaire Survey

A second, more comprehensive Qualtrics questionnaire was developed to gather data on PDB projects in which respondents were involved and to assess the importance of the final list of procurement- and implementation-related success indicators for successfully completing PDB projects. This survey was distributed to a wider group of professionals, including DOT personnel and project managers, public and private owners, design-builders, PDB researchers, and practitioners. Respondents were also asked to forward the questionnaire to colleagues with PDB project experience. The questionnaire consisted of four main sections: 1. respondent's background (name and contact information, years of experience, number of PDB projects involved); 2. characteristics of the PDB projects the respondents were involved with (name and location of project, respondent's role in the project, project type, procurement method, payment method, project's cost, and schedule performance ranges); 3. importance rating of procurement-related indicators for completing PDB projects successfully; and 4. importance rating of implementation-related indicators for completing PDB projects successfully. The importance rating was measured on a 5-point Likert Scale (1 = Not at all important, 2 = Slightly important,

3 = Moderately important, 4 = Very important, and 5 = Extremely important). It included all indicators identified through the literature review and expert screening. Respondents were asked about the range of cost and schedule performance for the PDB projects they were involved in. If the respondents were involved in more than one PDB project, they were instructed to provide the average performance values. These project performance data were collected to determine, on average, whether the PDB projects they had worked on were completed on time and within budget. The authors did not ask respondents to rate these SIs based on the performance of the PDB projects they had completed. Respondents rated these indicators based on their perception of successful completion of PDB projects. Appendix A.15 shows the questionnaire.

2.2.3. Statistical Testing

This research used an exploratory factor analysis to determine procurement- and implementation-related success factors for PDB project success. The questionnaire was sent to owners, designers, engineers, contractors, consultants, and academicians with experience in PDB projects. The sample population includes all people in the US with experience in PDB methods across any type of project. To obtain contact addresses, the authors used previously available contact emails and searched for engineers' and personnel's contact addresses through networks and websites. This study used non-random convenience and voluntary response sampling methods. Descriptive statistics were used to determine the relative importance index and identify the most important SIs. Finally, Principal Axis Factoring (PAF) grouped the SFs from these indicators. This statistical test was conducted using IBM SPSS Statistics 32.0.0.. It is described below.

The Relative Importance Index (RII) was used to rank the perceived importance of the identified SIs based on responses collected using a 5-point Likert scale. The RII test is commonly used in construction research because it allows success indicators to be ranked based on the importance assigned to each [19]. The RII is calculated as in Equation (1):

$$\mathrm{RII} = \frac{\sum \mathrm{W}}{\mathrm{A} \times \mathrm{N}}, \quad (1)$$

where

W is the weight assigned to each indicator by respondents.

A is the highest possible weight, equal to 5.

N is the total number of respondents.

RII values range from 0 to 1, with values closer to 1 indicating greater importance. After calculating the RII values, the SIs were ranked from most to least important. We ranked procurement- and implementation-related indicators separately to better understand how rankings differ across project phases.

In this study, we used exploratory factor analysis with principal axis factoring (PAF) to reduce the total number of correlated indicators to a smaller set of underlying factors. The study used 19 procurement-related and 18 implementation-related indicators to form PDB success factors. The extracted factors represent groups of related indicators that explain the dataset's major patterns. These factors were then interpreted and labeled based on the common characteristics of the indicators within each group, representing the PDB SFs. Before conducting PAF, we evaluated the data's suitability for factor analysis using the Kaiser-Meyer-Olkin (KMO) test. A test value greater than 0.60 indicates that the data are appropriate for factor analysis. Bartlett's Test of Sphericity was used to examine whether the variables are correlated in the population. If the *p*-value is less than

0.05, the test rejects the null hypothesis that the variables are orthogonal (i.e., not correlated). The initial and extracted communalities of each variable were also reviewed to assess the proportion of each variable's variance explained. To determine the number of factors, the eigenvalues and the scree plot were reviewed. The pattern matrix table was used to identify each variable's factor loadings. The rotation method used was Oblimin with Kaiser Normalization. The pattern matrix table is reviewed to decide which variables are loaded in which factor. Generally, a loading threshold of 0.5 is used for this analysis.

3. Results

This section presents the questionnaire survey results and the RII and PAF analyses conducted to identify and prioritize the procurement- and implementation-related SIs and SFs affecting the PDB project success.

3.1. Demography of the Respondents

In the questionnaire survey, the response rate among contacted respondents was about 20%. Of the 72 responses received, 11 participants reported no experience with PDB, and several entries were incomplete or contained missing data (six responses). Ultimately, we analyzed 55 valid responses from professionals with PDB experience. Respondents reported the average cost and schedule performance of PDB projects they worked on. Of these respondents, 27 worked on transportation projects, 19 on building projects, six on water and wastewater projects, two on airport projects, and one on a stormwater project.

Participants' PDB experience ranged from less than 2 years to over 10 years, and most professionals worked on one to three PDB projects. Respondents also reported serving in a wide range of professional roles for each project, such as procurement manager, project manager, principal engineer, project engineer, design manager, project director, owner's advisor/representative, owner executive, architect, partner-in-charge, design principal, construction manager, and design-build manager.

3.2. Projects' Characterization

The projects in which the respondents were involved varied geographically, with 54 located in the United States and one in Canada. The highest number of respondents was reported working in California (13), followed by Washington (8), Arizona (3), Oklahoma (3), Texas (3), Michigan (3), North Carolina (3), Indiana (3), Kansas (3), Virginia (3), Ohio (2), and Utah, Missouri, Maryland, Colorado, Georgia, New Mexico, and Kentucky (1 each). The types of construction represented included expansion, new construction, repair and maintenance, rehabilitation, and other projects.

Regarding procurement methods (Figure 2a), about 62% of respondents used qualification-based selection (QBS), 33% used best value (BV), and 5% used other methods. Regarding payment methods (Figure 2b), 58% used GMP, 33% used lump sum, and 9% used other methods.

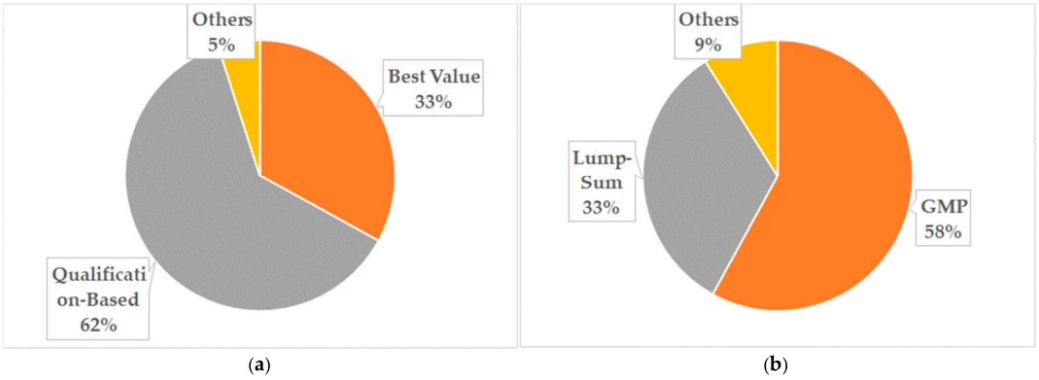


Figure 2. Distribution of procurement and payment methods among surveyed projects: (**a**) procurement methods; (**b**) payment methods.

Regarding cost performance (Figure 3), on average, 58% of PDB projects in which the respondents were involved were completed on budget, 16% under the planned cost by less than 10%, and 6% under the planned cost by more than 10% (22% under budget). However, 20% of PDB projects had cost overruns: 11% were over the planned cost by less than 10%, and 9% were over the planned cost by more than 10%.

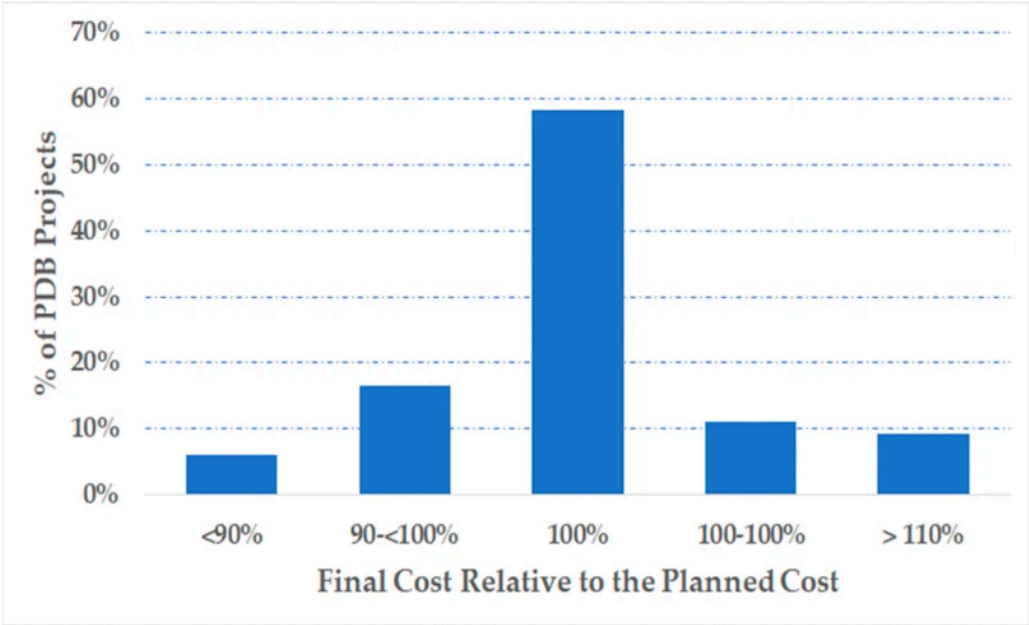


Figure 3. Reported cost performance relative to planned cost.

Schedule performance (Figure 4) shows that 55% of PDB projects the respondents were involved in were delivered on schedule; 19% were ahead of schedule (4% by more than 10% and 15% by less than 10%); and 27% were behind schedule. Of the delayed projects, about 16% were delayed by 10% relative to planned duration, and 11% were delayed by more than 10% relative to planned duration. Based on these performance data, most PDB projects in which respondents were involved were completed on or under budget and on or ahead of schedule.

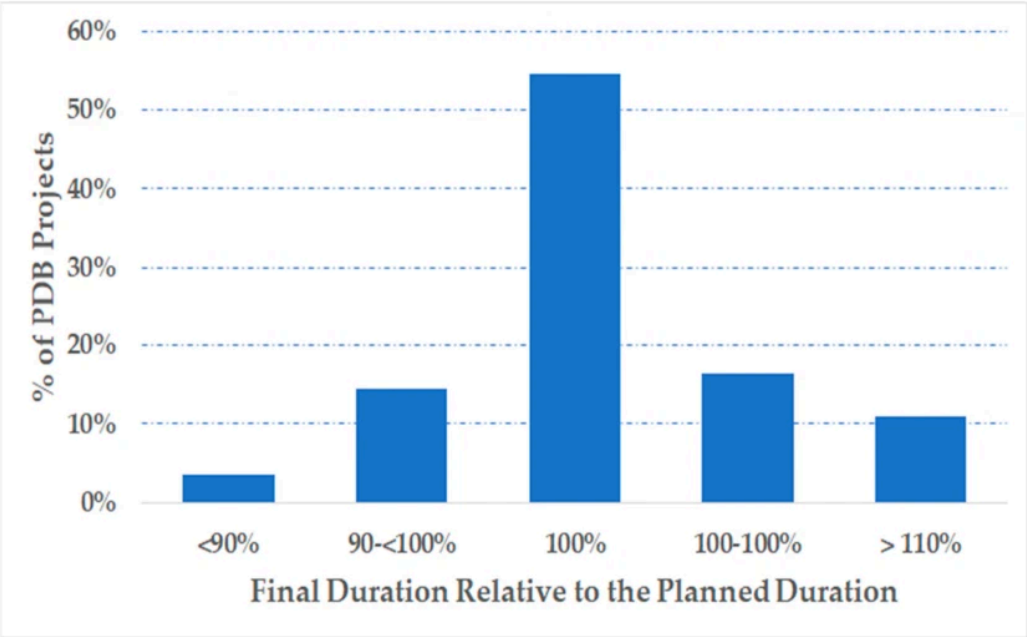


Figure 4. Reported schedule performance relative to planned duration.

3.3. Procurement-Related Success Factors

3.3.1. Ranking of Procurement-Related Success Indicators

The RII values identified the top SIs in the procurement phase. Table 1 presents the top five highest-rated procurement-phase SIs, along with their RII values and rankings for PDB projects. These include effective communication between the owner and design-builder during the procurement phase (SI #14), early involvement of the design-builder during the project design phase (SI #10), the owner clearly communicating their end needs of the project (SI #2), proper risk identification and allocation from the owner (SI #1), and collaboration between the owner and design-builder during the procurement phase (SI #15). In Appendix A.3 and Table A3 shows the ranking of all 19 procurement-related indicators and their RII values.

Table 1. Ranking of top five procurement-related SIs based on RII values.

SI #	Success Indicators' Description	RII	Rank
14	Effective communication between the owner and design-builder during the procurement phase	0.93	1
10	Early involvement of the design-builder during the project design phase	0.92	2
2	The owner has clearly communicated their end needs of the project	0.92	2
1	Proper risk identification and allocation from the owner	0.90	4
15	Collaboration between the owner and design-builder during the procurement phase	0.88	5

3.3.2. Principal Axis Factoring Analysis of Procurement-Related Success Indicators

An exploratory factor analysis (Principal Axis Factoring) was used to identify the success factors among these 19 procurement-related success indicators. These factor analysis results show how the indicators align within factors, so the owner can focus on the perceived important factors that make the PDB project successful. Oblimin rotation with the Kaiser Normalization method was used to form factors from these indicators. The appropriateness of the PAF and the correlations between the SIs and their corre-

sponding factors were assessed using the Kaiser–Meyer–Olkin (KMO) test. The KMO value was 0.76 when the PAF analysis included all 19 variables. A value greater than 0.6 indicates that the data are appropriate for factor analysis. The initial communality values range from 0.82 to 0.41 (see Table A4 in Appendix A.4). In addition, Bartlett's Test of Sphericity was statistically significant ($p < 0.001$), indicating significant correlations among the SIs and factors (Table 2).

Table 2. Bartlett's Test of Sphericity results for procurement-related SIs.

Chi-Square Value	Degree of Freedom	*p*-Value
609.73	171	<0.001

When conducting PAF, we retained factors with eigenvalues greater than 1 (refer to Table A5 in Appendix A.5). The authors also reviewed the scree plot to determine the number of factors retained (Figure A1 in Appendix A.6). Both datasets show that these indicators can be reduced to four factors. Table 3 shows four factors extracted from the PAF test, their correlated indicators, and the factor names. For detailed PAF test results, including the factor loadings and % variance explained, refer to Table A6 in Appendix A.7. The factor loadings were set at 0.50. If the variables are loaded in two factors, whichever factor loading is higher is selected. The pattern matrix was used to determine each indicator's factor loading (refer to Appendix A.8 and Table A7). The analysis identified four SFs correlated with 17 of 19 SIs. SI #10 and SI #17 did not load on any of these factors. The first SF shows a high correlation with seven SIs, each with a factor loading greater than 0.50. The first factor accounts for 39.74% of the total variance explained and captures the relationship among these 7 SIs. The second SF consists of 2 SIs and explains 10.27% of the total variance. Together, these two factors explain 50.01% of the total variance. The third and fourth SFs relate to four SIs each. These factors explain 9.30% and 7.24% of the variance, respectively. These 17 SIs account for 66.55% of the variance explained for these four SFs. Thus, four SFs can be identified for the procurement phase of successful PDB projects.

Table 3. Procurement-related factors and correlated indicators.

SF #	Name of SF	Correlated Indicators
1	Owner Competencies	Proper risk identification and allocation from the owner
		Owner's flexibility with project scope and design
		The owner has established a procurement policy for PDB projects
		Consistent communication of the owner's procurement plan and expectations from project initiation to procurement
		Types of contract procurement methods used to select the design-builder
		Design-builder's participation in the procurement phase, through the competitive bidding and selection of subcontractors' packages
		Collaboration between the owner and the design-builder during the procurement phase
2	Independent Third Parties' Experience	Independent QA/QC firm's experience
		Independent Cost Estimator's (ICE) experience
3	Design-Builder Competencies	Owner's experience with the PDB process
		Types of payment methods used for construction work (GMP or Lump-Sum)
		Design-builder's experience with the PDB process
		Design-builder's financial capacity

SF #	Name of SF	Correlated Indicators
4	Owner and Design-Builder Working Relationship	The owner has clearly communicated their end needs of the project
		The owner's process of open-book negotiations for design and construction costs
		Effective communication between the owner and the design-builder during the procurement phase
		Timing of the construction cost setting

The four extracted SFs are interpreted according to the common characteristics of the indicators loading on each component, as described below:

- SF #1—Owner Competencies: This SF includes indicators related to the owner's risk identification and allocation process, flexibility in making changes in scope and design, procurement policies and types, communication practices, and collaborative efforts with the design-builder during the procurement phases. The owner should have a policy requiring the design-builder to participate in the procurement phase so that both can align with project goals
- SF #2—Independent Third Parties' Experience: This SF includes indicators related to third parties' experience. Generally, in PDB projects, independent consultants can conduct cost analysis and QA/QC tasks during the construction phase. This factor highlights their experience in making PDB projects successful
- SF #3—Design-Builder Competencies: This SF consists of indicators related to the design-builder's ability to effectively manage project risks, resources, project requirements, financial capacity, and payment methods used in the construction contract. This factor also highlights the value of PDB process experience with both the owner and the design-builder. If the owner has PDB experience, they can select a highly competent design-builder. In addition, the design-builder should know what types of payment methods can be used in a construction contract so that they can ensure cost certainty.
- SF #4—Owner and Design-Builder Working Relationship: This SF represents the quality of interaction and collaboration between the owner and design-builder during the procurement phase, including clear communication of project needs, open-book negotiations, effective communication between stakeholders, and timing of construction cost setting. It highlights the importance of transparency and effective collaboration between the owner and design-builder during the PDB project procurement phase.

3.4. Implementation-Related Success Factors

3.4.1. Ranking of Implementation-Related Success Indicators

Using the same criteria as the procurement phase, the RII values helped to identify the top implementation-related SIs. Eight implementation-related SIs were perceived as the most important indicators for successful PDB projects. These include level of trust between the owner and the design-builder (SI #11), effective communication between the owner and the design-builder during the implementation phase (SI #13), the owner clearly communicating the project requirements to the design-builder (SI #1), the owner and the design-builder share common project goals (SI #12), design-builder's upper management support (SI #7), owner's upper management support (SI #4), level of the owner's involvement during the design phase (SI #2), and the design-builder having good project management capability for PDB projects (SI #8). Table 4 presents the top eight implementation-related SIs, ranked by RII values, as the top indicators for success-

ful PDB projects. For the ranking and RII values of all the implementation-related indicators, refer to Appendix A.10 and Table A9.

Table 4. Ranking of top eight implementation-related SIs based on RII values.

SI #	Success Indicators' Description	RII	Rank
11	Level of trust between the owner and the design-builder	0.94	1
13	Effective communication between the owner and the design-builder during the implementation phase	0.93	2
1	The owner has clearly communicated the project requirements to the design-builder	0.92	3
12	The owner and the design-builder share common project goals	0.89	4
7	Design-builder's upper management support	0.87	5
4	Owner's upper management support	0.87	5
2	Level of the owner's involvement during the design phase	0.87	5
8	Design-builder has good project management capability for PDB projects	0.87	5

3.4.2. Principal Axis Factoring Analysis of Implementation-Related Success Factors

As in the procurement phase, Principal Axis Factoring analysis identified the critical success factors among these 18 indicators. In this case, the 18 implementation-related indicators had initial communality values ranging from 0.48 to 0.86 (see Table A9 and Appendix A.10). As in the procurement phase, similar criteria, eigenvalues, and scree plot observations were used to determine the number of factors (see Appendix A.11 and Table A10, and Appendix A.12 and Figure A2). These factor analysis results show how the implementation-related success indicators align within factors, so PDB project owners can focus on the perceived important factors to make their PDB project implementation phase successful. Oblimin rotation with the Kaiser Normalization method was also used to form factors from these indicators. The appropriateness of the PAF and the correlations among the SIs and their corresponding factors were assessed using the Kaiser–Meyer–Olkin (KMO) test and Bartlett's Test of Sphericity. The KMO value was 0.848, indicating that PAF was appropriate for this dataset. A KMO value greater than 0.60 is considered acceptable. In addition, Bartlett's Test of Sphericity was statistically significant ($p < 0.001$), indicating significant correlations among the SIs and factors (Table 5).

Table 5. Bartlett's Test of Sphericity results for implementation-related SIs.

Chi-Square Value	Degree of Freedom	*p*-Value
735.07	153	<0.001

Table 6 shows the implementation-related success factors for PDB projects. Appendix A.13 and Table A11 shows the results of the PAF analysis for implementation-related SIs and their factor loadings. The analysis identified four implementation-related SFs that correlate with 15 out of 18 SIs. The first implementation-related SF correlates with 6 SIs, each with a factor loading greater than 0.50. The first factor accounts for 48.77% of the total variance explained and captures the relationship among these six SIs. The second implementation-related SF consists of 4 SIs (SI #14, SI #16, SI #17, and SI #18) and explains 11.87% of the total variance. In aggregate, these two SFs explain 60.63% of the total variance. The third and fourth implementation-related SFs relate to 3 SIs (SI #5, SI #7, and SI #8) and 2 SIs (SI #2 and SI #3), explaining 6.74% and 6.53% of the total variance, respectively. These 15 SIs account for 73.90% of the total variance explained for

these four SFs. So, four SFs could be identified for the implementation phase to correlate with the perceived success of PDB projects. The factor loadings were set to 0.50. Three implementation-related SIs (SI #6, SI #10, and SI #15) did not load on any of these four factors. The rotation method used was Oblimin with Kaiser Normalization. The pattern matrix was used to determine each variable's factor loading. Appendix A.14 and Table A12 shows the pattern matrix for implementation-related SIs.

Table 6. Implementation-related factors and correlated indicators.

SF #	Name of SF	Correlated Indicators
1	Owner and Design-Builder Working Relationship	The owner has clearly communicated the project requirements to the design-builder
		Owner's upper management support
		Design innovations from the design-builder
		Level of trust between the owner and design-builder
		The owner and the design-builder share common project goals
		Effective communication between the owner and the design-builder during the implementation phase
2	Owner Project Management Processes	Quality of work packaging during the construction phase
		Effective QA/QC program in place
		An effective project control mechanism is in place
		Availability of construction workforce and materials
3	Owner and Design-Builder Competencies	The owner has good project management capability for PDB projects
		Design-builder's upper management support
		Design-builder has good project management capability for PDB projects
4	Owner Design and Change Management Processes	Level of the owner's involvement during the design phase
		Owner's effective change management process

The four factor groups are explained below:

- SF #1—Owner and Design-Builder Working Relationship: This factor includes six success indicators associated with communication, trust, alignment of project goals, and the owner's upper management support. It emphasizes the importance of strong working relationships and collaboration between the owner and design-builder during implementation.
- SF #2—Owner Project Management Processes: This factor consists of four success indicators related to project execution and management, including work packaging quality, effective QA/QC programs and project controls, and workforce and material availability.
- SF #3—Owner and Design-Builder Competencies: This factor represents three success indicators: the organizational and managerial capabilities of both the owner and design-builder, including project management capability and design-builder upper management's support.
- SF #4—Owner Design and Change Management Processes: This factor includes two success indicators associated with the owner's involvement during the design phase and the ability to manage project changes throughout implementation effectively.

Both success indicators will help reduce change orders and, if required, manage them properly in PDB projects.

4. Discussion

4.1. Procurement-Related Success Indicators (SI) Rankings

First, this study identified the procurement-related success indicators perceived as important for successfully completing PDB projects. Based on ratings from experts involved in PDB projects, the study identified the top five highly rated success indicators that will play an important role during the procurement phase for successful execution of PDB projects. The results showed that SI #14 was the top-ranked procurement-related indicator and was assessed as important to successfully completing PDB projects. This indicator reflects effective communication between the owner and the design-builder during procurement. The owner must be transparent and provide up-to-date information about the procurement process to design-builders bidding on PDB projects. Therefore, most owners hold pre-bid meetings with prospective design-builders to communicate project goals effectively during procurement. The owner also invites all design-builders to present their proposals separately so the owner can discuss their plans for the PDB projects.

The two second-ranked indicators were SIs #10 and #2. SI #10 relates to the design-builder's early involvement in the design phase. This is a critical issue for both the design-builder and the owner. If the owner brings the design-builder in early, they can introduce innovative design to keep the project on budget and on schedule. Generally, it is helpful to bring the design-builder in when the preliminary design is 15% complete.

SI #2 indicator relates to the owner's process for clearly communicating the project's end needs. As in PDB projects, the owner can provide extensive feedback during the design phase, so the owner must provide the design-builder with the project's end needs so they can design and build the project in a way that lets the owner operate and maintain it cost-effectively and without difficulty.

The fourth-ranked indicator was SI #1, which relates to the owner's capability to identify and allocate risks for the PDB project. This issue is critical in the PDB project because if the risk identification process is not carried out in detail during the procurement phase, it can negatively affect the project's success. Without proper risk identification, the owner cannot allocate the risk to the appropriate party. If the owner properly identifies and allocates risks during the procurement phase, the chances of the PDB project being successful will increase.

The fifth-ranked indicator was SI #15. This indicator relates to collaboration between the owner and the design-builder during procurement. Respondents perceived that the key driver of PDB project success during procurement is maintaining constant communication and collaboration with the design-builder. If the owner and design-builder work as a team, they can easily solve potential problems that arise in PDB projects.

4.2. Procurement-Related Success Factors (SFs)

The PAF analysis showed that 17 of 19 procurement-related success indicators correlated with four factors. Two SIs (#10 and #17) were not correlated with any SF during the procurement phase. The indicators correlated with these four factors were owner competencies, independent third parties' experience, design-builder competencies, and owner and design-builder working relationship.

The first success factor, which strongly correlates with seven procurement-related success indicators, is the owner's competencies, as all attributes in this factor relate to the owner. The owner should have a proper risk identification and allocation process (SI #1)

that may help execute PDB projects successfully. In addition, the owner should be flexible with the project scope and design (SI #4), as working with the design-builder to finalize the scope and design alternatives can improve cost and schedule performance. SIs #6 and #8 relate to procurement laws, policies, and the types of procurement processes used to hire a design-builder. Because PDB is a relatively new delivery method and few state agencies have used it to design and construct projects, the owner should revise the state procurement policy so the state agency can hire a contractor capable of successfully designing and constructing the project using PDB. In addition, the state agency should select the procurement method that best identifies the most qualified design-builder to complete the project successfully. SI #7 discusses the owner's effective communication with the design-builder regarding the contract procurement plan. This highlights the need for transparency in the design-builder selection process and the owner's project expectations. In PDB projects, owners select the design-builder based on qualifications. Therefore, the owner should be transparent with prospective design-builder bidders about the attributes they seek for their PDB projects. This will help the design-builder prepare their best-qualified team for the PDB projects. In addition, the owner should disclose during the procurement phase how non-cost factors will be scored in the proposal. SIs #13 and #15 relate to the collaboration between the owner and the design-builder during the procurement phase. The design-builder should actively participate in procurement and selection of subcontractor packages during construction.

The second SF comprises two SIs related to the owner's procurement process: SIs #18 and #19. In the PDB project, a performance-based specification is generally used. Under this specification, the owner generally hires an experienced independent quality assurance/quality control (QA/QC) firm to control project quality effectively. The owner should also hire an ICE with extensive experience in construction costs for PDB projects. Without ICE experience, it will be difficult to negotiate the construction portion of the PDB project GMP with the design-builder.

The third SF includes SIs #3, #9, #11, and #12. These indicators show the design-builder's competencies. While negotiating construction costs with the owner, the design-builder should decide on the payment types. Generally, PDB uses a GMP for construction costs. However, the design-builder can negotiate payment terms with the owner. Another important aspect is that the design-builder should have sufficient financial capacity to bid on the construction portion of the PDB project. They should also have enough PDB project experience to complete it successfully. These design-builder attributes were grouped into a single factor, indicating that, for the PDB project to succeed, the design-builder should also have strong competencies.

The final SF comprises the attributes related to the working relationship between the owner and the design-builder. The owner must communicate their project's end needs to the design-builder (SI #2) for the PDB project. Similarly, the working relationship and communication between the owner and the design-builder should be honest and fair (SI #14), and negotiations over design and construction costs should be transparent (SI # 5). The owner and the design-builder should discuss and decide when to set the GMP for construction costs (SI #16). If the construction cost is set early without sufficient design advancement, there is a risk of a construction cost overrun. If the construction-cost GMP is fixed after most of the design is complete, the risk of design and construction overlap decreases, reducing cost uncertainty.

The authors could not compare the success indicators and factors for PDB projects with those identified in previous studies; no prior studies have identified procurement-related SIs and SFs for PDB or lump-sum DB projects. Some studies compare the SIs and SFs of lump-sum DB projects to assess their successful completion during the design and

construction phases.

4.3. Implementation-Related Success Indicators (SI) Rankings

This study also asked PDB experts to rank the most important indicators of PDB project success during the design and construction phases. Generally, successful design and construction depend on completing projects on time, on schedule, and to a high-quality standard. Eight indicators made the top five.

The top implementation-related success indicator for a successful PDB project is the trust between the owner and the design-builder (SI #11). SI #13, which relates to communication between the owner and the designer during the design and construction phases, is also very important and ranked as the second-highest indicator. The owner should communicate continuously with the design-builder about design and construction requirements, enabling the design-builder to conduct value engineering and assess constructability during the design phases. The owner should communicate any changes during construction to the design-builder continuously so they can use a proper change management process to minimize impacts on the cost and schedule of PDB projects.

The third-ranked indicator was that the owner has clearly communicated the project requirements to the design-builder (SI #1). To prevent changes during design and construction, the owner should clearly communicate the project's end requirements to the design-builder. In PDB projects, the owner works with the design-builder to develop the design; the owner should communicate project requirements during the design phase, not during construction. This reduces change orders and helps prevent delays and cost overruns.

The fourth-ranked indicator is SI #12, which states that the owner and the design-builder should have common project goals. They should meet to set project goals and work together to achieve them. Four indicators ranked fifth were SIs #2, #4, #7, and #8. SIs #4 and #7 relate to upper management support. Because PDB projects are complex and the design is often in its early stages when the design-builder is selected, upper management should support the owner and design-builder project managers, as many negotiations can occur throughout the project.

SI #2 was also highly rated, suggesting the owner must be highly involved in the design phase. As a variation of lump-sum DB, the PDB gives the owner greater control over the design. Therefore, the owner should be involved early in the design process and provide feedback to the design-builder so they can design the project to meet the owner's requirements and reduce operation and maintenance costs. The 5th-ranked indicator was SI #8: the design-builder should have the management capacity to handle PDB projects. Because PDB is a relatively new delivery method and many design-builders lack sufficient experience to execute a PDB project, successful PDB projects require project management capacity.

Compared with previous studies of top-ranked SIs for PDB projects, none have examined implementation-phase SIs for PDB projects. However, some studies have identified SIs for overall DB projects. These studies have not differentiated between procurement- and implementation-phase SIs. Table 7 compares the implementation-phase SI rankings of PDB projects with those of overall DB projects from previous studies.

Table 7. Comparison of the ranking of implementation-related SI for PDB with overall DB projects.

SIs#	Rankings This Study	Rankings Shrestha et al. [19]	Rankings Chan et al. [20]	Rankings Lam et al. [21]	Rankings Lee et al. [22]
11	1	2	1	4	NA
13	2	2	9	NA	13
1	3	2	9	NA	13
8	5	1	NA	5	7

There are four prior studies on lump-sum DB projects in which the authors ranked the overall SIs. Their findings show that only four SIs, ranked highly in this study for the implementation phase, were also ranked in some of these studies. Chan et al. [20] ranked SI #11, related to trust between the owner and the designer, 1st; Shrestha et al. [19], 2nd; and Lam et al. [21], 4th. SI #13 ranks second among PDB projects in terms of success. However, Chan et al. [20] ranked this indicator 9th, Shrestha et al. [19] ranked it 2nd, and Lee et al. [22] ranked it 13th for lump-sum DB projects.

In this study, SI #1 ranked 3rd for PDB projects; for lump-sum DB projects, Shrestha et al. [19] ranked it 2nd, Chan et al. [20] ranked it 9th, and Lee et al. [22] ranked it 13th. In this study, SI #8 ranked 5th for PDB projects, whereas for lump-sum DB projects, Shrestha et al. [19], Lam et al. [21], and Lee et al. [22] ranked it 1st, 5th, and 7th, respectively. These comparisons show that some indicators that are ranked highly for the implementation phase of PDB projects also ranked highly in DB project studies, which is intuitive because PDB is another form of the DB method.

4.4. Implementation-Related Success Factors (SFs)

The PAF analysis shows that 15 of 18 SIs correlate with four factors. Those factors are named owner and design-builder working relationship, owner project management processes, owner and design-builder competencies, and owner design and change management processes. Six SIs are highly correlated with the first factor, with correlation coefficients higher than 0.50. All these indicators relate to the owner and design-builder working relationship. Because PDB is a collaborative method, both project participants should work arm-in-arm to ensure its success. The most highly correlated indicators are SIs #11 and #12, which relate to trust and shared project goals between the owner and the design-builder. Both project participants should share a common goal and trust each other. In addition, SIs #13 and 1 were also highly related to good communication between the owner and the design-builder regarding project requirements during the design and construction phases. Chan et al. [20] also found these four indicators to be highly correlated with the factor the authors call Project Team Commitment. Two other SIs, #4 and #9, relate to the owner's upper management support and the design-builder's design innovation, and both are also moderately correlated with this factor. All these attributes are part of the owner-design-builder working relationship, which is perceived as important to PDB project success.

The second SF, "Owner Project Management Processes," is highly correlated with SIs #16 and #17. All these attributes are related to the owner's project control process during the design and construction phases. SI #18 is related to the availability of labor and materials, which the owner should consider before initiating the PDB project. SI #14 is also highly correlated with this factor, which concerns the quality of construction work packaging. In the PDB project, the construction work package is key to setting the GMP. If the owner and design-builder can collaboratively prepare a quality work pack-

age, they can reduce the risk of construction cost overruns. Chan et al. [20] also found that some of these attributes were required for the successful implementation of DB projects, and the authors termed this factor "Client's Competencies."

SIs #5, #7, and #8 were correlated with the third SF, named "Owner and Design-Builder Competencies." This factor includes one indicator related to the owner and two related to the design-builder. The owner should have strong project management personnel to implement PDB projects effectively, as these are newer versions of lump-sum DB projects. A design-builder should have upper-management support for design and construction personnel, as well as strong project management personnel to support the design and construction phases. In [20], these attributes were grouped into two factors, "Contractor's Competencies" and "Client's Competencies," for lump-sum DB projects.

The final SF, "Owner Design and Change Management Processes," had two highly correlated attributes. They are SIs #2 and #3 and relate to the owner's involvement in the design phase and the owner's effective change management process. One drawback of lump-sum DB projects is that the owner has little input during the design phase because the design-and-construction contract is executed early. However, in a PDB project, the owner selects design-builders based on their qualifications and negotiates their design fees, leaving room for design feedback. In addition to design involvement, the owner can implement an effective change management process, as construction costs are set later once the design is 60 to 90% complete. Respondents consider these owner attributes important to PDB project success. Figure 5 depicts the four factors identified for the procurement and implementation phases of PDB projects: three are phase-specific, and one is common to both phases. The common factor kept the same name because its indicators in the procurement and implementation phases relate to the owner-design-builder working relationship.

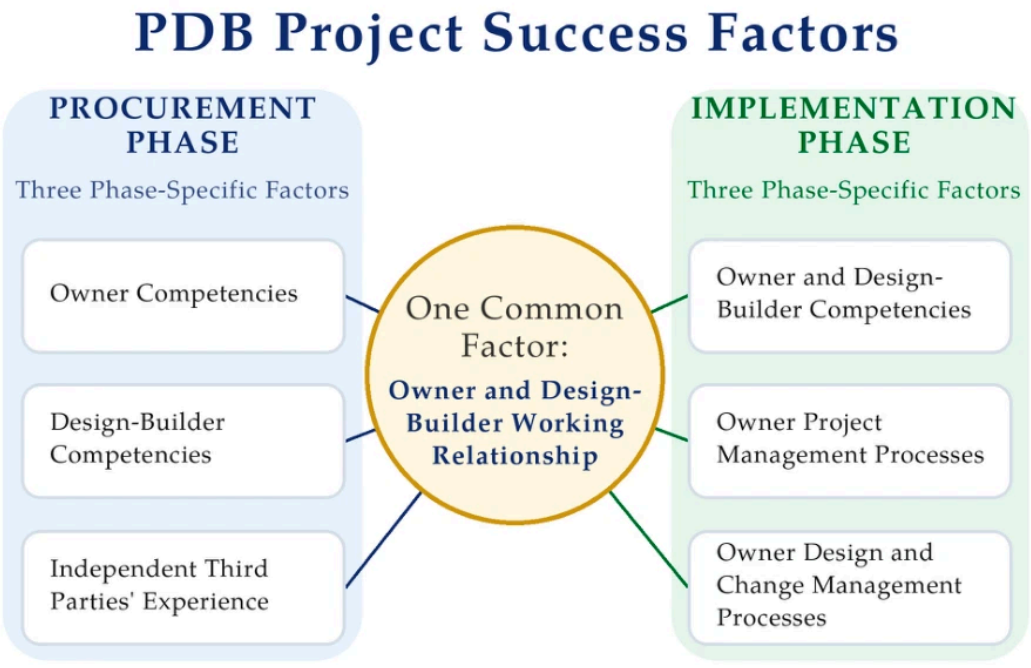


Figure 5. Procurement- and implementation-related success factors of PDB projects.

4.5. Limitations

This study has certain limitations. The first one is the sample size. The authors collected responses from 55 experts; because PDB is currently in use, finding experts in this area is difficult. Similarly, previous studies that conducted factor analyses, Shrestha et al.

[19] and Chan et al. [20], used 27 and 53 responses, respectively. However, Lam et al. [21] and Lee et al. [22] had 92 and 111 responses, respectively. Generally, factor analysis requires at least five samples per variable. Therefore, for 19 indicators, the study should have at least 95 total responses. However, PDB is a very new delivery method, so few professionals have experience with it. The authors recommend conducting further studies with a large sample size after many public agencies have started using the PDB delivery method to design and construct their projects.

This study did not divide responses by project type because of the limited number of responses. Because PDB is a new delivery method, many state agencies have not yet adopted it, making it difficult to obtain a large sample size across building and infrastructure project types. Previous factor analyses of lump-sum DB projects have also not separated responses by project type, except for Shrestha et al. [19], who surveyed experts on lump-sum DB water and wastewater projects.

Additionally, this study did not include the attributes necessary during the preplanning, operation, and maintenance phases. For successful procurement and implementation, the owner should plan PDB projects well during preplanning. The owner should have conducted sufficient studies to ensure that the projects are suitable for the PDB delivery method. The owner should also conduct preliminary design, complexity, and economic analyses to support successful procurement and implementation. Another aspect to consider is carefully reviewing operational and maintenance attributes, as well as end users' requirements, to support the success of PDB projects. Therefore, it is helpful to include attributes from the preplanning, operation, and maintenance phases.

5. Conclusions

This study focuses on identifying the SIs for the procurement and implementation phases of PDB projects. The literature review identified the SIs related to the procurement and implementation phases of PDB projects. Because few studies examined PDB success factors, the authors reviewed DB projects and identified procurement- and implementation-related SIs for inclusion in the questionnaire. First, the authors sent these SIs to two experts (one academic and the other professional) involved in PDB building and infrastructure projects to assess their importance and add any missing SIs. The experts added two SIs for the procurement phase. The final questionnaire sent to respondents included 19 procurement-related SIs and 18 implementation-related SIs. The authors analyzed 55 completed responses to rank the procurement- and implementation-related SIs.

Respondents ranked five procurement-related and eight implementation-related indicators as perceived to be very important for successfully completing PDB projects. The owner should maintain constant communication with the design-builder regarding project end needs, the procurement plan, and expectations for the PDB project. Thus, two procurement-related indicators were related to communications. Other SIs respondents ranked include the owner's early involvement in the design phase, risk identification and allocation during procurement, and collaboration among project participants. These attributes play an important role in selecting the right design-builder during procurement.

As with the procurement phase, two implementation-related indicators related to communication between the owner and the design-builder about project requirements and goals ranked highly. This shows that effective communication is considered important to successfully procuring and implementing PDB projects. Indicators related to the support the owner and design-builder project managers received from upper management were also perceived to be important for PDB execution. Both project managers

need support from higher-level personnel because PDB projects require collaboration between the two. The remaining indicators relate to trust between them, common goals, the owner's involvement in the design process, and the design-builder's management capabilities. All these attributes are perceived as important for successfully implementing PDB projects.

The study also conducted an exploratory factor analysis (Principal Axis Factoring) to identify procurement- and implementation-related success factors that are highly correlated among these indicators. The factor analysis results showed that 17 out of 19 procurement-related indicators were highly correlated with four factors. Similarly, the analysis identified 4 factors for 15 of the 18 implementation-related indicators. One factor, "Owner and Design-Builder Working Relationship," is similar across both phases. In the procurement phase, the analysis assesses the owner and the design-builder competencies separately; in the implementation phase, it combines them. These factors matter whether the project is in the procurement phase or the design-construction (implementation) phase. One factor in the procurement phase and two factors in the implementation phase differ and are specific to their respective phases. The "Independent Third Parties' Experience" factor involves selecting an experienced QA/QC firm and ICE, which can be important during procurement.

Two implementation-related factors, distinct from procurement-related factors, are "Owner Project Management Processes" and "Owner Design and Change Management Processes," which relate specifically to the implementation phase. All the attributes loaded into these two factors relate to the design and construction phase and have nothing to do with the procurement phase. Therefore, some factors are common to the procurement and implementation phases and are assessed as crucial for successful procurement and implementation of PDB projects. The owner's and design-builder's competencies, and their working relationship, are important factors to consider in both the procurement and implementation phases. However, to proceed with procurement, the owner should ensure certain requirements are met before engaging a qualified design-builder. Once the owner engages a qualified design-builder, they should ensure effective project management to collaboratively manage scope, changes, inspections, schedules, and costs.

This study's major contribution is identifying the top five procurement-related and top eight implementation-related indicators of PDB projects, enabling the owner and prospective design-builders to focus on these attributes perceived as important for project success. Another major contribution of this study is identifying the procurement- and implementation-related factors respondents assessed as key to successfully executing PDB projects. No prior studies have identified the success factors for PDB infrastructure projects. These findings have practical implications for state agencies considering using PDB in their projects. State agencies can focus on the factors identified in this study and review them carefully during procurement and implementation of PDB projects. Lump-sum DB and PDB projects differ, so when selecting the PDB delivery method, state agencies can use these new factors to help future PDB projects be completed successfully.

The authors recommend a follow-up study to collect more data as more project managers gain PDB experience. Also, once there are enough buildings, highway, water, wastewater, and aviation PDB projects, this study can be repeated by project type. Collecting data from only one group of experts will help identify the success factors specific to a single type of PDB project. In the future, it is also recommended to examine whether state and federal policies are based on these success factors and whether state agencies can use them during PDB project procurement and implementation. Public

agencies that use the PDB method in their projects should take this study's recommendations and conclusions with caution. Because this study is based on respondents' perceptions rather than empirical data, agencies should use these findings cautiously when implementing them. In addition, these findings cannot be applied to specific project types because the respondents in this study have experience with various project types. Therefore, this study's findings cannot be generalized across buildings and all types of infrastructure.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Appendix A.1

Table A1. Procurement phase critical success indicators synthesized for PDB projects.

SI #	Success Indicators' Description	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
1	Proper risk identification and allocation from the owner	√	√	√	-	-	-	√	-	√	-	√	-
2	The owner has clearly communicated their end needs of the project	-	-	-	-	√	-	-	-	√	-	-	√
3	Owner's experience with the PDB process	√	√		√	-	√	-	-	-	-	-	-
4	Owner's flexibility with project scope and design	-	-	-	-	√	-	-	√	√	√	-	-
5	The owner's process of open-book negotiations for design and construction costs	-	-	√	-	-	-	-	-	√	√	√	-
6	The owner has established a procurement policy for PDB projects	-	√	-	√	-	-	-	-	-	-	-	-
7	Types of contract procurement methods used to select the design-builder	-	-	-	-	-	-	-	-	√	-	-	-

SI #	Success Indicators' Description	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
8	Types of payment methods used for construction work (GMP or Lump-Sum)	-	-	-	-	-	√	-	-	-	-	-	-
9	Early involvement of the design-builder during the project design phase	-	-	-	√	√	-	-	-	√	√	√	-
10	Design-builder's experience with the PDB process	-	-	-	-	-	-	-	-	-	-	-	√
11	Design-builder's financial capacity	-	-	-	-	-	-	-	-	-	-	-	-
12	Effective communication between the owner and the design-builder during the procurement phase	-	-	-	-	√	-	-	-	√	-	-	√
13	Collaboration between the owner and the design-builder during the procurement phase	-	-	-	-	-	-	√	-	√	-	√	-
14	Timing of the construction cost setting	-	-	-	-	-	-	-	-	√	-	-	-
15	Early procurement of long-lead equipment and materials	-	-	-	-	-	-	-	√	-	-	-	-
16	Independent quality assurance /quality control (QA/QC) firm's experience	-	√	-	-	-	-	-	-	-	-	-	-
17	Independent Cost Estimator's (ICE) experience	-	-	-	-	√	-	-	-	√	-	-	-

Note. √ indicates the indicator was identified in the corresponding study. Study key: S1 = Adamtey & Onsarigo [7]; S2 = Gad et al. [12]; S3 = Gransberg & Molenaar [3]; S4 = Alleman & Tran [1]; S5 = Shang & Migliaccio [13]; S6 = Alleman & Tran [23]; S7 = Jeong et al. [9]; S8 = Alameri & Esmaeili [10]; S9 = Alameri & Esmaeili [11]; S10 = Gransberg [4]; S11 = Salih et al.[15]; S12 = Chan et al. [20]; S13 = Lam et al. [21]; S14 = Shrestha et al. [24]; S15 = Lee et al. [22]; S16 = Shrestha et al.[19].

Appendix A.2

Table A2. Implementation phase success indicators synthesized for PDB projects.

SI #	Success Indicators' Description	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S1
1	The owner has clearly communicated the project requirements to the design-builder	-	-	-	-	-	-	-	-	√	-	-	√
2	Level of owner's involvement during the design phase	-	-	-	√	√	-	√	-	-	-	√	-
3	Owner's effective change management process	-	√	-	-	-	-	-	-	-	-	-	√
4	Owner's upper management support	-	√	-	-	-	-	-	-	√	-	-	-
5	The owner has good project management capability for PDB projects	-	-	-	-	-	-	-	-	-	-	-	√

SI #	Success Indicators' Description	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S1
6	Clearly defined roles and responsibilities of the owner's staff	-	-	-	-	-	-	-	-	-	-	-	√
7	Design-builder's upper management support	-	√	-	-	-	-	-	-	√	-	-	-
8	Design-builder has good project management capability for PDB projects	-	-	-	-	-	-	-	-	-	-	-	√
9	Design innovations from the design-builder	√	-	-	-	-	-	-	-	-	√	-	-
10	Clearly defined roles and responsibilities of the design-builder's staff	-	-	-	-	-	-	-	-	-	-	-	√
11	Level of trust between the owner and the design-builder	-	-	-	-	-	-	-	-	√	-	-	√
12	The owner and the design-builder share common project goals	-	-	-	-	-	-	-	-	-	-	-	-
13	Effective communication between the owner and the design-builder during the implementation phase	-	-	-	-	-	-	-	-	-	-	-	√
14	Quality of work packaging during the construction phase	√	-	-	-	-	√	-	-	-	-	-	-
15	Feedback was provided from the stakeholders, including end users and operations personnel, during the design phase	-	-	-	-	-	-	-	-	-	-	-	-
16	Effective QA/QC program in place	-	√	-	-	-	-	-	-	-	-	-	-
17	An effective project control mechanism is in place	√	-	-	-	-	-	-	-	-	-	-	√
18	Availability of construction workforce and materials	-	-	-	-	-	-	-	-	-	-	-	-

Note. √ indicates the indicator was identified in the corresponding study. Study key: S1 = Adamtey & Onsarigo [7]; S2 = Gad et al. [12]; S3 = Gransberg & Molenaar [3]; S4 = Alleman & Tran [1]; S5 = Shang & Migliaccio [13]; S6 = Alleman & Tran [23]; S7 = Jeong et al. [9]; S8 = Alameri & Esmaeili [10]; S9 = Alameri & Esmaeili [11]; S10 = Gransberg [4]; S11 = Salih et al.[15]; S12 = Chan et al. [20]; S13 = Lam et al. [21]; S14 = Shrestha et al. [24]; S15 = Lee et al. [22]; S16 = Shrestha et al.[19]. SI #15 was identified based on expert opinion.

Appendix A.3

Table A3. Ranking of procurement-related success indicators and their RII values.

SI #	Success Indicators' Description	RII	Rank
14	Effective communication between the owner and design-builder during the procurement phase	0.93	1
10	Early involvement of the design-builder during the project design phase	0.92	2
2	The owner has clearly communicated their end needs of the project	0.92	2
1	Proper risk identification and allocation from the owner	0.90	4
15	Collaboration between the owner and design-builder during the procurement phase	0.88	5
7	Consistent communication of the owner's procurement plan and expectations from project initiation to procurement	0.85	6
13	Design-builder's participation in the procurement phase, through the competitive bidding and selection of subcontractors' packages	0.84	7
4	Owner's flexibility with project scope and design	0.83	8
5	The owner's process of open-book negotiations for design and construction costs	0.83	8
17	Early procurement of long-lead equipment and materials	0.80	10
11	Design-builder's experience with the PDB process	0.80	10
16	Timing of the construction cost setting	0.80	10
6	The owner has established a procurement policy for PDB projects	0.78	13
9	Types of payment methods used for construction work (GMP or lump-sum)	0.78	13
8	Types of contract procurement methods used to select the design-builder	0.75	15
12	Design-builder's financial capacity	0.73	16
19	Independent Cost Estimator's (ICE) experience	0.71	17
3	Owner's experience with the PDB process	0.71	17
18	Independent quality assurance/ quality control (QA/QC) firm's experience	0.65	19

Appendix A.4

Table A4. Initial and extracted communalities of procurement-related success factors analysis.

SI #	Success Indicators' Description	Initial	Extraction
1	Proper risk identification and allocation from the owner	0.807	0.696
2	The owner has clearly communicated their end needs of the project	0.510	0.420
3	Owner's experience with the PDB process	0.758	0.666
4	Owner's flexibility with project scope and design	0.755	0.679
5	The owner's process of open-book negotiations for design and construction costs	0.748	0.590
6	The owner has established a procurement policy for PDB projects	0.815	0.600
7	Consistent communication of the owner's procurement plan and expectations from project initiation to procurement	0.709	0.668
8	Types of contract procurement methods used to select the design-builder		
9	Types of payment methods used for construction work (GMP or Lump-Sum)	0.805	0.781
10	Early involvement of the design-builder during the project design phase	0.674	0.646
11	Design-builder's experience with the PDB process	0.404	0.276
12	Design-builder's financial capacity	0.540	0.307
13	Design-builder's participation in the procurement phase, through the competitive bidding and selection of subcontractors' packages		
14	Effective communication between the owner and the design-builder during the procurement	0.609	0.529

SI #	Success Indicators' Description	Initial	Extraction
	phase		
15	Collaboration between the owner and the design-builder during the procurement phase	0.756	0.612
16	Timing of the construction cost setting	0.780	0.534
17	Early procurement of long-lead equipment and materials	0.686	0.672
18	Independent quality assurance /quality control (QA/QC) firm's experience	0.568	0.452
19	Independent Cost Estimator's (ICE) experience	0.668	0.525

Appendix A.5

Table A5. Eigenvalues of procurement-related success factors analysis.

Factor	Total	Initial Eigenvalues	
		% Variance	Cumulative %
1	7.483	39.740	39.740
2	1.949	10.269	50.009
3	1.778	9.304	59.313
4	1.394	7.242	66.555
5	0.951	4.787	71.342
6	0.821	4.323	75.665
7	0.788	4.147	79.812
8	0.665	3.498	83.310
9	0.581	3.056	86.366
10	0.488	2.570	88.937
11	0.431	2.271	91.207
12	0.336	1.768	92.975
13	0.328	1.725	94.699
14	0.268	1.410	96.109
15	0.238	1.251	97.360
16	0.189	0.993	98.353
17	0.140	0.738	99.091
18	0.112	0.591	99.682
19	0.060	0.318	100.000

Appendix A.6

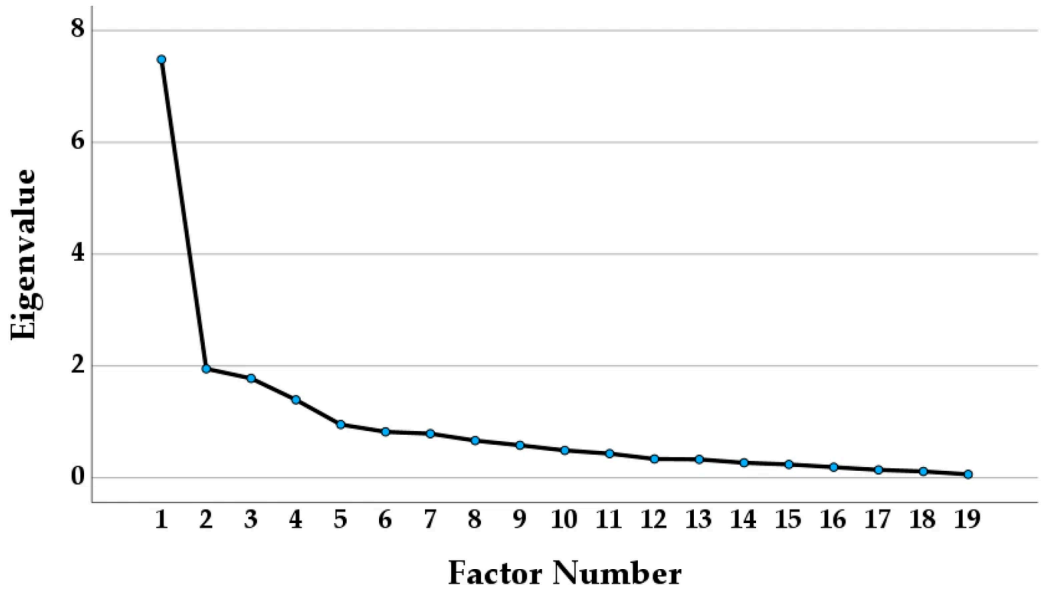


Figure A1. Scree plots for Principal Axis Factoring of procurement-related SIs.

Appendix A.7

Table A6. Principal Axis Factoring analysis results for procurement-related SIs.

SI #	Success Indicators' Description	Factor Loading	% Variance Explained	% Cumulative
	Success Factor (SF) #1: Owner Competencies			
1	Proper risk identification and allocation from the owner	0.549	39.74	39.74
4	Owner's flexibility with project scope and design	0.806		
6	The owner has established a procurement policy for PDB projects	0.505		
7	Consistent communication of the owner's procurement plan and expectations from project initiation to procurement	0.730		
8	Types of contract procurement methods used to select the design-builder	0.584		
13	Design-builder's participation in the procurement phase, through the competitive bidding and selection of subcontractors' packages	0.696		
15	Collaboration between the owner and the design-builder during the procurement phase	0.691		
	Success Factor (SF) #2: Independent Third Parties' Experience			
18	Independent QA/QC firm's experience	0.619	10.27	50.01
19	Independent Cost Estimator's (ICE) experience	0.840		
	Success Factor (SF) #3: Design-Builder Competencies			
3	Owner's experience with the PDB process	0.510	9.30	59.31
9	Types of payment methods used for construction work (GMP or Lump-Sum)	0.536		
11	Design-builder's experience with the PDB process	0.523		
12	Design-builder's financial capacity	0.561		
	Success Factor (SF) #4: Owner and Design-Builder Working Relationship			
2	The owner has clearly communicated their end needs of the project	0.623	7.24	66.55

SI #	Success Indicators' Description	Factor Loading	% Variance Explained	% Cumulative
5	The owner's process of open-book negotiations for design and construction costs	0.716		
14	Effective communication between the owner and the design-builder during the procurement phase	0.610		
16	Timing of the construction cost setting	0.646		

Appendix A.8

Table A7. Pattern matrix for procurement-related SIs.

SI #	Success Indicators' Description	SF # 1	SF # 2	SF # 3	SF # 4
1	Proper risk identification and allocation from the owner	0.549			
2	The owner has clearly communicated their end needs of the project				0.623
3	Owner's experience with the PDB process			0.510	
4	Owner's flexibility with project scope and design	0.806			
5	The owner's process of open-book negotiations for design and construction costs				0.716
6	The owner has established a procurement policy for PDB projects	0.505			
7	Consistent communication of the owner's procurement plan and expectations from project initiation to procurement	0.730			
8	Types of contract procurement methods used to select the design-builder	0.584		00.542	
9	Types of payment methods used for construction work (GMP or lump-sum)			0.536	0.520
10	Early involvement of the design-builder during the project design phase	-	-	-	-
11	Design-builder's experience with the PDB process			0.523	
12	Design-builder's financial capacity			0.561	
13	Design-builder's participation in the procurement phase, through the competitive bidding and selection of subcontractors' packages	0.696			
14	Effective communication between the owner and the design-builder during the procurement phase				0.610
15	Collaboration between the owner and the design-builder during the procurement phase	0.691			
16	Timing of the construction cost setting				0.646
17	Early procurement of long-lead equipment and materials	-	-	-	-
18	Independent quality assurance /quality control (QA/QC) firm's experience		0.619		
19	Independent Cost Estimator's (ICE) experience		0.840		

Appendix A.9

Table A8. Ranking of implementation-related success indicators and their RII values.

SI #	Success Indicators' Description	RII	Rank
11	Level of trust between the owner and the design-builder	0.94	1
13	Effective communication between the owner and the design-builder during the implementation phase	0.93	2
1	The owner has clearly communicated the project requirements to the design-builder	0.92	3
12	The owner and the design-builder share common project goals	0.89	4
7	Design-builder's upper management support	0.87	5

SI #	Success Indicators' Description	RII	Rank
4	Owner's upper management support	0.87	5
2	Level of the owner's involvement during the design phase	0.87	5
8	Design-builder has good project management capability for PDB projects	0.87	5
6	Clearly defined roles and responsibilities of the owner's staff	0.85	9
10	Clearly defined roles and responsibilities of the design-builder's staff	0.83	10
18	Availability of construction workforce and materials	0.82	11
9	Design innovations from the design-builder	0.82	11
16	Effective QA/QC program in place	0.81	13
5	The owner has good project management capability for PDB projects	0.81	13
3	Owner's effective change management process	0.81	13
15	Feedback was provided from the stakeholders, including end users and operations personnel, during the design phase	0.80	16
14	Quality of work packaging during the construction phase	0.80	16
17	An effective project control mechanism is in place	0.78	18

Appendix A.10

Table A9. Initial and extracted communalities of implementation-related success factors analysis.

SI #	Success Indicators' Description	Initial	Extraction
1	The owner has clearly communicated the project requirements to the design-builder	0.618	0.437
2	Level of owner's involvement during the design phase	0.650	0.629
3	Owner's effective change management process	0.793	0.845
4	Owner's upper management support	0.635	0.432
5	The owner has good project management capability for PDB projects	0.842	0.892
6	Clearly defined roles and responsibilities of the owner's staff	0.731	0.696
7	Design-builder's upper management support	0.774	0.742
8	Design-builder has good project management capability for PDB projects	0.713	0.647
9	Design innovations from the design-builder	0.675	0.581
10	Clearly defined roles and responsibilities of the design-builder's staff	0.720	0.647
11	Level of trust between the owner and the design-builder	0.864	0.825
12	The owner and the design-builder share common project goals	0.836	0.893
13	Effective communication between the owner and the design-builder during the implementation phase	0.803	0.749
14	Quality of work packaging during the construction phase	0.683	0.674
15	Feedback was provided from the stakeholders, including end users and operations personnel, during the design phase	0.482	0.419
16	Effective QA/QC program in place	0.808	0.736
17	An effective project control mechanism is in place	0.779	0.756

Appendix A.11

Table A10. Eigenvalues of implementation-related success factors analysis.

Factor	Total	Initial Eigenvalues	
		% Variance	Cumulative %
1	8.779	48.771	48.771
2	2.136	11.867	60.638

Factor	Total	Initial Eigenvalues	
		% Variance	Cumulative %
3	1.214	6.744	67.381
4	1.174	6.523	73.905
5	0.851	4.727	78.632
6	0.669	3.717	82.349
7	0.537	2.981	85.330
8	0.461	2.563	87.893
9	0.419	2.329	90.222
10	0.374	2.079	92.301
11	0.303	1.684	93.986
12	0.283	1.570	95.555
13	0.235	1.306	96.861
14	0.179	0.994	97.856
15	0.129	0.717	98.573
16	0.094	0.524	99.097
17	0.086	0.478	99.575
18	0.076	0.425	100.000

Appendix A.12

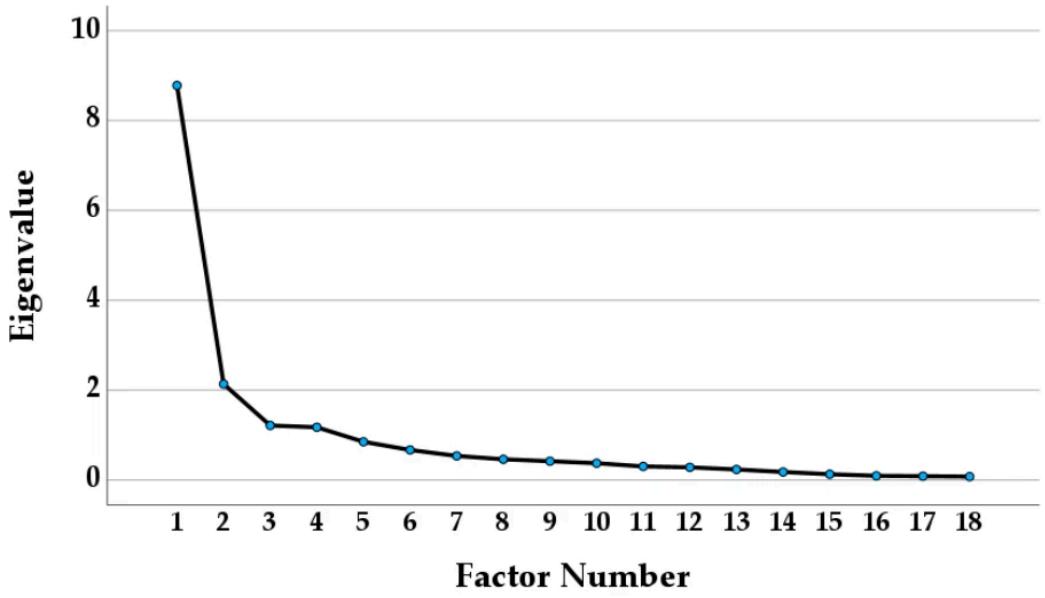


Figure A2. Scree plots for Principal Axis Factoring of implementation-related SIs.

Appendix A.13

Table A11. Principal Axis Factoring analysis results for implementation-related SIs.

SI #	Success Indicators' Description	Factor Loading	% Variance	Cumulative %
	Success Factor (SF) #1: Owner and Design-Builder Working Relationship			
1	The owner has clearly communicated the project requirements to the design-builder	0.654	48.77	48.77
4	Owner's upper management support	0.512		

SI #	Success Indicators' Description	Factor Loading	% Variance	Cumulative %
9	Design innovations from the design-builder	0.501		
11	Level of trust between the owner and design-builder	0.830		
12	The owner and the design-builder share common project goals	0.985		
13	Effective communication between the owner and the design-builder during the implementation phase	0.763		
	Success Factor (SF) #2: Owner Project Management Processes			
14	Quality of work packaging during the construction phase	0.718	11.87	60.64
16	Effective QA/QC program in place	0.776		
17	An effective project control mechanism is in place	0.818		
18	Availability of construction workforce and materials	0.759		
	Success Factor (SF) #3: Owner and Design-Builder Competencies			
5	The owner has good project management capability for PDB projects	0.813	6.74	67.38
7	Design-builder's upper management support	0.768		
8	Design-builder has good project management capability for PDB projects	0.546		
	Success Factor (SF) #4: Owner Design and Change Management Processes			
2	Level of the owner's involvement during the design phase	0.700	6.52	73.90
3	Owner's effective change management process	0.749		

Appendix A.14

Table A12. Pattern matrix for implementation-related SIs.

SI #	Success Indicators' Description	SF # 1	SF # 2	SF # 3	SF # 4
1	The owner has clearly communicated the project requirements to the design-builder	0.654			
2	Level of the owner's involvement during the design phase				0.700
3	Owner's effective change management process				0.749
4	Owner's upper management support	0.512			
5	The owner has good project management capability for PDB projects			0.813	
6	Clearly defined roles and responsibilities of the owner's staff	-	-	-	-
7	Design-builder's upper management support			0.768	
8	Design-builder has good project management capability for PDB projects			0.546	
9	Design innovations from the design-builder	0.501			
10	Clearly defined roles and responsibilities of the design-builder's staff	-	-	-	-
11	Level of trust between the owner and the design-builder	0.830			
12	The owner and the design-builder share common project goals	0.985			
13	Effective communication between the owner and the design-builder during the implementation phase	0.763			
14	Quality of work packaging during the construction phase		0.718		
15	Feedback was provided from the stakeholders, including end users and operations personnel, during the design phase	-	-	-	-
16	Effective QA/QC program in place		0.776		
17	An effective project control mechanism is in place		0.818		
18	Availability of construction workforce and materials		0.759		

Appendix A.15

Factors Affecting Progressive Design-Build Projects Success– Questionnaire Survey

Section IA—Respondents' information

Q-A.1 Respondent's Name:

Q-A.2 Company/Organization:

Q-A.3 Phone Number:

Q-A.4 Have you ever been involved or are you currently involved in a Progressive Design-Build (PDB) project or research effort?

- Yes
- No

Q-A.5 What is your primary involvement with PDB projects?

- I conduct academic research on PDB
- I work professionally on PDB projects (engineering, construction management, project owner, etc.)

Section IB—Professionals' Experience

Q-B.1 How many years of experience do you have in PDB projects?

- 2 years and below
- 3 to 5 years
- 6 to 10 years
- Over 10 years

Q-B.2 How many projects using PDB methods have you participated in or are currently involved in?

- 1
- 2
- 3 or more

Section II—PDB Projects

Q 2.1 Name of the project involved in:

Q 2.2 Location of the PDB project:

Q 2.3 Role/Title in the PDB project:

Q 2.4 Type of the PDB project:

- Transportation
- Water/Wastewater
- Airports
- Buildings
- Others

Q 2.5 Construction Type of PDB project:

- New Construction
- Rehabilitation
- Repair and Maintenance
- Expansion
- Others

Q 2.6 Procurement process utilized for the PDB project:

- Qualification-Based Selection (QBS)
- Best-Value Selection
- Other

Q 2.7 Payment method utilized for the PDB project:

- Lump Sum
- Guaranteed Maximum Price (GMP)
- Other

Q 2.8 Using a scale of 1=Overrun budget by more than 10% to 5=Underrun budget by more than 10%, please rate the PDB project average cost performance you were involved in. (Note: If you have worked on more than one project, please report the average value)

- Overrun budget by more than 10%
- 2. Overrun budget by below 10%
- 3. On budget
- 4. Underrun budget by below 10%
- 5. Underrun budget by more than 10%

Q 2.9 Using a scale of 1=Behind schedule by more than 10% to 5 = Ahead of schedule by more than 10%, please rate the PDB project's average schedule performance. (*Note: If you have worked on more than one project, please report the average value*)

- Behind schedule by more than 10%
- 2. Behind schedule by below 10%
- 3. On schedule
- 4. Ahead of schedule by below 10%
- 5. Ahead of schedule by more than 10%

Section III—Rating of Procurement-related Success Indicators to complete PDB Projects Successfully

Q 3.1 Please rate the importance of the following procurement-related success indicators for completing the PDB project successfully.

Success Indicators	Extremely important	Very important	Moderately important	Slightly important	Not at all important
Proper risk identification and allocation from the owner	•	•	•	•	•
The owner has clearly communicated their end needs of the project	•	•	•	•	•
Owner's experience with the PDB process	•	•	•	•	•
Owner's flexibility with project scope and design	•	•	•	•	•
The owner's process of open-book negotiations for design and construction costs	•	•	•	•	•
The owner has established a procurement policy for PDB projects	•	•	•	•	•
Consistent communication of the owner's procurement plan and expectations from project initiation to procurement	•	•	•	•	•

Types of contract procurement methods used to select the design-builder	•	•	•	•	•
Types of payment methods used for construction work (GMP or lump-sum)	•	•	•	•	•
Early involvement of the design-builder during the project design phase	•	•	•	•	•
Design-builder's experience with the PDB process	•	•	•	•	•
Design-builder's financial capacity	•	•	•	•	•
Design-builder's participation in the procurement phase, through the competitive bidding and selection of subcontractors' packages	•	•	•	•	•
Effective communication between the owner and the design-builder during the procurement phase	•	•	•	•	•
Collaboration between the owner and the design-builder during the procurement phase	•	•	•	•	•
Timing of the construction cost setting	•	•	•	•	•
Early procurement of long-lead equipment and materials	•	•	•	•	•
Independent quality assurance/quality control (QA/QC) firm's experience	•	•	•	•	•
Independent Cost Estimator's (ICE) experience	•	•	•	•	•

Section IV—Rating of Implementation-related Success Indicators to complete PDB Projects Successfully

Q 4.1 Please rate the importance of the following implementation-related success indicators for completing the PDB project successfully.

Success Indicators	Extremely important	Very important	Moderately important	Slightly important	Not at all important
The owner has clearly communicated the project requirements to the design-builder	•	•	•	•	•

Level of the owner's involvement during the design phase	•	•	•	•	•
Owner's effective change management process	•	•	•	•	•
Owner's upper management support	•	•	•	•	•
The owner has good project management capability for PDB projects	•	•	•	•	•
Clearly defined roles and responsibilities of the owner's staff	•	•	•	•	•
Design-Builder's upper management support	•	•	•	•	•
Design-Builder has good project management capability for PDB projects	•	•	•	•	•
Design innovations from the design-builder	•	•	•	•	•
Clearly defined roles and responsibilities of the design-builder's staff	•	•	•	•	•
Level of trust between the owner and the design-builder	•	•	•	•	•
The owner and the design-builder shared common project goals	•	•	•	•	•
Effective communication between the owner and the design-builder during the implementation phase	•	•	•	•	•
Quality of work packaging during the construction phase	•	•	•	•	•
Feedback was provided from the stakeholders, including end users and operations personnel, during the design phase	•	•	•	•	•
Effective QA/QC program in-place	•	•	•	•	•
An effective project control mechanism is in place	•	•	•	•	•
Availability of construction workforce and materials	•	•	•	•	•

References

1. Alleman, D.; Tran, D. Challenges of Implementing Progressive Design-Build in Highway Construction Projects. *J. Leg. Aff. Disput. Resolut. Eng. Constr.* **2020**, *12*, 04519036. [Google Scholar] [CrossRef]
2. Design-Build Institute of America. *Progressive Design-Build: A Design-Build Done Right Primer*; Design-Build Institute of America: Washington, DC, USA, 2017. [Google Scholar]
3. Gransberg, D.D.; Molenaar, K.R. Critical Comparison of Progressive Design-Build and Construction Manager/General Contractor Project Delivery Methods. *Transp. Res. Rec.* **2019**, *2673*, 261–268. [Google Scholar] [CrossRef]
4. Gransberg, D.D. Implementing Progressive Design Build: Enabling Legislation May Not Be Required. *J. Leg. Aff. Disput. Resolut. Eng. Constr.* **2023**, *15*, 04523033. [Google Scholar] [CrossRef]
5. Design-Build Institute of America. *Progressive Design-Build: A Design-Build Done Right Deeper Dive*; Design-Build Institute of America: Washington, DC, USA, 2023. [Google Scholar]
6. American Council of Engineering Companies of New York. Progressive-Design-Build. 2026. Available online: https://acecny.org/page/progressive-design-build (accessed on 6 November 2026). [Google Scholar]
7. Adamtey, S.; Onsarigo, L. Effective Tools for Projects Delivered by Progressive Design-Build Method. In Proceedings of the CSCE Annual Conference: Growing with Youth—Croître Avec Les Jeunes, Laval, QC, Canada, 12–15 June 2019. [Google Scholar]
8. Adamtey, S. Cost and Time Performance Analysis of Progressive Design-Build Projects. *J. Eng. Des. Technol.* **2021**, *19*, 686–697. [Google Scholar] [CrossRef]
9. Jeong, E.; Anderson, C.; Lin, K.-Y.; Migliaccio, G. Progressive Design-Build: Its Functions as a Contracting Method and the Four Pillars of Project Success. In Proceedings of the 9th International Conference on Construction Engineering and Project Management, Las Vegas, NV, USA, 20–23 June 2022. [Google Scholar]
10. Alameri, R.; Esmaeili, B. Selection Factors for Progressive Design-Build Delivery Method. In *Construction Research Congress 2022*; American Society of Civil Engineers: Reston, VA, USA, 2022; pp. 244–253. [Google Scholar]
11. Alameri, R.; Esmaeili, B. Progressive Design-Build Delivery Method: Assessment of Project Performance. *Int. J. Constr. Educ. Res.* **2023**, *19*, 22–41. [Google Scholar] [CrossRef]
12. Gad, G.; Davis, B.; Shrestha, P.; Harder, P. Lessons Learned from Progressive Design-Build Implementation on Airport Projects. *J. Leg. Aff. Disput. Resolut. Eng. Constr.* **2019**, *11*, 04519020. [Google Scholar] [CrossRef]
13. Nguyen, P.H.D.; Trans, D.; Scott, S.; Konrath, L. Implementation of Progressive Design-Build in Airport Capital Construction Projects. *Transp. Res. Rec.* **2024**, *2678*, 1098–1109. [Google Scholar] [CrossRef]
14. Shang, L.; Migliaccio, G. Demystifying Progressive Design-Build: Implementation Issues and Lessons Learned through Case-Study Analysis. *Organ. Technol. Manag. Constr.* **2020**, *12*, 2095–2108. [Google Scholar] [CrossRef]
15. Salih, F.; Eissa, R.; El-Adaway, I. Data-Driven Analysis of Progressive Design Build in Water and Wastewater Infrastructure Projects. *J. Constr. Eng. Manag.* **2024**, *150*, 04023149. [Google Scholar] [CrossRef]
16. ACEC Research Institute. Progressive Design-Build: Practice, Perception, and Potential. 2026. Available online: https://www.acec.org/resource/progressive-design-build-practice-perceptions-and-potential/ (accessed on 6 November 2026). [Google Scholar]
17. Alazzam, M.; Celoza, A.; Molenaar, K.R. Progressive Design-Build Opportunities and Challenges: A Literature Review. In Proceedings of the Joint CSCE Construction Specialty & CRC Conference, Montreal, CA, Canada, 28–31 July 2025; CON-042-1 to CON-042-10. [Google Scholar]
18. Tavares, C.B.; Shrestha, P.P. Factors affecting Progressive Design-Build Transportation Project performance. In Proceedings of the Construction Research Congress, San Antonio, TX, USA, 18–21 March 2026; pp. 161–170. [Google Scholar]
19. Shrestha, P.P.; Shrestha, S.; Basnet, P. Budget and Schedule-Related Critical Success Factors for Design-Build Water and Wastewater Projects: Principal Component Analysis. *Buildings* **2025**, *15*, 1653. [Google Scholar] [CrossRef]
20. Chan, A.P.C.; Ho, D.C.K.; Tam, C.M. Design and Build Project Success Factors: Multivariate Analysis. *J. Constr. Eng. Manag.* **2001**, *127*, 93–100. [Google Scholar] [CrossRef]
21. Lam, E.W.M.; Chan, A.P.C.; Chan, D.W.M. Determinants of Successful Design-Build Projects. *J. Constr. Eng. Manag.* **2008**, *134*, 333–341. [Google Scholar] [CrossRef]
22. Lee, Z.P.; Rahman, R.A.; Doh, S.I. Critical Success Factors for Implementing Design-Build: Analysing Malaysian Public Projects. *J. Eng. Des. Technol.* **2022**, *20*, 1041–1056. [Google Scholar] [CrossRef]

23. Alleman, D.; Tran, D. Exploring a Progressive Design-Build Best-Value Delivery Method in Highway Construction. *J. Leg. Aff. Disput. Resolut. Eng. Constr.* **2021**, *13*, 04021009. [Google Scholar] [CrossRef]
24. Shrestha, P.P.; Batista, J.; Maharjan, R. Impediments in Using Design-Build or Construction Management-at-Risk Delivery Methods for Water and Wastewater Projects. In *Construction Research Congress 2016: Old and New Construction Technologies Converge in Historic San Juan*; American Society of Civil Engineers: Reston, VA, USA, 2016; pp. 380–387. [Google Scholar]

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