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Lean Construction: A Sustainability Operation for Government Projects

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Abstract: The current state budget allocated for Indonesian government projects has exceeded 10% for infrastructure development. This large budget indicates a need for the construction industry to implement more professional management practices for better cost, time, quality, safety, and environmental impact. Lean construction is used to increase productivity and reduce waste in a project. Therefore, this study aimed to extend lean construction principles to the planning and execution phases of DB projects, where these two entities are integrated into the main contractor. Quantitative and qualitative study methods were used to analyze secondary data from six DB project sites and conduct focus group discussions (FGDs) with expert panels using the Delphi method for consensus. The results showed the factors and variables that influence the implementation of lean construction in government projects in Indonesia.

Keywords: design and build; lean construction; productivity and waste; project performance

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1. Introduction

The government is responsible for the budget allocated for infrastructural development [1–3], and several projects have been delayed, resulting in increased costs beyond the initial estimates [4,5]. This issue is commonly witnessed in traditional contract arrangements, typically awarded to the lowest bidder [3,4]. However, the procurement strategy has been adopted by most developing countries [3,5]. For example, Latham [6] focused on the timely delivery of a project, which is essential in the construction industry, where projects often last longer than planned [1,4,5,7,8].

A significant indicator of an efficient construction industry is the timely completion of projects [9]. There is a need for contractors to balance quality, time, and cost [1,10], although several projects mainly focus on two parameters: time and cost [11–14]. Several studies focused on time as a critical success indicator, with delays typically occurring during the execution phase due to numerous unexpected factors [15]. In construction, delay is defined as exceeding the scheduled completion time stated in the contract or agreed upon by the parties [1,4,5]. Projects that exceed the planned schedule are a common challenge in the construction industry. Furthermore, delays result in revenue losses due to unavailability of facilities or dependency on existing ones [1,4]. In several cases, delay has caused contractors to face higher overhead costs arising from increased work hours, inflation-driven material price hikes, and rising labor expenses [1,7,8]. While timely project completion is an indicator of efficiency, the construction process is influenced by a multi of variables and unexpected factors originating from various sources [16–18]. These include the performance of the parties, resource availability, environmental conditions, third-party participation, contractual relationships, and the rarity of on-time project completion [18,19].

Costing and schedule extensions were also attributed to a range of factors, and exceeding these indicators can adversely affect client satisfaction [18]. Furthermore, discrepancies between the financing profile and budget requirements may cause delays [20]. According to Ahmad et al. [21], construction project delays are a universal phenomenon, followed by cost overruns [22]. This weakens contractors and consultants, strains relationships, fosters distrust, and contributes to litigation, arbitrage, cash flow problems, and a competitive atmosphere among parties [21]. Several studies have been conducted on the factors that cause delay and excessive costs and their influence on quality, safety, productivity, etc., particularly in specific project types [21,22].

The construction industry plays a crucial role in the global economy, particularly in Indonesia, but it faces significant challenges. An essential problem currently faced by Indonesia is the inadequate state of infrastructure in terms of both quantity and quality [23]. Building failures often result from shortcomings among service providers and contractors, including insufficient skills and training, substandard materials, and errors in planning that do not meet technical standards and requirements [24]. A major challenge encountered in the construction sector is the low level of productivity [25], a concern shared by construction industries worldwide [26]. This productivity deficit poses significant risks, including potential inflation, social conflicts, and lack of confidence in the economy [27,28].

The government faces significant challenges in managing the development of the national city (IKN), which includes extensive infrastructure projects. The increasing trend in government projects toward Design and Build (DB) presents both opportunities and challenges, and assuming it is not managed effectively, it could lead to low productivity and high waste. DB projects offer the advantage of having a single entry point for both design and construction, requiring careful consideration of the unity between designers and builders. Lean construction principles, obtained from the literature, are being applied in the implementation (builder) phase. The adoption in DB projects poses a new challenge, where lean principles are implemented in both the design and construction phases. This gap presents an area for further study of the application of lean construction to government DB projects. In addition, various factors and variables influencing the implementation of lean construction in DB projects can be analyzed.

1.1. Productivity and Waste

Detecting low productivity in construction projects early is important to minimalize time and cost overruns [29–33]. Various factors impacting productivity relevant to construction project performance in many countries, including Indonesia, have been identified [1,7,21,33–35]. These include (1) lack of materials, (2) delayed arrival of materials, (3) unclear instruction to laborers, (4) labor strikes, and (5) financial difficulties faced by project owners [36]. Furthermore, additional challenges are observed in construction projects globally. These comprise incompetent supervisors or poor management and planning, worker efficiency or skills training, delayed payments, poor construction methods, and safety hazards or accidents [23,24,35,37–41].

In Indonesia, waste is caused by multiple factors, such as policy, asset management, technology, human resources, and knowledge [23]. A model integrating these five factors was recommended to effectively manage and minimalize construction project waste in infrastructural development. From Previous Research on waste management in Indonesia stated four main recommendations, namely (1) build long-term relationships with producers and suppliers to develop efficient shipping methods, thereby minimizing inventory accumulation and delays [23,35,37–41]; (2) prioritize the use of local materials and natural resources when feasible [23,35,37–41]; (3) provide regular training programs for foremen and laborers to enhance the understanding of waste management concepts [23,35,37–41]; and (4) build collaboration and hold routine meetings with all construction personnel across various levels to foster trust and cooperation among team members, who are treated as partners [35].

1.2. Design and Build

The Constitution mandates effective management of government-financed Design and Build (DB) projects. The construction services law No. 2, Year 2017 in Indonesia, manages partner selection in the execution of construction services, focusing on the importance of an objective selection process to drive professionalism in project hosting. Meanwhile, from project initiation, various analyses must be conducted collaboratively with the owner [42–47]. DB projects that have a single-entry advantage [42,43,45,48] in planning and execution facilitate deeper risk management through collaboration between the main contractors and suppliers or subcontractors.

A state-owned enterprise conducted a mapping exercise on a total of 30 projects from 2018 to 2022. However, 35% of the mapped projects were DB, while 50% experienced losses, contradicting the improved performance compared to the Design Bid Build (DBB). Recognizing this anomaly as significant, the present study aims to address the issue by implementing lean construction. Lean construction, known for reducing waste and increasing productivity, offers a promising method to improve the performance of DB projects.

Figure 1 shows the project life cycle, which consists of four main phases. In a DB project, the main contractor manages the planning, design, and execution phases through a single entry [42–45,48].

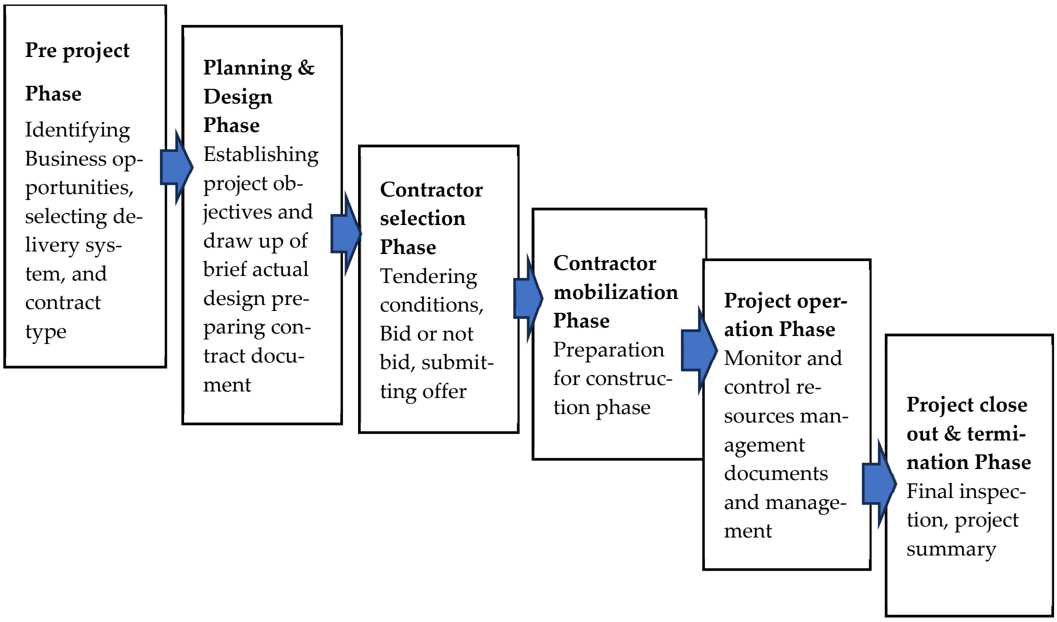

Figure 1. Schematic of project life cycle [49].

From Figure 1 above illustrate project life cycle phase, beginning from initiation phase with pre project for identification business opportunities, planning and design phase, then bid phase for selection contractors to build the project. After contractor selected, contractor must mobilization and operation project, after that closing and termination project.

2. Materials and Methods

The study adopted the quantitative method comprising a schematic literature review that formulated lean construction to measure the effectiveness of government projects. In addition, the qualitative method was also used because it had a direct influence on productivity and project waste. Furthermore, the quantitative method focused on analyzing project progress report data every month. Comprehensive details of the study methods are shown in Table 1.

Table 1. Steps of study methods.

Main Steps	Research Procedure	Results
RQ1	Literature review, monthly progress report	What are the factors affecting productivity and waste in the construction project?
RQ2	Results RQ1 Delphi method	What are the factors affecting LC in government DB projects?
RQ3	Results RQ2 Empirical study in field, results & analysis	Reporting of results and conclusion

The steps shown in Table 1 aim to establish a mapping of the study variables. The variables were used to formulate a lean construction strategy to improve project performance. The resulting mapping, which identified significant variables, is shown in the following figure.

Figure 2 shows the variable mapping process derived from Design and Build (DB) projects as a single entry in both the design and construction phases. The next step is mapping the related factors in the two phases, including the relevant stakeholders. These factors interconnect to form sustainability factors that influence construction project performance.

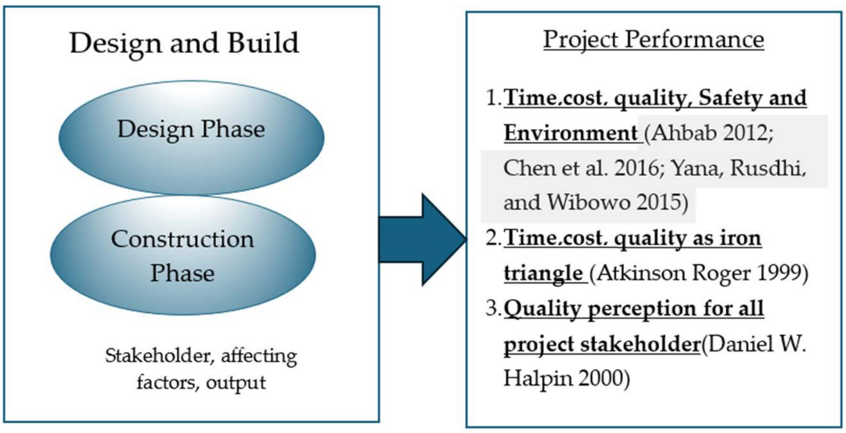

Figure 2. Schematic of variable research [18,50–53].

Collecting Data

Data collection was carried out in two stages, namely the following:

1. Quantitative methods were used to analyze secondary data through monthly progress reports from DB projects completed at six different DB project locations in Java and Kalimantan.
2. In-depth, face-to-face interviews were conducted with owners, contractors, designers, and academics to explore perceptions of lean construction in government projects. Next, an FGD was carried out using the Delphi method to reach consensus.

During the data collection process, respondents were grouped based on their respective functions in the construction project. The next step was to reach a consensus to identify certain variables for deeper analysis in order to obtain accurate results. To facilitate a comprehensive analysis, all interviews were recorded, allowing accurate translation and data cleaning to occur. The Delphi method was used for the following purposes:

1. obtain accurate information that is not available based on the experience of the respondent (expert);
2. handle complex problems that require more in-depth analysis; and
3. study or define areas where there is a lot of uncertainty, lack of knowledge, or differences of opinion, so that more accurate decisions can be made.

This activity comprised nine experts who collectively contributed to the consensus process. The profiles of the experts in this study consist of the owner (CEO), contractor (CEO, director, project manager), designer (senior designer), and academic (associate professor of construction management). The detailed profiles of each expert are shown in Table 2.

Table 2. Profile of respondents for FGD.

Actor	Resp.	Position/Role
Owner	1	Chief Executive Officer
	2	Chief Executive Officer
Designer	3	Senior Designer
	4	Senior Designer
Contractor	5	Chief Executive Officer
	6	Project Manager
	7	Operational Director
Academic	8	Professor of Construction Management
	9	Professor of Construction Management

The collected data was analyzed using standard qualitative method procedures, including data cleaning, data calibration, verification, presentation, and then, conclusions. The first round carried out measurements of the prerequisites, strengths and weaknesses, challenges, and obstacles, as well as the experience of each respondent during the implementation of the DB project through the implementation of lean construction, and the possibility of deeper factors influencing DB practices in LC implementation experienced by the participants. Next, the data was classified based upon the lean construction dimensions found in the literature, namely high productivity and low waste. Follow-up discussions were held with several respondents to strengthen the validity of the analysis and draw definite conclusions.

3. Results

3.1. Research Question 1: Factors Affecting Productivity and Waste

The schematic literature review (SLR) from various prior studies focused on productivity and waste in construction projects. Meanwhile, the Delphi method was used by attaching the results from the previous literature review schematic, grouped into clusters as shown in Table 3. In Round One, the experts obtained eight factors using the Delphi method.

Table 3. SLR productivity and waste.

Description Factors	Factors Affecting
High Productivity	• Labor productivity [25,31] • Quality of material [4] • Finance and payment [4] • Construction method [4] • Crew number and composition [25] • Leadership skills [25,54] • Technology usage [54]
Waste	• Slow decision-making by owner [4] • Improper planning [4,35] • Mistake during construction [4] • Lack of communication between parties [4,25,35] • Change order [4] • Regulation [4] • Late design preparation [4,35] • Delay of material [4,25,35] • Delay of approval test and inspection [4] • Payment delay [25,54] • Equipment availability [4,25,35] • Skills of labor [25,35,54] • Quality of supervision [25,35,54] • Method of working [25,35] • Complexity of information [25] • Lack of leadership [25,54] • Lack of training [25,54] • Poor scheduling/unscheduled [25,35] • Poor procurement strategy • Absenteeism [4,25] • Site acquisition [25]

3.2. Delphi Method Round One: Affecting Factors in Lean Construction (RQ2)

During the first round of the Delphi method, nine experts were questioned about the factors affecting lean construction implementation in a construction project. A literature review schematic was also delivered to the respondents as a reference. Experts were requested to identify a minimum of seven factors that have the most effect on lean construction. The result of this first round produced a mapping of the most influential factors affecting lean construction, as shown in Table 4.

Table 4. Classification of factors.

Classification	Criteria
Quality of human resources	Labor productivity and skills, supervision and leadership skills, absenteeism, lack of training, crew number and composition
Engineering	Scheduling, design, improper planning, poor procurement, technology usage
Payment	Lack of payment or delays
Construction method	Method of working, equipment
Regulation	Regulation
Quality of communication	Lack of communication, late response, delay of approval test and inspection, complexity of information
Quality of supplier/subcon	Equipment, delay and quality of materials
Environment	Environment, site acquisition

Table 5 shows that experts have suggested additional factors necessary for achieving lean construction. These factors include compliance with government regulations, project organizational structure, stakeholder participation, budget control and effectiveness, building information modeling applications, the establishment of long-time partnerships, and risk sharing.

Table 5. Results of Delphi Method Round One.

No.	Factors	Percentage of Experts
1	Quality of human resources	11.1%
2	Engineering	14.3%
3	Payment	6.3%
4	Construction method	7.9%
5	Regulation	1.6%
6	Quality of communication	11.1%
7	Quality of supplier/subcon	4.8%
8	Environment	6.3%
9	Compliance with government regulation	4.8%
10	Organizational structure of project	3.2%
11	Stakeholder participation	4.8%
12	Budget control and effectiveness	4.8%
13	Building information modeling application	4.8%
14	Long-time partnerships	11.1%
15	Risk sharing	4.8%

3.3. Delphi Method Round Two: Refining Affecting Factors (RQ2)

Based on the results of Delphi Method Round One, the experts were presented with the criteria for categorizing the factors as either very important, important, or not important. The results of Round Two are shown in Table 6.

Table 6. Results of Delphi Method Round Two.

Factors	% Experts Who Stated Very Important and Important	Very Important	Important	Not Important
Quality of human resources	100%	44%	56%	0%
Engineering	100%	33%	67%	0%
Payment	100%	33%	67%	0%
Construction method	100%	33%	56%	11%
Regulation	89%	22%	56%	22%
Quality of communication	100%	44%	56%	0%
Quality of supplier/subcon	100%	33%	67%	0%
Environment	56%	11%	44%	44%
Compliance with government regulation	100%	22%	78%	0%
Organizational structure of project	44%	11%	33%	56%
Stakeholder participation	100%	11%	89%	0%
Budget control and effectiveness	100%	11%	78%	0%
Building information modeling application	67%	0%	67%	33%
Long-time partnerships	100%	11%	78%	0%
Risk sharing	44%	0%	44%	56%

Table 6 shows that the percentage of experts who answered "important" and "very important" for organizational structure and risk sharing was less than 50%. Therefore, these two factors are perceived to have less effect on lean construction implementation in construction projects.

3.4. Delphi Method Round Three: Utility of Affecting Factors (RQ2)

During the third round of the Delphi method, the experts revisited factors that had an effect greater than 50% in order to identify suitability. The experts provided an average rating for these factors. An average more significant than 50% was considered suitable for mapping the most influential factors in lean construction implementation for six projects. A scale of one to five was used, with the numbers representing low and high suitability, respectively. The results of the third round of the Delphi method are shown in Table 7.

Table 7. Results of Delphi Method Round Three.

No.	Factors	Suitability
1	Quality of human resources	3.89
2	Engineering	3.67
3	Payment	3.89
4	Construction method	4.11
5	Regulation	3.33
6	Quality of communication	4.44
7	Quality of supplier/subcon	2.78
8	Environment	3.89
9	Compliance with government regulation	3.67
10	Stakeholder participation	3.44
11	Budget control and effectiveness	3.00
12	Building information modeling application	2.67
13	Long-time partnerships	2.67

Table 7 shows that the factors suitable for lean construction implementation are communication quality and construction method. However, 13 of these factors met the criteria (2.5) of having a suitability rating greater than 50%.

3.5. Research Question 3: Empirical Study Project

Six projects were analyzed to understand the influence of the factors in practice when identifying the effectiveness of lean construction implementation in the field. These project analyses aimed to evaluate the success of lean construction strategy implementation in Design and Build (DB). The data characteristics of the projects are stated as follows.

Table 8 shows the nationally distributed building projects with a value of over IDR 100 billion. The progress reports for these six projects included evaluations of project duration based on the existing schedules. Figure 3 compares the planned and actual durations of the projects.

Table 8. Characteristics of projects for research.

No.	Title	Value (IDR Billion)	Location
1	DB "A"	200	DKI Jakarta
2	DB "B"	159	DKI Jakarta
3	DB "C"	265	Bukit Tinggi, West Sumatra
4	DB "D"	293	DKI Jakarta
5	DB "E"	145	DKI Jakarta
6	DB "F"	265	East Kalimantan

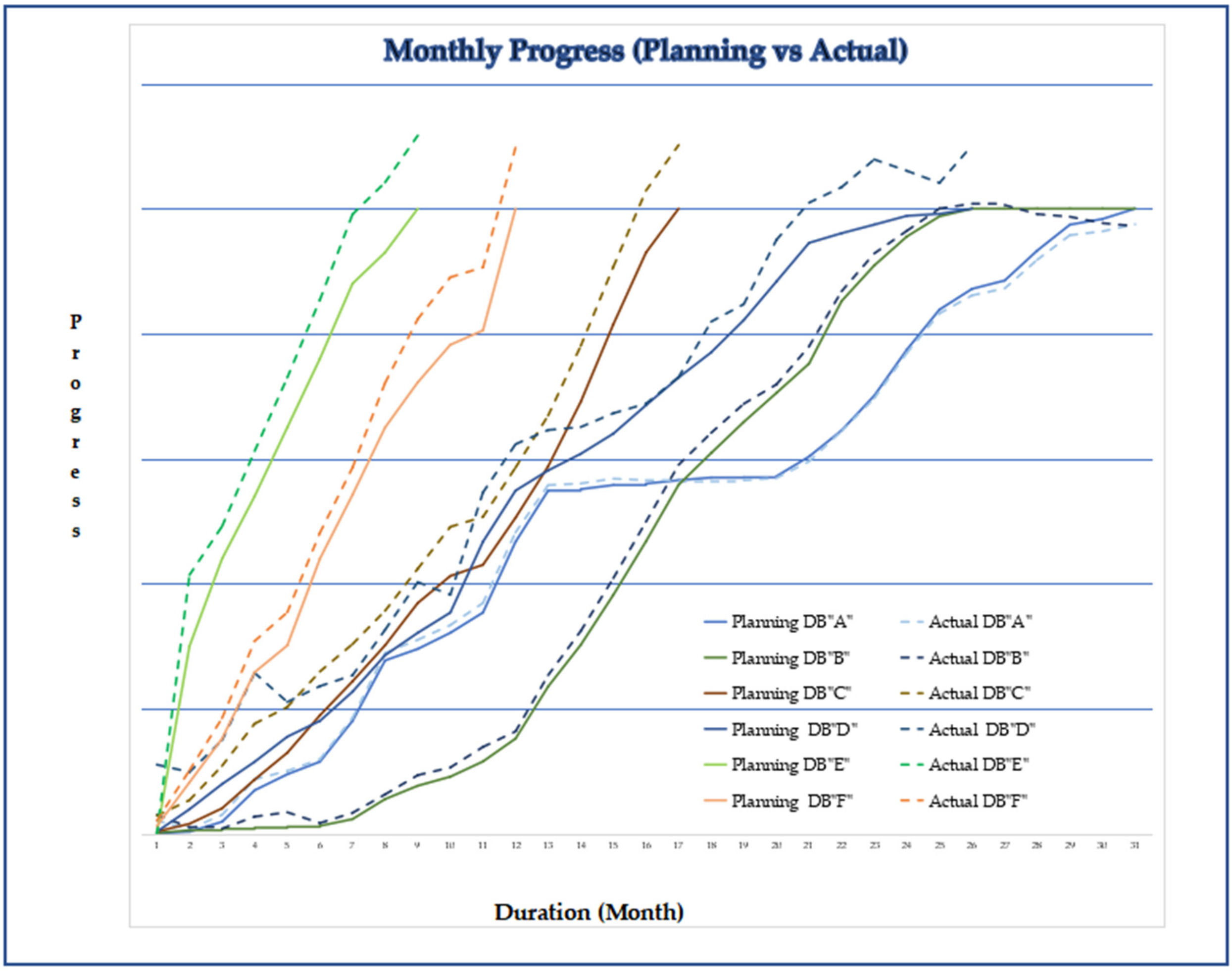

Figure 3. Plan vs. actual schedule.

In Figure 3, DB projects A and B experienced delays in completion due to COVID-19, affecting the project productivity and increasing overhead costs. However, lean construction helped prevent higher deficits, showing controlled milestone schedules and innovative work methods across all six projects. This innovation is precious for large-scale DB projects exceeding IDR 100 billion, ensuring efficiency and maximizing benefits. In addition, Figure 4 shows that DB A and B experienced losses in planning and actual project value.

Figure 4 shows incurred losses of DB A and B of 2% and 3%, respectively. This marked a significant increase in trend compared to prior projects, some of which had experienced losses of approximately 10% due to delays. Therefore, the implementation of lean construction in projects offered long-term benefits. Basic improvements related to project communication from the initiation phase enabled the early detection of problems. Furthermore, improvements in planning and scheduling during the engineering phase led to more comprehensive project management. Compliance with government regulations, such as the ministry circulars General Infrastructure, enhanced project security for future investigations. Suppliers were invited and partnered with based upon their track records of previously conducted projects, thereby contributing to a project's success.

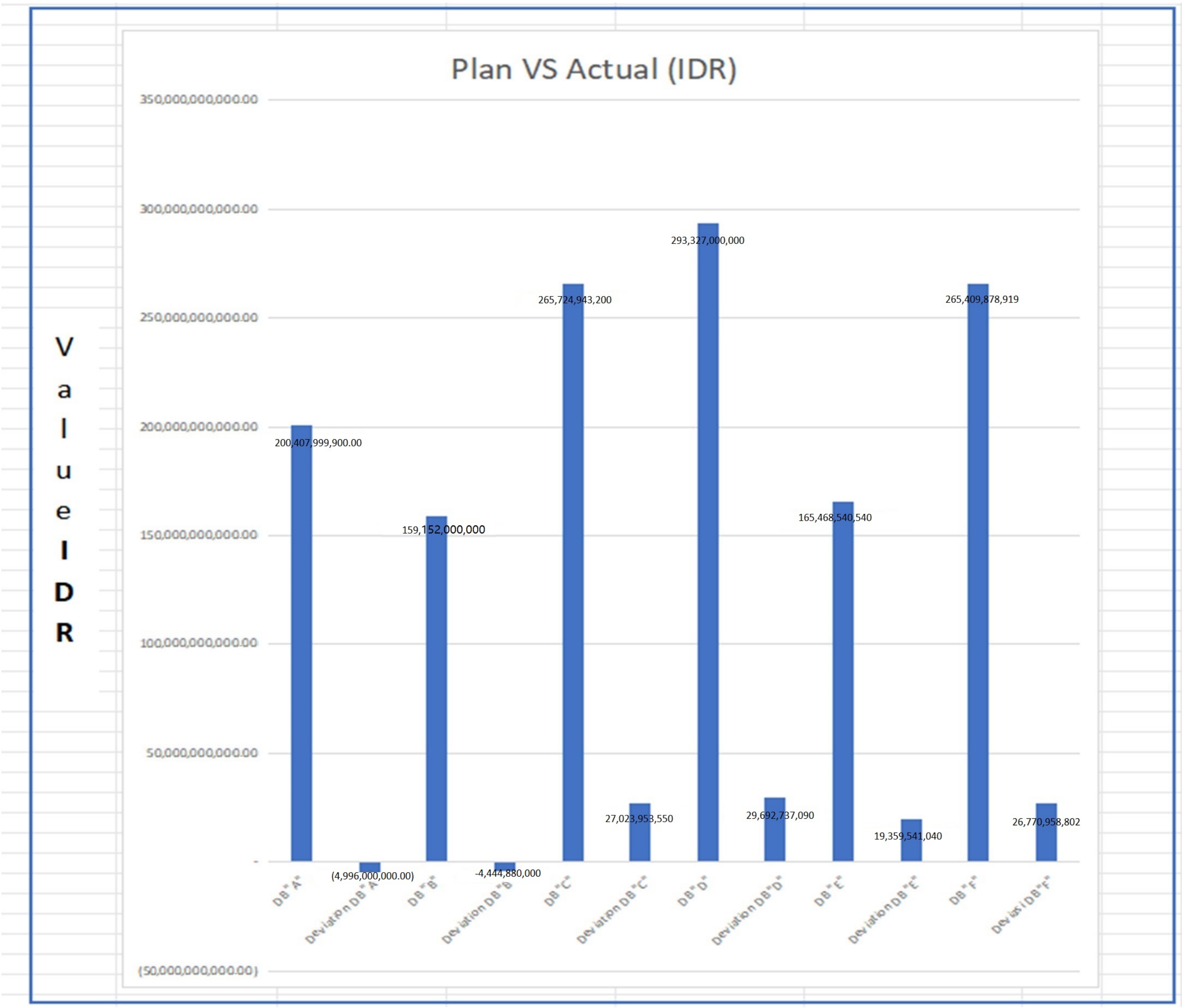

Figure 4. Deviation of plan vs. actual.

4. Discussion

The conclusion drawn from RQ1 and RQ3 is that implementing lean construction in government Design and Build projects is affected by 13 factors. In addition, Table 9 shows the factors affecting the implementation of this construction process in government projects in Indonesia. The analysis of Table 9 showed a significant difference in the factors influencing the enactment of lean construction between government DB projects and the implementation phase. This disparity arises from the unity between designers and builders, causing certain factors to intersect. For example, factors such as compliance with regulations, stakeholder participation, regulation, long-time partnerships, and subcon quality are interconnected. The factors rely on the effective management of DB projects by the government, focusing on project implementation and enhancing the initial phases of the project life cycle, namely initiation and design. This section is important because design maturity in a DB project does not have to be 100%; according to Asmar (2013) [55] 20% is ideal. The neglect of stakeholder participation and long-time partnerships may result in losses during delivery. Stakeholder participation is crucial for collaboratively designing and planning project goals, while long-time partnerships ensure effective risk sharing.

Table 9. Factors affecting the implementation of lean construction.

No.	Factors	References
1	Quality of human resources	[3,4,7,8,25,35]
2	Engineering	[3,4,7,8,25,35]
3	Payment	[3,4,7,8,25,35,56]
4	Construction method	[3,4,7,8,25,35]
5	Regulation	[4,23]
6	Quality of communication	[3,4,7,8,25,35,38]
7	Quality of supplier/subcon	[3,4,7,8,25,35]
8	Environment	[3,4,7,8,25,35]
9	Compliance with government regulation	[4,23]
10	Stakeholder participation	[57–63]
11	Budget control and effectiveness	[56,64,65]
12	Building information modeling application	[47,66–69]
13	Long-time partnerships	[58,59,62,70–74]

Adhering to government regulations is essential in Indonesia, especially given the inspection of the implemented budget by the authorities. The implementation of lean construction must comply with procurement regulations and any restrictions on additional work, even when there is prior agreement with the owner.

A. Lean Construction

The efficient implementation of lean construction is essential for the development of the national city (IKN) infrastructure. This study needs to be referenced for lean construction implementation in IKN infrastructure projects. Meanwhile, through the mapping analysis, it was observed that lean construction implementation was influenced by various factors. The results of the focus group discussion (FGD) provided stakeholders with valuable viewpoints on the implementation of lean construction in IKN, such as the following.

- Owner: The implementation of lean construction is essential for reducing waste and increasing productivity across project phases. By taking control of the work carried out by contractors, including both design and construction, lean construction can improve performance in terms of cost, quality, time, safety, and environment [11,13,14,18,19,75–79].
- Contractor: Contractors play an important role in ensuring the successful implementation of lean construction in a project by overseeing the selection process of suppliers, engineering procedures, financial management, safety protocols, and environmental considerations. This careful oversight is necessary to ensure that lean construction serves as a targeted strategy, providing maximum value to the project. Lean construction control must be planned with respect to the execution process of the contractors, recognizing that the focus and benefits achieved tend to vary [2,34,38,80–96].
- Consultant (Designer): Designers play an important role in ensuring that the design produced is compatible with lean construction practices and not vice versa. The accuracy in preparing design optimizes the effectiveness of lean construction and maximizes the benefits [97–101].
- Academic: It is essential to collaborate with various sectors to realize superior performance. The lean construction method focuses on project execution as well as Design and Build (DB) superiority, enabling control from the initiation of the design process. Long-term partnering with suppliers is important for ensuring lasting success in lean construction [34,38,72–74,80–82,102].

5. Conclusions

In conclusion,

1. The implementation of lean construction strategies in projects led to improved performance across various dimensions, including cost, quality, time, safety, and environment [2,34,38].
2. The study stated that the implementation of lean construction needed to consider various influencing factors. These factors comprised the quality of human resources (such as skills, management, leadership, etc.), engineering considerations (including scheduling, planning, material schedule, tech usage, etc.), payment procedures, regulatory compliance, construction method, communication, supplier/subcon quality, environmental factors, stakeholder participation, budget control and effectiveness, implementation of BIM, and long-term partnerships [3,4,7,8,23,25,35,47,66,67,72–74].
3. Compliance with government regulation is necessary in Indonesia due to the inspection of the implemented budget. Furthermore, the implementation of lean construction should not violate government regulations related to procurement and permitted additional work, even when there is an agreement with the owner.
4. The result of the focus group discussion (FGD) reflected that the readiness for implementing lean construction in IKN government projects, particularly those of a Design and Build (DB) type and a value exceeding IDR 100 billion, requires further investigations of perceptions through quantitative methods. The expectation and readiness need to be evaluated and clear guidelines provided for effective implementation. The readiness for implementation includes several parties that agree to similar principles and perceptions of lean construction in a project [2,38].

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References

1. Shridhar, D.S. Delays in Construction Project and Their Preventions. 2016. Available online: http://www.mospi.nic.in (accessed on 11 February 2024).
2. Abdelhamid, T.S.; El-Gafy, M.; Salem, O. Lean Construction: Fundamentals and Principles. 2008. Available online: https://www.researchgate.net/publication/289380759 (accessed on 11 February 2024).
3. Okpala, D.C.; Aniekwu, A.N. Causes of High Costs of Construction in Nigeria. *J. Constr. Eng. Manag.* **1988**, *114*, 233–244. [CrossRef]
4. Odeh, A.M.; Battaineh, H.T. Causes of Construction Delay: Traditional Contracts. 2002. Available online: www.elsevier.com/locate/ijproman (accessed on 11 February 2024).
5. Wang, W.C.; Lin, C.L.; Wang, S.H.; Liu, J.J.; Lee, M.T. Application of importance-satisfaction analysis and influence-relations map to evaluate design delay factors. *J. Civ. Eng. Manag.* **2014**, *20*, 497–510. [CrossRef]
6. Latham, M. *Constructing the Team: Final Report: Joint Review of Procurement and Contractual Arrangements in the United Kingdom Construction Industry*; HMSO: London, UK, 1994.
7. Amarkhil, Q.; Elwakil, E.; Hubbard, B.; Byrd, V.L. A framework to standardize causes of construction delay. *Int. J. Constr. Manag.* **2021**, *23*, 1791–1804. [CrossRef]

8. Ramanathan, C.; Narayanan, S. Construction Delays Causing Risks on Time and Cost-a Critical Review. *Constr. Econ. Build.* **2012**, *12*, 37–57. [CrossRef]
9. Kumaraswamy, M.M.; Chan, D.W.M. Determinants of construction duration. *Constr. Manag. Econ.* **1995**, *13*, 209–217. [CrossRef]
10. Albtoush, A.M.F.; Doh, S.I.; Rahman, R.A.; Al-Momani, A.H. Critical success factors of construction projects in Jordan: An empirical investigation. *Asian J. Civ. Eng.* **2022**, *23*, 1087–1099. [CrossRef]
11. Wang, J.; Lin, W.; Huang, Y.H. A performance-oriented risk management framework for innovative R&D projects. *Technovation* **2010**, *301–312*, 601–611. [CrossRef]
12. Bakare, A. Good Corporate Governance and Organisational Performance: An Empirical Analysis. 2014. Available online: www.ijhssnet.com (accessed on 11 February 2024).
13. Hanna, A.S.; Iskandar, K.A.; Lotfallah, W. Benchmarking project performance: A guideline for assessing vulnerability of mechanical and electrical projects to productivity loss. *Constr. Manag. Econ.* **2019**, *37*, 101–111. [CrossRef]
14. Chan, A.P.C.; Chan, A.P.L. Key performance indicators for measuring construction success. *Benchmarking* **2004**, *11*, 203–221. [CrossRef]
15. Chan, D.W.M.; Kumaraswamy, M.M. A comparative study of causes of time overruns in Hong Kong construction projects. *Int. J. Proj. Manag.* **1997**, *15*, 55–63. [CrossRef]
16. Mesa, H.A.; Molenaar, K.R.; Alarcón, L.F. Exploring performance of the integrated project delivery process on complex building projects. *Int. J. Proj. Manag.* **2016**, *34*, 1089–1101. [CrossRef]
17. Enshassi, A.; Kochendoerfer, B.; Al Ghoul, H. Factors Affecting Sustainable Performance of Construction Projects during Project Life Cycle Phases. 2016. Available online: http://penerbit.uthm.edu.my/50 (accessed on 11 February 2024).
18. Chen, Q.; Jin, Z.; Xia, B.; Wu, P.; Skitmore, M. Time and Cost Performance of Design–Build Projects. *J. Constr. Eng. Manag.* **2016**, *142*, 2016. [CrossRef]
19. KKabirifar; Mojtahedi, M. The impact of Engineering, Procurement and Construction (EPC) phases on project performance: A case of large-scale residential construction project. *Buildings* **2019**, *9*, 15. [CrossRef]
20. Kaliba, C.; Muya, M.; Mumba, K. Cost escalation and schedule delays in road construction projects in Zambia. *Int. J. Proj. Manag.* **2009**, *27*, 522–531. [CrossRef]
21. Ahmed, S.M.; Azhar, S. Construction Delays in Florida: An Empirical Study. 2022. Available online: https://www.researchgate.net/publication/228584635 (accessed on 11 February 2024).
22. Alinaitwe, H.; Apolot, R.; Tindiwensi, D. Investigation into the Causes of Delays and Cost Overruns in Uganda's Public Sector Construction Projects. *J. Constr. Dev. Count.* **2013**, *18*, 33.
23. Suripin, E.; Wibowo, M.A. Model of Construction Waste Management Using AMOS-SEM for Indonesian Infrastructure Projects, EDP Sciences. *MATEC Web Conf.* **2017**, *138*, 05005. [CrossRef]
24. Rusdiani, R. Analisis Kegagalan Konstruksi Pada Bangunan Gedung di Provinsi Jawa Barat. Master's Thesis, Universitas Katolik Parahyangan, Jawa Barat, Indonesia, 2017.
25. Jarkas, A.M.; Bitar, C.G. Factors Affecting Construction Labor Productivity in Kuwait. *J. Constr. Eng. Manag.* **2012**, *138*, 811–820. [CrossRef]
26. Ayele, S.; Fayek, A.R. A framework for total productivity measurement of industrial construction projects. *Can. J. Civ. Eng.* **2019**, *46*, 195–206. [CrossRef]
27. Dixit, S.; Mandal, S.N.; Sawhney, A.; Singh, S. Area of Linkage Between Lean Construction and Sustainability in Indian Construction Industry. *Int. J. Civ. Eng. Technol.* **2017**, *8*, 623–636.
28. Dixit, S.; Pandey, A.K.; Mandal, S.N.; Bansal, S. A Study of Enabling Factors Affecting Construction Productivity: Indian Scenario. *Int. J. Civ. Eng. Technol.* **2017**, *8*, 741–758.
29. Kaming, P.F.; Olomolaiye, P.O.; Holt, G.D.; Harris, F.C. Factors influencing craftsmen's productivity in Indonesia. *Int. J. Proj. Manag.* **1997**, *15*, 21–30. [CrossRef]
30. Kaming, P.F.; Olomolaiye, P.O.; Holt, G.D.; Harris, F.C. Factors influencing construction time and cost overruns on high-rise projects in Indonesia. *Constr. Manag. Econ.* **1997**, *15*, 83–94. [CrossRef]
31. Kadir, M.R.A.; Lee, W.P.; Jaafar, M.S.; Sapuan, S.M.; Ali, A.A.A. Factors affecting construction labour productivity for Malaysian residential projects. *Struct. Surv.* **2005**, *23*, 42–54. [CrossRef]
32. Palikhe, S.; Kim, S.; Kim, J.J. Critical Success Factors and Dynamic Modeling of Construction Labour Productivity. *Int. J. Civ. Eng.* **2019**, *17*, 427–442. [CrossRef]
33. Seddeeq, A.B.; Assaf, S.; Abdallah, A.; Hassanain, M.A. Time and cost overrun in the Saudi Arabian oil and gas construction industry. *Buildings* **2019**, *9*, 41. [CrossRef]
34. Wandahl, S. Lean Construction with or without Lean-Challenges of Implementing Lean Construction Exploring Last Planner System in Search of Excellence View Project. 2014. Available online: https://www.researchgate.net/publication/276417464 (accessed on 11 February 2024).
35. Alwi, S.; Mohamed, S.; Hampson, K. Waste in the Indonesian Construction Projects. 2002. Available online: https://eprints.qut.edu.au/4163/1/4163.pdf (accessed on 11 February 2024).
36. Momade, M.H.; Durdyev, S.; Van Tam, N.; Shahid, S.; Mbachu, J.; Momade, Y. Factors influencing adoption of construction technologies in Vietnam's residential construction projects. *Int. J. Build. Pathol. Adapt.* **2022**. [CrossRef]

37. Ajayi, S.O.; Oyedele, L.O. Waste-efficient materials procurement for construction projects: A structural equation modelling of critical success factors. *Waste Manag.* **2018**, *75*, 60–69. [CrossRef] [PubMed]
38. Pinch, L. Lean Eliminating the Waste Construction. *Constr. Exec.* **2005**, *15*, 34–37.
39. Letcher, T.M.; Vallero, D.A. *Waste: A Handbook for Management*; Elsevier: Amsterdam, The Netherlands; Academic Press: Cambridge, MA, USA, 2011.
40. Ajayi, S.O. Design, Procurement and Construction Strategies for Minimizing Waste in Construction Projects. Ph.D. Thesis, UWE, Bristol, UK, 2016.
41. Treloar, G.J.; Gupta, H.; Love, P.E.D.; Nguyen, B. An analysis of factors influencing waste minimisation and use of recycled materials for the construction of residential buildings. *Manag. Environ. Qual. Int. J.* **2003**, *14*, 134–145. [CrossRef]
42. Lam, E.W.M.; Chan, A.P.C.; Chan, D.W.M. Benchmarking design-build procurement systems in construction, Emerald Group Publishing Ltd. *Benchmarking* **2004**, *11*, 287–302. [CrossRef]
43. Katar, I.M. Enhancing the Project Delivery Quality; Lean Construction Concepts of Design-Build & Design-Bid-Build Methods. *Int. J. Manag.* **2019**, *10*, 324–337. [CrossRef]
44. Tran, D.; Molenaar, K.R.; Gransberg, D.D. Implementing best-value procurement for design-bid-build highway projects. *Transp. Res. Rec.* **2016**, *2573*, 26–33. [CrossRef]
45. Xia, B.; Chen, Q.; Xu, Y.; Li, M.; Jin, X. Design-Build Contractor Selection for Public Sustainable Buildings. *J. Manag. Eng.* **2015**, *31*, 04014070. [CrossRef]
46. Ghassemi, R.; Gerber-Becerik, B. Transitioning to IPD: Potential Barriers & Lessons Learned. 2011. Available online: https://lean-construction-gcs.storage.googleapis.com/wp-content/uploads/2022/11/18014349/Transitioning_to_Integrated_Project_Delivery_Potential_barriers_and_lessons_learned.pdf (accessed on 11 February 2024).
47. Glick, S.; Guggemos, A.A. IPD and BIM: Benefits and opportunities for regulatory agencies background of IPD and BIM. In Proceedings of the 45th Associated Schools of Construction National Conference, Gainesville, FL, USA, 1–4 April 2009.
48. Chan, A.P.C.; Scott, D.; Lam, E.W.M. Framework of Success Criteria for Design/Build Projects. *Manag. Eng.* **2002**, *18*, 120–128. [CrossRef]
49. Fishwick, P.A. *Handbook of Dynamic System Modeling*; Chapman and Hall: Sundridge, ON, Canada, 2002; pp. 1–30.
50. Ahbab, C. An Investigation on Time and Cost Overrun in Construction Projects. Master's Thesis, Institute of Graduate Studies and Research, Eastern Mediterranean University, Gazimağusa, North Cyprus, 2012.
51. Yana, A.A.G.A.; Rusdhi, H.A.; Wibowo, M.A. Analysis of factors affecting design changes in construction project with Partial Least Square (PLS). *Procedia Eng.* **2015**, *125*, 40–45. [CrossRef]
52. Atkinson, R. Project management: Cost, time and quality, two best guesses and a phenomenon, its time to accept other success criteria. *Int. J. Project Manag.* **1999**, *17*, 337–342. [CrossRef]
53. Halpin, D.W. *Construction Management*, 4th ed.; John Wiley & Son, Inc.: New York, NY, USA, 2000; ISBN 978-0-470-44723-9.
54. Ayodele, O.A.; Chang-Richards, A.; González, V. Factors Affecting Workforce Turnover in the Construction Sector: A Systematic Review. *J. Constr. Eng. Manag.* **2020**, *146*, 03119010. [CrossRef]
55. El Asmar, M.; Hanna, A.S.; Loh, W.-Y. Quantifying Performance for the Integrated Project Delivery System as Compared to Established Delivery Systems. *J. Constr. Eng. Manag.* **2013**, *139*, 04013012. [CrossRef]
56. Ward, S.; Chapman, C. Choosing Contractor payment term. *Int. J. Proj. Manag.* **1994**, *12*, 216–221. [CrossRef]
57. Lahdenperä, P. Making sense of the multi-party contractual arrangements of project partnering, project alliancing and integrated project delivery. *Constr. Manag. Econ.* **2012**, *30*, 57–79. [CrossRef]
58. Chen, W.T.; Merrett, H.C.; Lu, S.T.; Mortis, L. Analysis of key failure factors in construction partnering-A case study of Taiwan. *Sustainability* **2019**, *114*, 3994. [CrossRef]
59. Nyström, J. Partnering: Definition, Theory and the Procurement Phase. Ph.D. Thesis, KTH, Stockholm, Sweden, 2005.
60. Peckiene, A.; Komarovska, A.; Ustinovicius, L. Overview of risk allocation between construction parties. *Procedia Eng.* **2013**, *57*, 889–894. [CrossRef]
61. Kania, E.; Śladowski, G.; Radziszewska-Zielina, E.; Sroka, B.; Szewczyk, B. Planning and monitoring communication between construction project participants. *Arch. Civ. Eng.* **2021**, *67*, 455–473. [CrossRef]
62. Malvik, T.O.; Engebø, A. Experiences with Partnering: A Case Study on the Development Phase. *Procedia Comput. Sci.* **2022**, *196*, 1044–1052. [CrossRef]
63. Bellini, A.; Aarseth, W.; Hosseini, A. Effective Knowledge Transfer in Successful Partnering Projects. *Energy Proc.* **2016**, *96*, 218–228. [CrossRef]
64. Emery, G.W.; Marques, M.A. The effect of transaction costs, payment terms and power on the level of raw materials inventories. *J. Oper. Manag.* **2011**, *29*, 236–249. [CrossRef]
65. Odeyinka, H.A.; Kaka, A. An evaluation of contractors' satisfaction with payment terms influencing construction cash flow. *J. Financ. Manag. Prop. Constr.* **2005**, *10*, 171–180. [CrossRef]
66. Elghaish, F.; Abrishami, S.; Hosseini, M.R.; Abu-Samra, S. Revolutionising cost structure for integrated project delivery: A BIM-based solution. *Eng. Constr. Archit. Manag.* **2020**, *28*, 1214–1240. [CrossRef]
67. Merschbrock, C.; Hosseini, M.R.; Martek, I.; Arashpour, M.; Mignone, G. Collaborative Role of Sociotechnical Components in BIM-Based Construction Networks in Two Hospitals. *J. Manag. Eng.* **2018**, *34*, 05018006. [CrossRef]

68. Davies, R.; Harty, C. Implementing 'site BIM': A case study of ICT innovation on a large hospital project. *Autom. Constr.* **2013**, *30*, 15–24. [CrossRef]
69. Park, T.; Kang, T.; Lee, Y.; Seo, K. Project Cost Estimation of National Road in Preliminary Feasibility Stage Using BIM/GIS Platform. *Comput. Civil Build. Eng.* **2014**, *2014*, 423–430.
70. Ganesan, S. Determinants of Long-Term Orientation in Buyer-Seller Relationships. *J. Mark.* **1994**, *58*, 1–19. [CrossRef]
71. Hermanto, E.; Soetomo, S.; Wibowo, M.A. Toward Partnership for Government Construction Project in Indonesia. *Int. J. Sci. Res. Publ.* **2018**, *80*, 716–720. [CrossRef]
72. Sari, E.M.; Irawan, A.P.; Wibowo, M.A.; Siregar, J.P.; Praja, A.K.A. Project Delivery Systems: The Partnering Concept in Integrated and Non-Integrated Construction Projects. *Sustainability* **2023**, *15*, 86. [CrossRef]
73. Sari, E.M.; Irawan, A.P.; Wibowo, M.A.; Siregar, J.P.; Tamin, R.Z.; Praja, A.K.A.; Dewi, M.P. Challenge and Awareness for Implemented Integrated Project Delivery (IPD) in Indonesian Projects. *Buildings* **2023**, *13*, 262. [CrossRef]
74. Sari, E.M.; Irawan, A.P.; Wibowo, M.A. Role of Technical Education in Partnering Construction Project: A Geographical Study on Indonesia. *Rev. Int. Geogr. Educ.* **2021**, *11*, 636–644.
75. Prajogo, D.; Oke, A.; Olhager, J. Supply chain processes: Linking supply logistics integration, supply performance, lean processes and competitive performance. *Int. J. Oper. Prod. Manag.* **2016**, *36*, 220–238. [CrossRef]
76. Molenaar, K.R.; Songer, A.D.; Barash, M. Public-sector design/build evolution and performance. *J. Manag. Eng.* **1999**, *15*, 54–62. [CrossRef]
77. Pocock, B.B.J.; Member, A.; Hyun, C.T.; Member, Z.; Liu, L.Y.; Kim, M.K. Relationsidp between project interaction and performance indicators. *J. Constr. Eng. Manag.* **1996**, *122*, 165–176. [CrossRef]
78. Matsuno, K.; Mentzer, J.T. Market Orientation-Performance Relationship/1 The Effects of Strategy Type on the Market Orientation-Performance Relationship. *J. Mark.* **2000**, *64*, 1–16. [CrossRef]
79. Alaloul, W.S.; Liew, M.S.; Zawawi, N.A.W.A. Identification of coordination factors affecting building projects performance. *Alex. Eng. J.* **2016**, *55*, 2689–2698. [CrossRef]
80. Achell, J.F.P. Introductión a Lean Construction. 2014. Available online: https://www.juanfelipepons.com/wp-content/uploads/2017/02/Introduccion-al-Lean-Construction-1.pdf (accessed on 11 February 2024).
81. Paez, O.; Salem, S.; Solomon, J.; Genaidy, A. Moving from lean manufacturing to lean construction: Toward a common sociotechnological framework. *Hum. Factors Erg. Manuf.* **2005**, *15*, 233–245. [CrossRef]
82. Zhang, L.; Chen, X. Role of Lean Tools in Supporting Knowledge Creation and Performance in Lean Construction, Elsevier Ltd. *Procedia Eng.* **2016**, *145*, 1267–1274. [CrossRef]
83. Wilson, L. *How to Implement Lean Manufacturing*; CiNii: Tokyo, Japan, 2010.
84. Green, S.D. The missing arguments of lean construction. *Constr. Manag. Econ.* **1999**, *17*, 133–137. [CrossRef]
85. Da, T.; Alves, C.L.; Tsao, C.C.Y. Lean Construction—2000 to 2006. *Lean Constr. J.* **2007**, *3*, 46–64.
86. Howell, G.; Ballard, G.; Guaruja, B. Implementing lean construction: Understanding and action. In Proceedings of the 6th Annual Conference of the International Group for Lean Construction, Berkeley, CA, USA, 13–15 August 1998.
87. Salem, O.; Asce, M.; Solomon, J.; Genaidy, A.; Minkarah, I. Lean Construction: From Theory to Implementation. *J. Manag. Eng.* **2006**, *22*, 168–175. [CrossRef]
88. Mahfouz, A. Lean distribution concept, constructs and practices. In Proceedings of the EUROMA 2010, Dublin, Ireland, 7–12 June 2010.
89. Suresh, M.; Nathan, R.B.A.R. Readiness for lean procurement in construction projects. *Constr. Innov.* **2020**, *20*, 587–608. [CrossRef]
90. Koskela, L.; Howell, G.; Ballard, G.; Tommelein, I. *The Foundations of Lean Construction Editorial Comment*; Routledge: London, UK, 2001.
91. Alves, T.D.C.L.; Milberg, C.; Walsh, K.D. Exploring lean construction practice, research, and education. *Eng. Constr. Archit. Manag.* **2012**, *19*, 512–525. [CrossRef]
92. Alarcon, L.F.; Alarcón, L.F.; Diethelm, S.; Rojo, O.; Calderon, R. Assessing the Impacts of Implementing Lean Construction. 2016. Available online: https://www.researchgate.net/publication/255606265 (accessed on 11 February 2024).
93. Mossman, A. What is lean construction: Another look—2018. In Proceedings of the IGLC 2018—26th Annual Conference of the International Group for Lean Construction: Evolving Lean Construction Towards Mature Production Management Across Cultures and Frontiers, The International Group for Lean Construction, Chennai, India, 16–22 July 2018; pp. 1240–1250. [CrossRef]
94. Salem, O.; Solomon, J.; Genaidy, A.; Luegring, M. Site Implementation and Assessment of Lean Construction Techniques. 2005. Available online: https://experts.syr.edu/en/publications/site-implementation-and-assessment-of-lean-construction-technique (accessed on 11 February 2024).
95. Sacks, R.; Treckmann, M.; Rozenfeld, O. Visualization of Work Flow to Support Lean Construction. *J. Constr. Eng. Manag.* **2009**, *135*, 1307–1315. [CrossRef]
96. Marhani, M.A.; Jaapar, A.; Bari, N.A.A.; Zawawi, M. Sustainability Through Lean Construction Approach: A Literature Review. *Procedia Soc. Behav. Sci.* **2013**, *101*, 90–99. [CrossRef]
97. Tousignant, E.; Fankhauser, O.; Hurd, S. *Guidance Manual for the Design, Construction and Operations of Constructed Wetlands for Rural Applications in Ontario*; Agricultural Adaptation Council: Guelph, ON, Canada, 1999.
98. Schwartz, C.; Morthland, L.; McDonald, S. Building a social framework: Utilising design/build to provide social learning experiences for architecture students, Routledge. *Archit. Theory Rev.* **2014**, *19*, 76–91. [CrossRef]

99. Laurent, J.; Leicht, R.M.; Asce, M. Practices for Designing Cross-Functional Teams for Integrated Project Delivery. *J. Constr. Eng. Manag.* **2019**, *145*, 05019001. [CrossRef]
100. Zimina, D.; Ballard, G.; Pasquire, C. Target value design: Using collaboration and a lean approach to reduce construction cost. *Constr. Manag. Econ.* **2012**, *30*, 383–398. [CrossRef]
101. Molenaar, K.R.; Sobin, N.; Antillón, E.I. A Synthesis of Best-Value Procurement Practices for Sustainable Design-Build Projects in the Public Sector. 2023. Available online: http://meridian.allenpress.com/jgb/article-pdf/5/4/148/2193488/jgb_5_4_148.pdf (accessed on 11 February 2024).
102. Sari, E.M.; Irawan, A.P.; Wibow, M.A.; Purwanto, S.K.; Sutawidjaya, A.H.; Dewi, M.P.; Santoso, J.T. Design bid build to integrated project delivery: Strategic formulation to increase partnering. *J. Infrastruct. Policy Dev.* **2023**, *8*, 1. [CrossRef]