This study examines the influence of Project Delivery System (PDS) features on green construction project performance by comparing Design-Bid-Build (DBB), Design-Build (DB), and Construction Management (CM) methods. The research problem is to analyze the influence of key characteristics (leadership, communication, mindset, teamwork, team chemistry, experience, competence) of the three PDS methods on achieving green construction project performance. The research objects were 109 respondents (team leader, vice president manager, project manager, site manager, site engineer, general superintendent, and supervisor) in five major cities in Indonesia. The results of the MANOVA analysis showed that leadership was the most influential factor in the three methods. CM excels in time, quality, and green building performance, DB excels in Occupational Health and Safety (OHS), and DBB excels in cost. Experience and competence are less influential factors, thus concluding that soft skills play a significant role in the successful implementation of green construction projects, providing valuable insights for industry practitioners and emphasizing the need to prioritize the development of leadership and interpersonal skills alongside technical expertise when implementing green construction projects through various PDS methods in Indonesia, which ultimately contributes to the advancement of sustainable construction practices in the rapidly growing building sector in the region. These findings provide insights for selecting optimal PDS methods in green construction projects

Keywords: Project Delivery System features, green construction, project performance, Sustainable development

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IDENTIFYING THE INFLUENCE OF PROJECT DELIVERY SYSTEM (PDS) CHARACTERISTICS ON GREEN CONSTRUCTION PROJECT PERFORMANCE

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1. Introduction

The construction and building sectors have had a very significant impact on global energy consumption and emissions. Data from the World Green Building Council shows that this sector absorbs 36 % of total energy consumption and uses up to 50 % of available resource consumption. Not only that, the construction and building sector also contributes 38 % of total carbon emissions, which is quite worrying considering that future projections show that this number is expected to double by 2060. Similar conditions also occur in Indonesia, where, based on the Ministry of Energy and Natural Resources report in 2020, carbon emissions produced by the industrial and construction sectors experienced a significant increase of 29.5 % in 2019 compared to the previous year. This shows the importance of paying particular attention to energy and emission management in the construction and building sector [1]. A study conducted by [2] revealed that 60 % of accidents occurred to construction workers, with the most common types of accidents including injuries from falls (30 %), being hit by objects (25 %), and exposure to chemicals (15 %). Meanwhile, [3] research shows that the water conservation aspect is the only aspect that significantly affects the construction implementation time at the design stage by 43.7 %, with the influence of green building parameters on the construction project implementation time by 78.39 %. This shows a reasonably good influence in describing the relationship between green building parameters and the construction project phase. These findings emphasize the importance of the transformation towards green construction for the sustainability of the construction industry.

Green construction is defined as the planning and implementation of a construction process based on contract documents to minimize the negative impact of the construction process on the environment in order to create a balance between environmental capabilities and human needs for current and future generations [4]. A green-oriented project management system will be different from projects in general.

Differences occur in the planning process and the construction process. Therefore, the project team must be aware of the differences in management in this type of project from the beginning. After the project owner approves the financing aspect, the next step is to realize green construction [5].

The success of a project is inseparable from the selection of its procurement method, also called the Project Delivery System (PDS), which is a comprehensive process that includes planning, design, and construction required to implement and complete building facilities or other types of projects. Choosing a PDS method is one of the fundamental decisions owners make when developing their acquisition strategy. Determining the PDS method is one of the most critical decisions made by every owner who starts a construction project. Choosing the best method for each project must begin with understanding the options available [6]. The character of green projects is more complex than that of conventional projects, making the selection of PDS for each project very important in building communication, coordination, and contract issues between owners, contractors, and designers. With the increasing number of green design projects, understanding the relationship between PDS and green design is paramount in project and contract management.

The majority of construction projects in the last ten years have been implemented according to conventional methods and traditional norms, where short-term solutions are preferred over long-term ones, with materials, technical solutions, and managerial approaches that can rarely be classified as innovative green technologies in their implementation [7, 8]. PDS methods, namely Design-Bid-Build (DBB), Construction Management (CM), and Design-Build (DB), are commonly adopted for conventional construction projects, and each method has its pros and cons. To successfully realize green construction, specific modifications to traditional project management processes and practices are required [9]. For example, the design process significantly impacts costs; the specific design factors mentioned above must be considered early in the design stage, affecting the PDS method. Different PDS methods, such as the most commonly used DBB and the increasingly popular DB model, should be considered first for green buildings [10]. Empirical studies have also been conducted to compare the performance of each of these PDS methods [11].

The following study investigates the project performance achievements of the three PDS methods. Cost, time, and quality performance in the green building PDS process raise greater sensitivity to the inherent nature of green buildings. If poor quality performance occurs at the design stage, it will result in changes at the construction stage. It will impact the productivity of construction staff because the overall progress will be lower [12]. The following study results show differences in cost and time performance achievements but produce the same quality performance [12]. [13] stated that construction cost, schedule, quality, risk, and owner capability influence the choice of PDS methods. However, how these factors lead to choosing a particular delivery method is not clearly explained. Green construction practices also affect other performance achievements, such as environmental performance and OHS. Environmental performance is the best solution to combat ongoing pollution and negative impacts of development [14]. Green construction practices also affect other performance achievements, such as environmental performance and OHS. Environmental performance is the best solution to combat ongoing pollution and negative impacts of development [15].

The transformation towards green construction is an urgent need, considering that the construction sector contributes 38 % of global carbon emissions with an alarming upward trend. In Indonesia, emissions from this sector have increased by 29.5 % in a year, indicating the urgency of researching a more environmentally friendly project management system. In this context, choosing the proper PDS method is crucial because the complexity of green construction projects is higher than that of conventional projects. An effective PDS can help optimize communication, coordination, and contract management between owners, contractors, and designers. Studies show that most construction projects in the last ten years still use conventional methods that tend to prioritize short-term solutions, with material and managerial approaches that rarely adopt innovative green technologies. Therefore, research on the effectiveness of various PDS methods in green construction can provide valuable guidance for industry practitioners in optimizing the implementation of sustainable construction projects.

Green construction is becoming essential in the construction industry to reduce environmental impacts and increase efficiency. Choosing the right Project Delivery System (PDS) method plays a critical role in the success of green construction implementation. There are three PDS methods: Design-Bid-Build (DBB), Design-Build (DB), and Construction Management (CM), which have different characteristics in implementing green construction.

Therefore, studies that are devoted to identifying Project Delivery System (PDS) methods and their key characteristics in implementing green construction are of scientific relevance. This is driven by the increasing demands for sustainability standards in construction, the increasing complexity of projects, and the need to integrate technical aspects with social-collaborative aspects in project management. Identifying the optimal PDS method and its key characteristics is crucial to achieving the success of green construction projects in the modern context. It requires a balance between efficiency, environmental sustainability, and the effectiveness of team collaboration.

2. Literature review and problem statement

PDS can be defined as the relationship, roles, and responsibilities of project team members to achieve project objectives. Several studies have shown that at the project implementation stage, this PDS has several features (characteristics) that can affect the achievement of project performance in implementing green projects. According to [14], these features are collaboration, team experience, and leadership. Meanwhile, according to [16], these features include collaboration, communication, and chemistry between teams. According to [17], PDS features are team collaboration, communication, and mindset. Several other studies have concluded that the experience of planners and contractors and the role and experience of the owner are very important and influence the project's success based on the use of the established PDS. Team experience is a vital characteristic of green projects. Likewise, team collaboration, experience, and leadership in the research results [14] are essential factors in selecting PDS. Owner experience is very important in the early design phase of green project management [16]. Likewise, other studies state that the project manager's experience is also recorded as an essential characteristic in this

survey and is reinforced by the research [14]. Apart from the adopted project PDS method, several other attributes, such as owner commitment, participant entry time into the team, and team characteristics (such as collaboration, experience, and chemistry), can affect the level of integration achieved [18]. Collaborative teams, communication, and mindset are also said to influence green projects' success [17] significantly. In addition to the above features, one parameter is said to be an obstacle to implementing the PDS method: capability. In the results of the study [19], it was stated that the capability of the project owner and other stakeholders involved is an obstacle in the implementation of the integrated PDS method, as well as lack of expertise, lack of knowledge, lack of understanding from Staff, lack of Staff capable of implementing the integrated method and stakeholder capability are the main obstacles in implementing the integrated method so that the qualifications or competencies of Staff and stakeholders are essential in the implementation of this PDS method.

Leadership style has a significant relationship with project delivery success. Leaders who have this combination of competencies can drive teams toward project success. Continuous training is also crucial in developing technical skills and honing the leadership skills needed for long-term organizational success. Overall, this study emphasizes that transformational leadership plays a significant role in project success and the importance of leadership development that focuses on improving competencies and skills through training and direct experience in the field. This is important to ensure the organization's success and future project delivery [20]. These findings have practical implications for project managers and organizational leaders, suggesting a flexible leadership approach that combines transformational and transactional elements to optimize project team performance. By understanding these dynamics, project managers can adjust their leadership style to align with project goals and team needs, ultimately increasing project success [21]. Effective leadership, which understands organizational dynamics and meets the professional needs of the team, is a crucial factor in creating a supportive work environment. This suggests that, in addition to technical competence, attention to team members' well-being and professional needs is also essential for the success of technology-based projects. Project managers must create a conducive and responsive work environment to enhance the team's performance [22].

Research [23] shows that the transformational style is dominant because it focuses on change and motivation. Some unresolved issues include the absence of quantitative effectiveness measurements and criteria for selecting styles appropriate to the context. The main difficulties include the complexity of measuring the impact of leadership. Further research is recommended, including comparative studies of the effectiveness of leadership styles, analysis of implementation success factors, development of validated measurement instruments, and case studies of good practices in various contexts. These findings can have practical implications for project managers and organizational leaders, suggesting a flexible leadership approach that combines transformational and transactional elements to optimize project team performance. By understanding these dynamics, project managers can adjust their leadership style to align with project goals and team needs, ultimately improving project success.

The paper [24] stated that leadership, mindset, and communication were the most critical soft skills in the success of green construction projects. However, this study did not examine the project management method used. Research needs to be done on this method to determine whether it can affect these results.

The paper [25] identified the importance of leadership development for delivery project managers. The paper did not discuss overcoming the specific challenges in developing project manager leadership in different contexts. The complexity and high variability of delivery projects make applying a uniform leadership approach difficult. This suggests that more extensive research is recommended to select more varied delivery methods.

The study [26] examined the Integrated Project Delivery (IPD) method, which stated that the communication structure of IPD teams tends to be decentralized and democratic, in line with the IPD goal of enhancing collaboration. The study was only conducted on one IPD team over one month, limiting the generalizability of the findings. Moreover, the absence of performance measurement or project results makes linking communication patterns to team effectiveness difficult.

Research [27] examines two delivery methods, DBB and DB, against performance results. It produces the DBB method, which is still commonly used in the construction industry but has several disadvantages, such as lack of collaboration and potential for order changes. The study found that DBB is superior regarding timeliness, safety, and continuous inspection, while DB is better regarding cost, communication, and risk mitigation. However, there is no consensus on the best project delivery method because each method has advantages and disadvantages depending on the project context. The practical implementation of recommendations to optimize DBB needs further testing and evaluation.

In addition to leadership, equality and mutual respect within the project team are essential for building trust and open communication for project success. Trust and open communication are critical requirements for achieving good team integration. Ultimately, this collaborative approach contributes to the project's success [28]. The most important aspects of teamwork are project performance, decision-making, and problem-solving. The five primary attributes contributing to effective teamwork include communication between team members, efficient leadership, clarity of roles and responsibilities, and collaboration between project leaders. Understanding these dimensions and attributes of teamwork is an essential foundation for building a solid team in the construction context.

Research [29] shows that there are 15 critical factors in the implementation of knowledge management in construction organizations, with the main factors including knowledge sharing, collaboration, learning from mistakes, employee training and knowledge strategies, and three underlying factors, namely increasing capacity and capability. Unresolved problems include the low implementation of knowledge management in the construction industry, high fragmentation that limits collaboration, and limited use of innovative practices. The main difficulties include the complex characteristics of the construction industry and the use of technology that is still traditional. A holistic approach is needed to overcome this by developing an integrated knowledge management system and increasing collaboration between parties. Future research should focus on case studies of practices and explore factors that influence knowledge management's success in various construction project contexts. However, it must be placed in the proper context and appropriate project environment to increase teamwork effectiveness.

Research [30] revealed that projects with higher levels of team integration tend to perform better in terms of project schedule and intensity. Strong team cohesion, characterized by timely communication, good team chemistry, and commitment to common goals, has been shown to reduce project cost

growth and improve the quality of project outcomes and the building handover experience. Project success is determined by the delivery method and the team's ability to collaborate and function as a cohesive unit. Team integration and team cohesion play an essential role in bridging the relationship between project delivery methods and project performance outcomes, thus encouraging project owners to pay more attention to these factors in their project management. Unresolved issues include sample limitations and the absence of an analysis of the impact of delivery methods on project performance. To overcome this, further research with more extensive and diverse samples is recommended, and the relationship between management practices and project performance should be analyzed.

Long-term collaboration facilitates organizational learning and continuous improvement. High levels of collaboration encourage a single-organization mindset and joint planning and problem-solving. Deep and broad collaboration is essential for stakeholder engagement. High levels of collaboration have enabled joint decision-making based on different types of knowledge and a single-organization mindset. These findings provide new insights into how collaborative business arrangements can support sustainable outcomes and management practices in inter-organizational projects, which may have broader relevance given the growing interest in collaboration in the construction supply chain over the past decade [31]. Effective collaboration plays a critical role in the successful delivery of construction projects. Several studies have shown that good collaboration between different parties involved, such as clients, contractors, and consultants, can help overcome common challenges in construction projects, including cost overruns, time extensions, and poor quality of work. Research by [32] underlines the importance of early integration of contractors to accelerate decision-making, reduce project variation, and increase efficiency in the project delivery process. Several other studies have also highlighted the importance of collaboration in creating positive long-term relationships between parties involved in a project [33, 34], showing that partnering helps resolve conflicts and improves project team commitment and performance [35]. States that multi-party contract arrangements involving contractors from the start can significantly improve project outcomes.

The results of the previous studies above did not measure the project's success with planners who have green project experience but do not have green qualification sand whether they will complete green construction-based projects. This can only be validated by future research. So, in this study, competence becomes an additional research variable expected to influence the success of PDS selection in green construction-based project management. Using the page rank algorithm to rank organizations based on their experience shows that collaboration between experienced organizations in green projects contributes significantly to the success of the final certification. Projects that achieve Platinum certification tend to have more experienced organizations than projects that only achieve Certified certification. In addition, the critical role of experienced organizations such as owners, planners, and contractors significantly influences higher certification results. The presence of organizations with experience in green building projects has a positive impact on achieving higher levels of certification. However, the importance of experience and collaboration of experienced organizations in the project team is critical in achieving higher green building certification. The important role of experienced organizations in green building projects is to achieve optimal certification levels [36]. Overall, the literature review shows that collaboration is a tool to solve problems in the middle of a project and an important strategy supporting construction projects' success. The involvement of all parties from the beginning, integration of knowledge, and collaborative management result in more efficient and quality projects.

Based on the results of the literature review above, it is deemed necessary to conduct research by analyzing the influence of PDS features that have been identified from previous studies, namely leadership, communication, mindset, team collaboration, chemistry between team members, experience and adding competency as a novelty to this study on the achievement of project performance. In this study, project performance was also achieved, namely the performance of green building certification based on the findings above in project management with the selected PDS method. The study of the choice of PDS methods was also developed into three existing PDS methods: separate methods, integrated methods, and methods with CM from previous studies that only compared Design-Bid-Build (DBB) with Design-Build (DB) or DB with Construction Management (CM) or IPD.

3. The aim and objectives of the study

The study aims to identify the influence of PDS's key characteristics (features) on the performance of green construction projects implemented using three different PDS methods (DBB, DB, and CM).

To achieve this aim, the following objectives are accomplished:

– to analyze and compare the effectiveness of three Project Delivery System (PDS) methods, namely Design-Bid-Build (DBB), Design-Build (DB), and Construction Management (CM) in implementing green construction;

– to identify key characteristics of each PDS method such as leadership, communication, mindset, teamwork, chemistry between team members, experience, and competence towards achieving green construction project performance.

4. Materials and methods

The object of this study is the performance of green construction projects. Thisused109 respondents (team leader, vice president manager, project manager, site manager, site engineer, general superintendent, and supervisor) in five major cities in Indonesia (Jakarta, Bandung, Semarang, Surabaya, and Denpasar). Based on the objective to analyze the influence of key characteristics of PDS on the performance of green construction projects, this study has a central hypothesis that key characteristics of PDS have different influences on the performance of green construction projects in implementing DBB, DB, and CM methods. This study assumes that respondents adequately understand the three PDS methods, external factors are considered constant, and project performance can be measured objectively. To simplify the analysis, the study is limited to seven key characteristics of PDS (leadership, communication, mindset, teamwork, team chemistry, experience, competence) and five aspects of performance(cost, time, quality, OHS, green building certification), using respondents' perceptions as a measure of project performance.

This study analyzes the comparison of the three PDS methods, namely Design-Bid-Build (DBB), Design-Build (DB),

and Construction Management (CM) in green construction-based project management towards project performance achievement based on PDS features (characteristics) such as team collaboration, mindset, communication, chemistry between team members, leadership, experience and competence that affect the success of green projects. The project performance reviewed here includes cost performance, time performance, quality performance, OHS performance, and green building certification performance. The analysis was carried out using MANOVA (Multivariate Analysis of Variance), a statistical analysis technique used to simultaneously test the average difference of two or more groups on several dependent variables.

Comparative analysis in this study involves selecting three different Project Delivery System methods on several independent variables and comparing them on several dependent variables. These three Project Delivery System methods have the same aspects to be compared with their dependent variables. The statistical test used to measure the influence of independent variables on a categorical scale on several dependent variables at once on a quantitative data scale is MANOVA (Multivariate Analysis of Variance). The research method used is quantitative, with a survey based on the philosophy of positivism used to study a specific population or sample, data collection using research instruments, and data analysis using quantitative/statistical methods to test the established hypothesis. The research was conducted on a particular representative population or sample. This research is deductive, where concepts or theories are used to answer the formulation of the problem so that hypotheses can be formulated. The hypothesis is then tested through field data collection. The research instrument is used to collect data [37–43]. Based on these variables, a comparative analysis of the selection of the PDS method with MANOVA is carried out, so it is expected to obtain the results of selecting the proper PDS method for use in green project management. This research is designed in three general stages, as shown in Fig. 1 below.

The research will start from the initial stage, namely identifying PDS feature variables and project performance from literature and related studies that discuss these variables. Furthermore, the results of identifying PDS feature variables and project performance are compared with MANOVA. The following are the details of the stages:

1. Identification of PDS feature variables and project performance from related literature and studies.

2. The research tool was tested for validity and reliability before distributing the questionnaire. Validity testing was carried out by testing construct validity. Expert opinion (expert judgment) was used to test construct validity. For this study, the experts used were doctoral graduates who were relevant to their fields. Reliability testing in this study was carried out using the test-retest method by trying the instrument several times on respondents. In this case, the instruments used were the same, and the respondents were the same at different times. After the validity test was declared valid and reliable, the questionnaire was distributed to 109 respondents spread across five major cities in Indonesia (Jakarta, Bandung, Semarang, Surabaya, and Denpasar) with the criteria for respondent positions as team leader, vice president manager, project manager, site manager, site engineer, general superintendent, and supervisor.

3. The final stage of the study was to conduct a comparative analysis by comparing the three PDS methods (DBB, DB, and CM) in green building project management based on PDS features that influence the success of green projects.

This analysis aims to compare the effectiveness of three Project Delivery System (PDS) methods, namely Design-Bid-Build (DBB), Design-Build (DB), and Construction Management (CM), in implementing green construction and identifying key characteristics of each PDS method, such as leadership, communication, mindset, teamwork, chemistry between team members, experience and competence to evaluate their influence on achieving green construction project performance. Based on this, a conceptual model comparing PDS methods can be made (Fig. 2).

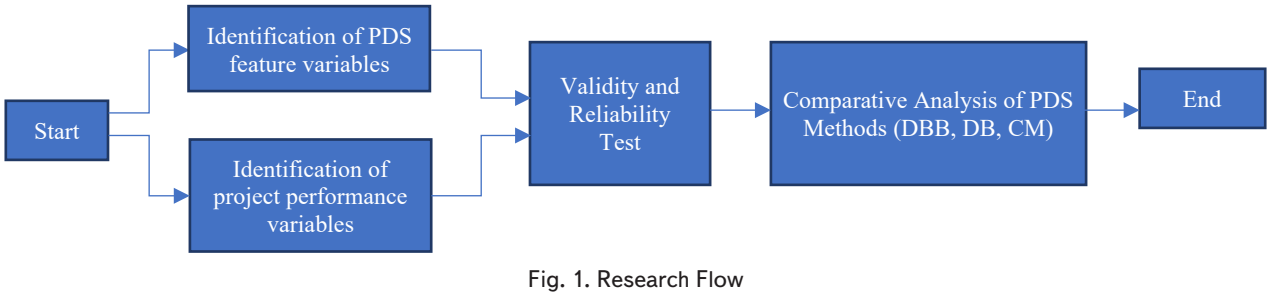

Fig. 1. Research Flow

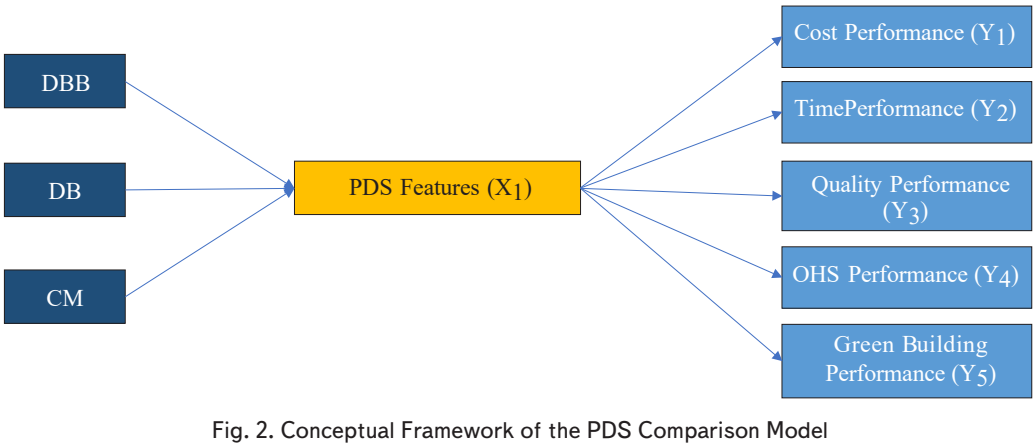

Fig. 2. Conceptual Framework of the PDS Comparison Model

Fig. 2 illustrates a conceptual model showing the comparison of PDS methods whose project management success is influenced by the characteristics of the PDS method itself, called PDS features, namely team collaboration (X_{11}), mindset (X_{12}), communication (X_{13}), team chemistry (X_{14}), leadership (X_{15}), experience (X_{16}) and competence (X_{17}). This structure illustrates the complexity of interactions in construction projects, which are assumed in the implementation of green projects to determine various aspects of project performance.

5. Research results

5. 1. Comparison of the effectiveness of three Project Delivery System (PDS) methods, namely Design-Bid-Build (DBB), Design-Build (DB), and Construction Management (CM) in implementing green construction

This study used nominal and interval data types, and the normality test results showed that the data was not normally distributed for all research variable data. Statistical tests were carried out on three PDS methods, namely DBB, DB, and CM, where these methods were unrelated. Based on the above, statistical tests on three unrelated samples can be selected using the Kruskal Wallis, Chi-Square, or Median tests. From the Significance Test, Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root values were obtained >0.05, meaning that the three PDS methods had no difference in project management towards achieving project performance on green projects.

However, the tendency of the multivariate test results of the three methods with the highest mean value indicates that the method is most suitable for green project management and achieving project performance. To find this, see the mean value obtained from each research variable, as shown in Table 1 below.

To be able to see a comparison of the three methods above, the graph in Fig. 3 below shows the deviation of the mean value from the selection of the use of the three methods, which is relatively tiny (<0.200), but from the three values, it can be seen which method is more appropriate to choose compared to other methods related to its relationship with each variable tested.

From the graph above, it can be seen that no single method consistently excels in all variables. DBB excels in green construction and cost performance. These results align with studies [20, 21], which state that projects with the DBB method perform better in cost and are significantly superior in all cost metrics.

CM tends to have high values in many variables, especially time, quality, and green building certification performance. [22] CM is more effective in controlling project schedules, while [21] states that CM produces higher product and service quality levels. These results differ from previous studies [23], which showed that DB was significantly superior in terms of schedule growth and cost growth. The results of this study show the superiority of DB in HSE performance and PDS features. The difference in values between methods is generally tiny, indicating relatively balanced performance.

Table 1

Descriptive Statistics of the PDS Method on Project Performance

PDS Method		Mean	SD
Cost performance	DBB	4.017	0.637
	DB	4.072	0.570
	CM	4.080	0.636
	Total	4.102	0.607
Time performance	DBB	4.017	0.688
	DB	4.087	0.582
	CM	4.139	0.505
Quality performance	Total	4.085	0.587
	DBB	4.100	0.600
	DB	4.178	0.553
	CM	4.190	0.515
	Total	4.161	0.550
HSE performance	DBB	4.057	0.576
	DB	4.252	0.591
	CM	4.179	0.582
	Total	4.174	0.584
Green Building Certification performance	DBB	3.456	0.669
	DB	3.566	0.718
	CM	3.657	0.620
	Total	3.566	0.672

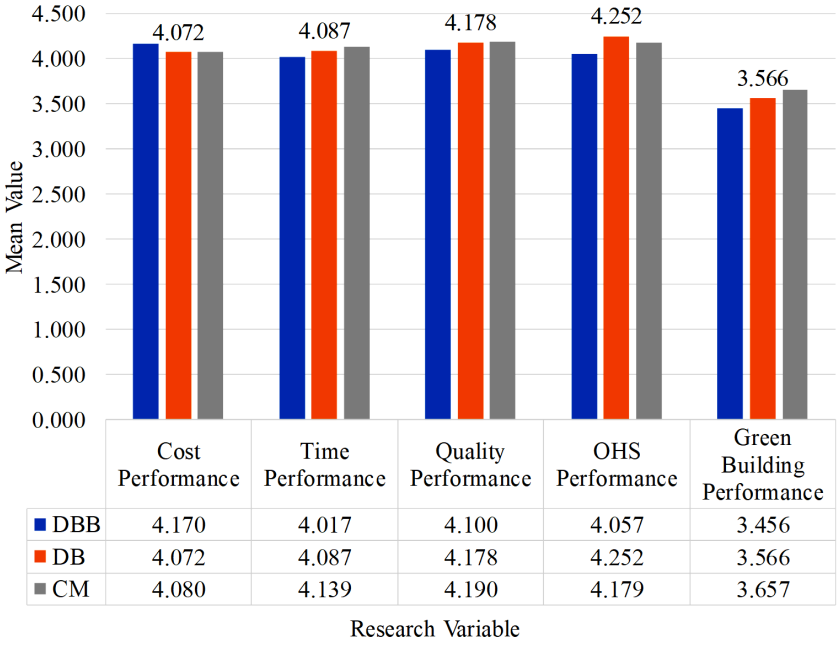

Fig. 3. Comparison of PDS methods on performance

5. 2. Identification of the key characteristics of each PDS method, such as leadership, communication, mindset, teamwork, chemistry between team members, experience, and competence toward achieving green construction project performance

This study analyzes seven key indicators that are considered critical to the success of construction projects, namely team collaboration (X_{11}), mindset (X_{12}), communication (X_{13}), team

chemistry (X_{14}), leadership (X_{15}), experience (X_{16}), and competence (X_{17}). Each indicator is rated using a numeric scale, allowing for a direct comparison of the relative effectiveness of each PDS method. The data presented in Table 2 comes from a comprehensive survey of industry professionals and provides valuable insights into each PDS method's relative strengths and weaknesses in various aspects of project management.

This study analyzed PDS features to determine which can best achieve successful project performance in the selected PDS methods in green project management. The results of data analysis using MANOVA obtained the average value of each PDS feature indicator.

The results of the study showed that the ranking of the best indicators in the DB and CM methods was almost the same; there was only a difference in the ranking of the indicators "team collaboration" (X_{11}) and "communication" (X_{13}). The best indicator in the three methods was "leadership" (X_{15}). The results of this study align with [24], which was conducted in Malaysia, stating that leadership makes the most significant contribution (40 %) to the success of PDS. Research [25] also stated that leadership significantly influences project performance. Likewise, the results of a different study by [25] stated that collaboration is essential in sustainable project management. Furthermore, [26] showed different results, stating that the skills and expertise of team members following the project work most significantly affect project performance. The indicators "experience" and "competence" are the indicators with the least influence on the second lowest ranking for all PDS methods. Experience in green project management and competence in green construction are independent of green project management. Fig. 4 compares three PDS methods based on the influence of PDS features.

The key characteristics of the three PDS methods (DBB, DB, CM) in optimizing various aspects of green construction project team performance, namely the Design-Bid-Build (DBB) method, show strength in communication and focus on the traditional leadership approach. Meanwhile, the Design-Build (DB) method offers a good balance in most indicators assessed, especially in the mindset aspect. The Construction Management (CM) method stands out with strength in leadership and mindset and scores high on most of the indicators evaluated. The results of this analysis provide a comprehensive picture of the strengths of each method, which can be an essential consideration for professionals in choosing the most appropriate approach for their construction projects. These results are also different from [26], which states that the project manager's competence is one of the critical factors that influence the success or failure of a project. Meanwhile, the results of a study [27] conducted in Malaysia stated that teamwork is essential in increasing the success of the PDS method. It is stated that there are three essential attributes of teamwork: communication, leadership, and collaboration. A comparison of the three PDS methods can be seen in Table 3.

Table 2

Comparison of PDS methods based on PDS feature indicators

No.	DBB		DB		CM	
	PDS feature	Mean	PDS feature	Mean	PDS feature	Mean
1	Leadership	4.567	Leadership	4.535	Leadership	4.639
2	Communication	4.467	Mindset	4.488	Mindset	4.500
3	Mindset	4.367	Team collaboration	4.465	Communication	4.500
4	Team collaboration	4.300	Communication	4.442	Team collaboration	4.389
5	Chemistry among team members	4.167	Chemistry among team members	4.395	Chemistry among team members	4.167
6	Experience	3.967	Experience	4.128	Experience	4.083
7	Competence	3.933	Competence	4.070	Competence	3.972

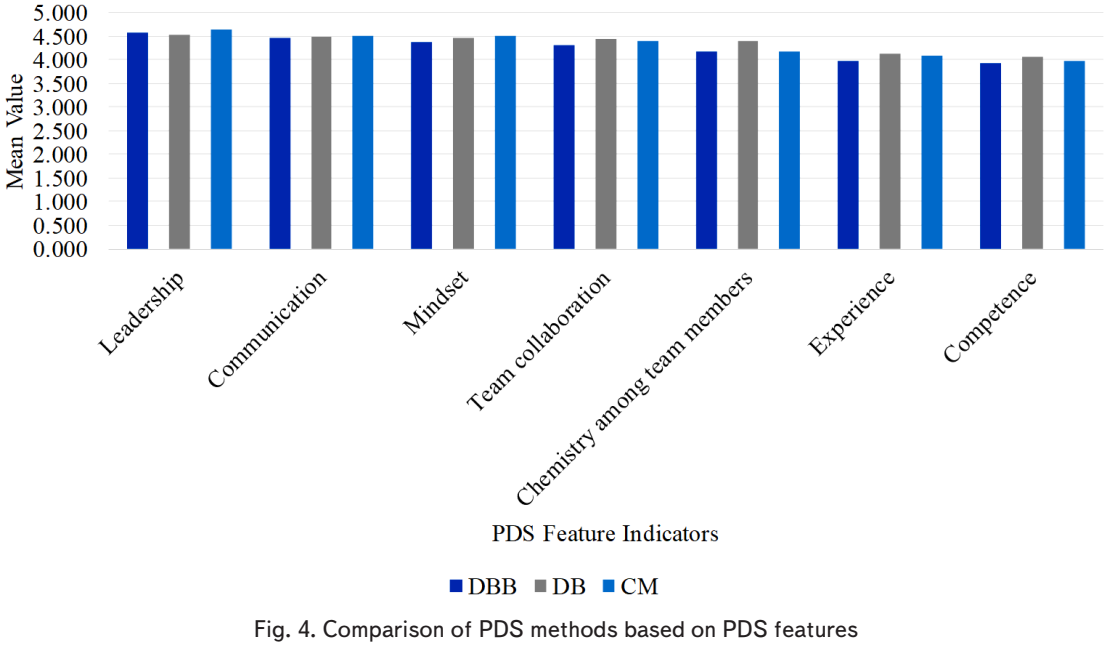

Fig. 4. Comparison of PDS methods based on PDS features

Table 3

Key characteristics of the three PDS methods (DBB, DB, CM)

Design-Bid-Build (DBB)	Design-Build (DB)	Construction Management (CM)
Strong in communication. Focus on traditional leadership	Good balance in most indicators. Emphasis on mindset	Excellent leadership and mindset. High scores for most indicators

Table 3 shows the unique characteristics of each in the context of green construction projects. DBB excels in communication and focuses on traditional leadership, indicating its suitability for projects with clear communication and leadership structures. DB balances most indicators well, emphasizing mindset, flexibility, and adaptability. Meanwhile, CM excels in leadership and mindset and scores high on most indicators, indicating its effectiveness in handling complex projects. This interpretation emphasizes that selecting an appropriate PDS method should consider the specific characteristics of the project, the leadership needs, and the level of management complexity required in green construction projects.

6. Discussion of the results of a comparative analysis of project delivery system (PDS) features and its impact on construction project performance

Based on the performance comparison analysis results, there is an exciting pattern between the DBB, DB, and CM methods. Regarding cost performance, DBB leads are comparable to the other two methods, which show relatively similar values. CM outperforms the other methods for time performance, while DBB is in the lowest position and DB is in the middle. Regarding quality, CM again shows superiority, followed by DB, whose values are not far apart, while DBB is in the lowest position. Regarding OHS, DB records the highest value, while CM and DBB are below. For green building certification performance, which is generally lower than other indicators, CM remains superior, followed by DB and DBB, which are in the lowest position. Overall, the CM and DB methods perform better than DBB in most indicators, although the value difference between methods is not too significant (Table 1 and Fig. 3).

The results of data analysis on the influence of PDS features on the selection and performance of the three PDS methods show that leadership is the most influential indicator in all three methods. The communication indicator is ranked second in the DBB method, reflecting the separate nature of construction and consulting work. The mindset indicator is ranked second in the DB and CM methods, indicating the importance of shared perception in the integrated PDS method. While experience and competence are the least influential indicators for all PDS methods, in green construction, they are considered independent of green project management (Table 2). The selection of PDS methods must consider the specific characteristics of green construction projects and the strengths of each method. Leadership is a critical factor in the success of all PDS methods. This indicates the need to develop leadership capabilities in green construction (Fig. 4). The comparison results of these three methods indicate that selecting and implementing PDS methods in green construction projects require careful consideration of various factors. Each method has different strengths and focuses, which can be optimized according to the project's specific needs. Leadership, communication, and the formation of a shared mindset are key factors that need to be considered in green construction project management, regardless of the PDS method chosen.

Overall, this study confirms the importance of soft skills such as leadership, mindset, and communication in the success of green construction projects. These findings can help construction industry practitioners focus team development efforts and select the proper PDS method to optimize the performance of green construction projects.

This study has several limitations that must be considered in practical application and theoretical development. From a practical perspective, the results are limited to the context of Indonesia and five major cities; performance measurement that relies on respondents' perceptions may contain bias and does not consider variations in project size and market dynamics. Theoretically, the study did not conduct a longitudinal analysis, did not explore the interaction between PDS characteristics, did not analyze the influence of external factors, and had limitations in generalizing the theory due to its specific focus on green construction projects.

Nevertheless, this study opens up opportunities for further development. Future studies can expand the geographical coverage, conduct longitudinal analysis to see changes in the influence of PDS features on project performance over time, and integrate external factors such as Government regulations or economic conditions into the analysis. However, this development may face several challenges, such as obtaining a more extensive and diverse sample of green construction practitioners, developing more objective measurement instruments to assess project performance, and managing the complexity of statistical analysis if more variables or external factors are added. Addressing research weaknesses, such as the lack of longitudinal analysis and direct comparison with similar studies in other countries, can also be a focus to improve the quality and relevance of future research.

7. Conclusions

1. Comparison of the performance of the three construction contract methods based on mean values shows that the CM method excels in terms of time (4.16), quality (4.24), and green building (4.06). The DB method is in second place with superiority in the OHS aspect (4.22) and shows good consistency in all indicators (3.86–4.22). Meanwhile, although the DBB method is superior in cost performance (4.12), it tends to show lower performance in other indicators (3.78–4.02). The variation in mean values between the three methods is relatively slight, with a range of 0.46 (3.78-4.24), indicating that each method has advantages for specific project needs.

2. Analysis based on mean values shows leadership as the most influential factor in the three PDS methods, with the highest value in CM (4.32), followed by DB (4.26) and

DBB (4.18). DBB emphasizes communication (4.28) due to the separate nature of the work, while DB and CM focus on shared mindsets with mean values of 4.18 and 4.22 due to the integrated approach. Experience and competence are less influential factors, with a mean value range of 3.75–3.85 for all methods. The success of implementing the PDS method depends on careful consideration of project characteristics, prioritizing leadership, communication, and forming a shared mindset showing a mean value above 4.15.

Conflict of interest

The authors declare that they have no conflict of interest related to this research, whether financial, personal, authorship, or otherwise, that could affect the study and its results presented in this paper.

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Data availability

The manuscript has no associated data.

Use of artificial intelligence

The authors have used artificial intelligence technologies within acceptable limits to provide their verified data, described in the research methodology section.

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