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Key Performance Indicators (KPI) to Measure Effectiveness of Lean Construction in Indonesian Project

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Abstract: The implementation of lean construction is very important in the construction industry to reduce waste and increase productivity. To ensure its effective implementation, clear and measurable Key Performance Indicators (KPIs) are necessary. Therefore, this research aimed to develop SMART-based KPIs (Specific, Measurable, Attainable, Realistic, and Time-bound) for lean construction implementation, which measure indicators throughout the project life cycle. In this context, both qualitative and quantitative methods were used to collect data. Quantitative data were collected through surveys, assessing the perceptions of respondents concerning KPIs that had been developed. Meanwhile, qualitative data were collected through interviews and expert Focus Group Discussions (FGDs), which included in-depth analysis and conclusions regarding lean construction KPIs. The results produced were KPIs that could be used to measure effectiveness in implementing lean construction, particularly for building projects in Indonesia. Consequently, this research provided new views concerning effective lean construction, which could be explored in more depth and implemented for stakeholders in the construction industry. This development could eventually improve project performance by reducing waste and increasing productivity in construction projects.

Keywords: key performance indicators; lean construction; project performance; project life cycle; SMART

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1. Introduction

Lean construction is essential in reducing waste and increasing productivity in construction projects [1–3]. The industry is gradually moving from traditional management models to more modern and streamlined methods in order to improve project performance [4,5]. This trend is evident in various countries where lean construction methods have been developed to improve project performance [6–8]. Even though this method has been used for a long time, not many projects have been able to implement it correctly. To solve this problem, various tools, such as Last Planner System (LPS), have been developed to assist with implementation [9–13]. However, the challenge in applying lean construction projects is about creating tools to measure effectiveness in the implementation [2,14,15]. Several projects experience high waste [2,16,17] due to various factors, specifically during the implementation phase. Typically, the root causes of these problems are often not properly investigated throughout all phases of the project life cycle [18].

Waste can be assessed both during the project implementation phase and in the initial phase when the project is being defined. In this context, procurement policies perform an important role in managing waste, particularly in projects based on lean construction [16,19]. Following this discussion, Ade [19] explained that many factors should be considered in managing procurement in government projects in Indonesia to achieve effectiveness in project implementation. Arviga [20] argued that to achieve government projects that have long-term sustainability, lean management should be conducted from the initiation phase. Given the urgency of previous research, it is essential to measure the effectiveness of lean construction as part of project management with good governance [21]. To achieve this objective, specific tools are required to implement KPIs. Antho [22] proposed that the measurement of project performance indicators could be categorized into five levels of depth. The highest level is at the institutional level and becomes a culture in the organization. However, this process presents the challenge of how to develop smart-based KPIs for lean construction. Therefore, the current research aims to contribute by improving lean construction-based project performance by developing in-depth SMART-based KPIs.

1.1. Lean Construction

The construction industry is experiencing very significant changes as well as complex problems, and innovation is required to improve construction performance. Consequently, lean construction aims to reduce waste, inventory delays, slow transportation, waiting time due to material shortages, corrections, and inefficient use of human resources [3].

Lean construction focuses on efficient building processes, leading to cost savings, a well-coordinated supply chain, and a simplified workflow. Relating to this discussion, lean construction starts with lean design and procurement [16].

Figure 1 shows that the lean construction process should start with a lean design, followed by procurement and project implementation, incorporating these phases into one unit to achieve the process of the method. Moreover, some efforts that can be made through lean construction include the following:

a. The process is conducted simultaneously to add value for the customer or government. This process includes subcontractors and suppliers from the start, beginning from when the contractor participates in the bidding process [20,23–26].
b. The design phase should be flexible and follow the proper obtaining process to reduce material discrepancies in the design and procurement process [16,27].
c. Structuring the work of the entire process to increase productivity and reduce waste at the project implementation level. This effort should be implemented from the planning phase, allowing the project implementation phase to increase [7,28–30].

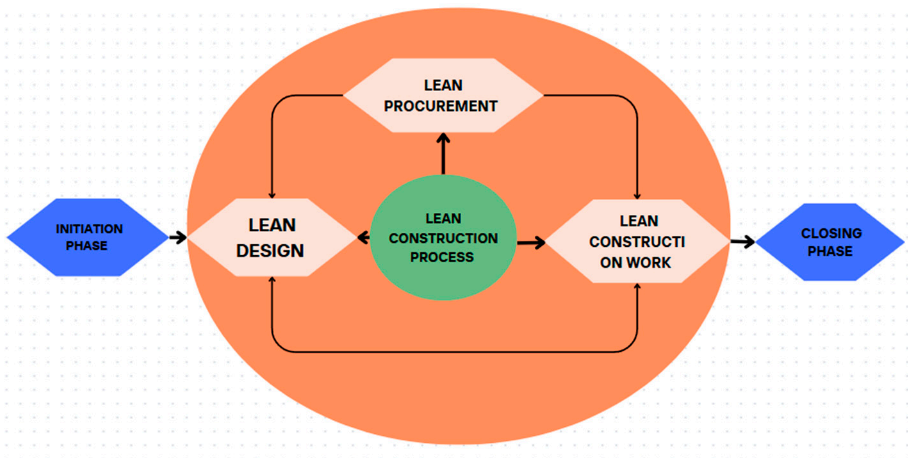

Figure 1. Lean construction process [2,16,20].

Lean construction also regulates the level of relationship between the parties included in the contract, namely the owner, designer, and contractor. In this scenario, subcontractors are hired early in the design phase to facilitate the development of Relational Contracts (RC) and Integrated Delivery Systems (IPD) [8,23,24,31,32]. This process is called implementing the concept of lean construction in projects. Additionally, the implementation of a lean project delivery system refers to five basic concepts, namely, definition phase, design phase, procurement, implementation, and project closure [33–36].

a. The initiation phase is the phase managed by the project implementer or manager who is responsible for the project, including the design and development phases. Moreover, during this phase, input and integration from past projects as well as planning design criteria and expected final project outcomes will be considered.
b. In the lean design phase, the conceptual design is developed from push to pull, which is consistent with the resulting criteria. The design process includes all stakeholders in planning and final design, but the results can be reviewed from the beginning.
c. The lean procurement phase consists of detailed engineering of product designs produced using lean design, then purchasing components and materials, delivery logistics management, and controlled inventory.
d. The implementation phase of the project is managed using lean principles, focusing on reducing waste and increasing productivity. Many of the tools used in this phase are commonly known as LPS.
e. The closing phase is the handover of assets and workforce consisting of operations, maintenance, commissioning, and decommissioning.

1.2. Project Life Cycle

Project success is very important and must be measured both objectively and subjectively [37], at the macro and micro levels, to comprehensively evaluate the achievement of the project. Consequently, the success of the project is assessed during the implementation phase, but for a more comprehensive evaluation, the phase should be measured at every stage of the project life cycle [35]. The life cycle of a project generally starts with the initiation, design, implementation, operation, and maintenance phases [35], with each phase having specific success criteria that can be measured. Moreover, this measurement considers the influencing factors and stakeholders included in each phase. Measuring project performance has become more complex, now including factors, such as cost, quality, time, safety, and environment [38,39].

Figure 2 shows that the project life cycle is divided into four phases, where each phase has criteria for determining success, which can be measured through factors, such as cost, quality, time, safety, and environment [19,20,25]. However, in implementing the project life cycle, controlling the procurement phase is crucial for influencing the success of the project.

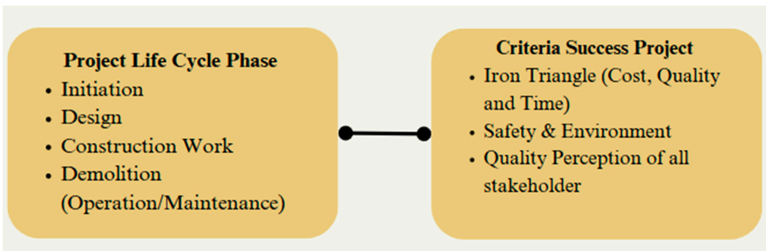

Figure 2. Relationship between project life cycle and success criteria [38,39].

1.3. Key Performance Indicators

KPIs are a series of activities that require time and resources to meet assessment standards or principles, which are used to measure [40] and evaluate performance, and the methods of measuring project success over time have been developed [40]. Initially, project success is assessed based on its duration and performance, followed by the "iron triangle" [38] of cost, quality, and time. Finally, the project assessment considers psychological criteria and the legal security of contracts. Relating to this discussion, project success criteria are shown in Figure 3.

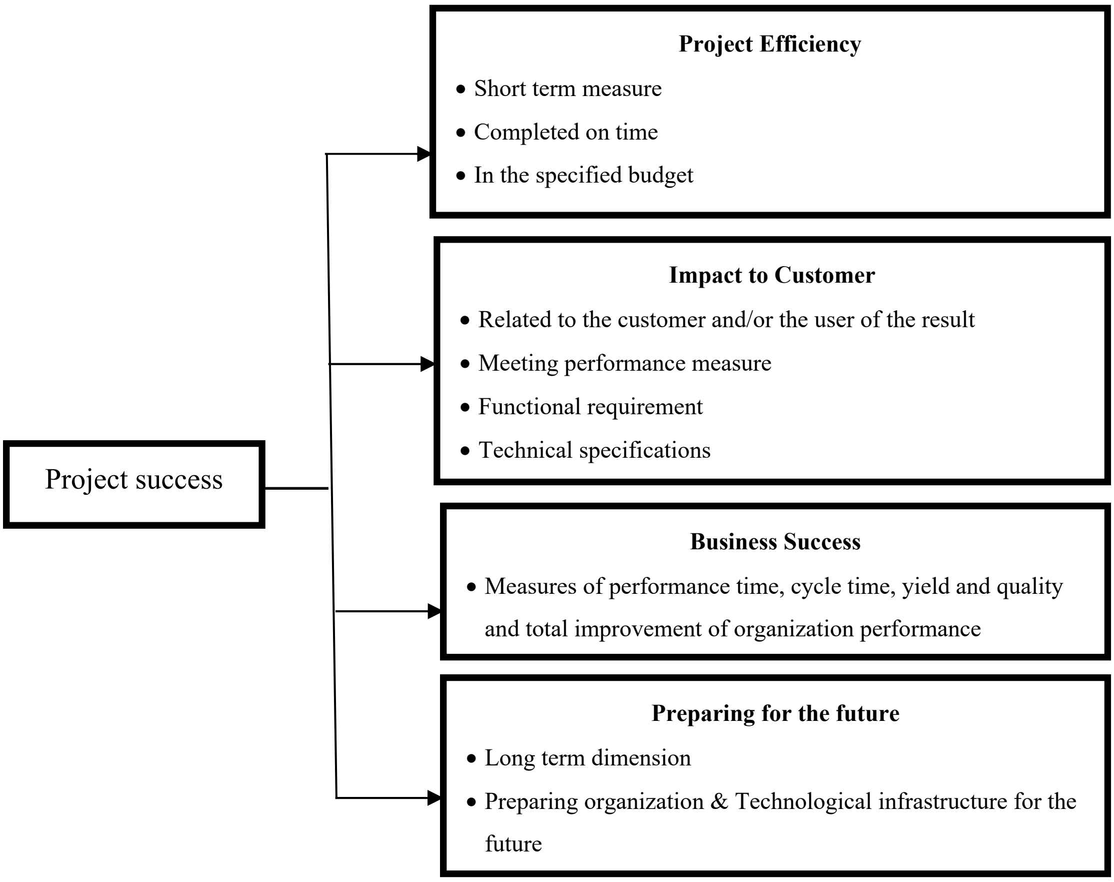

Figure 3. Success criteria of construction project [40].

Figure 3 shows that the criteria for construction project success are measured in four dimensions, namely project efficiency, impact on customers, business success, and preparing for the future. Moreover, this process shows that, when setting KPIs for construction projects, considering both project efficiency and how to prepare the organization and technology for future requirements is necessary.

1.4. SMART Analysis

KPIs will be used at all levels of the organization to assess the achievement of project objectives. Each organization and department will use different KPIs to measure organizational success based on specific business aims and objectives [41]. In addition, a way to assess the relevance of performance indicators is according to the SMART concept, which is defined by the following criteria.

a. Specific: specific to a particular aim or task focus in the project life cycle phase.
b. Measurable: this can be easily measured in numbers or percentages, each person can transparently measure with indicators determined based on clear standardization of measurements.
c. Attainable: should be achievable; can be imagined to be achieved.
d. Realistic: the product of a strong and realistic foundation is not outside the business process.
e. Time-bound: have a time frame attached, usually a measurement period for each project duration or yearly.

The first step taken by an organization is to identify relevant performance and criteria to support organizational objectives. KPIs are set to reflect and define organizational aims and should influence business decisions over a certain period based on the available time. Given this scenario, KPIs show consistency, communication, and ability to act, which are interconnected between main indicators, aims, objectives, and strategies [41]. The purpose of performance appraisal is to compare current and different levels of accomplishments against expected performance levels and improvement gaps. This process adds value, helps achieve organizational purposes, and also motivates employees to perform better. Moreover, the effectiveness of any assessment effort depends on its proper application to provide the highest value to the entire organization, and a scoring system is used to determine the best way to achieve success [42].

2. Material and Methods

A mixed method, namely qualitative and quantitative, was used in this methodology. A detailed description of the methodology is presented in the following figure.

The steps of this research are presented in Figure 4, with the following explanation.

Step 1: Defined KPIs according to lean construction criteria for all phases in project life cycle. These KPIs were formulated from schematic literature review (SLR) of previous research for each phase in the life cycle.
Step 2: Conducted selection and determination of KPIs that had been prepared from Step 1, then selected according to project criteria in Indonesia. Moreover, the research was performed for buildings in the large government project category in the design and build (DB) category.
Step 3: KPIs selected from Step 2 were validated through FGD with 12 experts, based on the criteria shown in Table 1.
Step 4. The conducted weighting of KPIs was validated by experts in FGD, and then the method was formed to conduct in-depth interviews with stakeholders to measure and implement KPIs in building projects on government schemes with DB contracts.

Step 5: Prepare KPI measurement report achieved in project as an investigation.

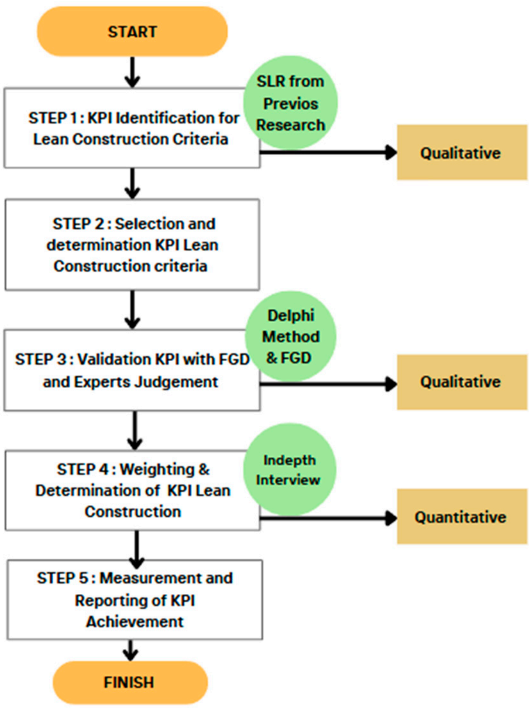

Figure 4. Step-by-step process of research.

Performing FGD included experts who had previously filled out a consent form to participate in the research [43–47]. Additionally, decision making was conducted using Delphi method with the following criteria.

a. The number of experts was 12 from diverse settings [43,46].

b. A minimum of 2 (two) rounds were performed to develop a consensus [43–45,47].
c. Experts were professionals with a minimum of 10 years of experience in the field as contractors, consultants, or academics.

Delphi method was performed in 2 rounds where each round was explained as follows.

a. The first round was conducted by providing a list of indicators from SLR adopted from journals and previous research. Experts were asked to select "YES" or "NOT", which meant that indicators could be used or not.
b. In the second round, the experts were again given the results of the questionnaire in Delphi round 1. For the next stage, the experts provided an assessment of indicators selected in round 1 for refining into "very important", "important" and "not important". Furthermore, professionals assigned percentages to the selected indicators, and when the value of indicators was very important and the total importance was >50%, the indicators would be used to assess lean construction.

The selection of expert composition in this research was formulated by explorers with a balanced composition, where there were 4 groups, each divided equally. This process limited experts allowing the composition of contractors to be more dominant because project implementers understood how to apply lean construction.

Relating to this discussion, a list of experts included in FGD is shown below.

Table 1. List of experts.

Expert No.	Criteria	Description
1	Owner/Government	Head of Region/PUPR
2		Head of Region/PUPR
3	Contractor	Operational Director
4		Marketing Director
5		General Manager/Head of PM
6		Project Manager
7	Senior Consultant for Designer	Senior Consultant for designer
9		Senior Consultant Supervision
10	Academic	P.H.D in Construction Management
11		Prof. In Construction Management
12		Prof. In Construction Management

Table 1 showed the experts included in FGD to validate KPIs and provide weighting for the assessments in project life cycle phase. Subsequently, measurements were conducted on the investigation of 6 (six) DB building project locations with data, as shown in Table 2.

Table 2. List of projects for exploration.

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

According to Table 2, testing was performed for lean construction-based KPI measurements using KPIs validated by experts. Following this process, in-depth interviews were conducted on the measurement of the methods. Comparisons of project achievement data were also performed to measure elements of project implementation.

3. Results

The preparation stages started with SLR, followed by a selection from lean construction-based KPIs. Additionally, the selected KPIs were then validated with expert judgment using the Delphi method for two rounds. The final results were validated by experts through FGD, as shown in the table below.

Table 3 shows KPIs for all phases in the project life cycle, including initiation, design, implementation, and closing phases (handing over project in the form of assets to the owner/government). Moreover, in Table 3, weighting was performed to assess KPIs on a scale of 0–4, enabling balanced weight according to the severity of each phase. The weighting for each KPI as a measure in the project investigation is shown below.

Table 3. List of KPIs for lean construction.

No.	Project Life Cycle Phase	KPIs	Indicators	References
1	Initiation	Collaboration to achieve common objectives	• Had the same point of view in completing project • Conducted intensive communication • Established partnerships to add value	[1–3,8,15,48–50]
		The same vision and mission in managing project	• High commitment among major participants • Intensive communication occurred • There was good coordination between major participants • Very fast decision making • Good knowledge transfer in project • Innovation and openness increase • Ownership of project • There were no land acquisition problems	
2	Design	Improved management design	• Design collaboration between owner and contractor • Design maturity > 20% • Clear specifications • The design details were excellent • Designs were built in collaboration between all stakeholders which created added value for customers • Value engineering focuses on the best value • Competent designer • Shared vision in planning joint designs • No repetitive designs (reduced waste) • Environmentally friendly design (green building) • Designing lean procurement • Design applied BIM	[3–5,7,8,29,30,50–53]

Table 3. *Cont.*

No.	Project Life Cycle Phase	KPIs	Indicators	References
3	Construction Work	Creation of a good project organizational culture	• BUMN AKHLAK culture (trustworthy, competent, harmonious, loyal, adaptive, collaborative)	[6,8,30,53–62]
		Achievement of project performance	• Project was performed in the specified time • The work results met the specified specifications and criteria • The results met quality control standards • No accidents in the work environment and there were no errors during the activities	
		Reduced waste	• No wrong work/repair/making do • No unused material • No material wasted	
		Competent workforce	• Competent managerial team • Competent subcontractors/suppliers • Effective cost of labor • Effective labor productivity	
		Project schedule on time	• Planning and realization of schedule following planning • Percent completed by provisions • There was project schedule that was understood by all stakeholders • Equipped with a good schedule monitoring information system	
		Fast decision-making process	• There was no pending approval due to work approval and test results • There were no sudden material changes	
		Knowledge management occurred well	• There was regular training related to lean principles • Regular training achieved better project quality • There was a cause-and-effect analysis in project with 5 "whys"	
		There was no variability in work	• There was no variability in work because it was arranged collaboratively from the start.	
		Financial	• Payment and settlement were not problematic during project • Term payment from the owner on time	
4	Closing/handover	The use of information systems effectively supported work and decision-making	The use of the system supports effectiveness in work and decision making	[62–69]
		Delivery of output and assets on time	• Delivery of output and assets was well received • The final project report was well received	
		Settlement of subcontractor/supplier payments	All settlements completed	
		Risk management was well managed	Management was well managed with partnering between major participants in project	

Table 4 shows the KPI weighting for each project life cycle phase to determine the weighting of lean construction-based KPI achievements. Furthermore, the assessment used a 0–4 scale to justify the achievements in each exploration with an explanation of each scale.

Table 4. Lean construction KPI weighting.

No.	Project Life Cycle Phase	Weighting
1	Initiation	10%
2	Design	20%
3	Construction Work	55%
4	Closing	15%

Table 5 shows levels 0–4 for measuring the depth for each indicator that was used to measure lean construction-based KPIs.

Table 5. Lean construction-based KPI measurement scale [22,69].

Level	Description
Level 0	Stakeholders in project did not coordinate and communicate effectively, leading to different views on project success indicators.
Level 1	Project stakeholders coordinated to share vision and mission in achieving project aims, but did not have a common vision in the objectives, thereby causing non-achievement of project indicators.
Level 2	Stakeholders managed to be part of the vision and mission for achieving project purposes, had the same views on project objectives, and expressed a unified commitment to executing project.
Level 3	Project stakeholders harmonized to partake in the vision and mission in achieving project aims, had united views for project objectives, and were committed to implementation.
Level 4	Project stakeholders coordinated to share vision and mission in achieving project plans and had associated views in achieving project aims. The stakeholders expressed a responsibility to implement project, however, committed project objectives exceeded the achieved purposes.

4. Discussion

KPI measurements were conducted on explorations from six building project locations with the DB delivery system with the following project achievements.

Table 6 shows the assessment results of the six KPI exploration projects in each project life cycle phase. Furthermore, the next stage included weighting and calculating an average for each KPI achievement across projects. The following shows the weighting of each achievement in each project life cycle, as shown in Table 7.

Table 6. KPI assessment results on the investigation project.

Project Life Cycle Phase	DB″A″	DB″B″	DB″C″	DB″D″	DB″E″	DB″F″
Initiation	2.450	2.360	3.180	3.270	3.630	3.360
Design	2.670	2.910	3.410	3.750	3.830	4.000
Construction Work	3.080	3.120	3.750	3.580	3.700	3.660
Closing	3.200	3.000	4.000	4.000	4.000	3.800

Table 7. Final review of KPIs.

Project Life Cycle Phase	DB"A"		DB"B"		DB"C"		DB"D"		DB"E"		DB"F"	
Initiation (10%)	2.450	0.245	2.360	0.236	3.180	0.318	3.270	0.327	3.630	0.363	3.360	0.336
Design (20%)	2.670	0.534	2.910	0.582	3.410	0.682	3.750	0.750	3.830	0.766	4.000	0.800
Construction Work (55%)	3.080	1.694	3.120	1.716	3.750	2.063	3.580	1.969	3.700	2.035	3.660	2.013
Closing (15%)	3.200	0.480	3.000	0.450	4.000	0.600	4.000	0.600	4.000	0.600	3.800	0.570
Sumarry KPI		2.953		2.984		3.663		3.646		3.764		3.719

Table 7 shows the final recap of KPIs after being weighted according to the project life cycle phase, which included initiation (10%), design (20%), construction work (55%), and closing (15%). In addition, a general description of KPI achievements is shown in Figure 5.

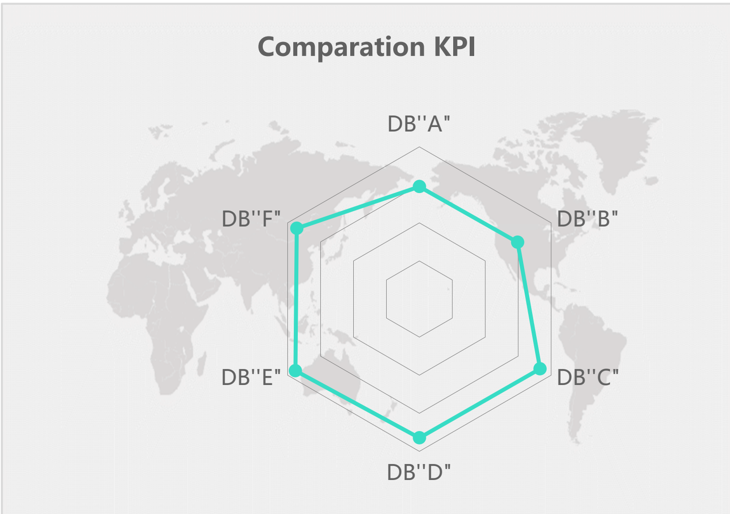

Figure 5. Comparison of KPIs.

Figure 5 shows that DB"A" and DB"B" were far from the required KPI target, with score 4. Meanwhile, DB"E" and DB"F" were close to the required KPIs based on lean construction. As project methods required KPIs, higher scores showed good performance following the lean construction concept, where waste was minimized and productivity increased.

5. Conclusions

In conclusion, the results established the following:

a. To measure the effectiveness of implementing lean construction in projects, it was necessary to have KPIs for each project life cycle phase, allowing the depth of performance achievements to be measured and evaluated in detail considering the weaknesses in performance.
b. Lean construction-based KPI measurements for each phase in the project life cycle were used to detect the biggest problems that prevented project performance from being achieved. This detection led to lessons being learned and the creation of a Standard Operating Procedure (SOP) for future projects, helping to make the organizational structure more sustainable and providing long-term benefits.
c. Modifications to implement lean construction using the indicators were adjusted and new indicators were added to each phase of the project life cycle, including initiation, design, project implementation, and closing. Moreover, additional indicators, such

as those related to location and project difficulty, were included, and the results were weighted in the assessment.

d. Future challenges for implementing lean construction would be the project size and organization. When indicators are developed, the size of the organization should be added, specifically in the project implementation phase. Following this discussion, the weighting could be performed according to team agreement in the organization. The indicators could still be used to measure the depth of lean construction implementation in projects.

e. The research developed lean construction-based KPIs for building projects and adapted the model for other delivery systems, such as Design Bid Build (DBB) and Integrated Project Delivery (IPD), by incorporating additional processes from the indicators identified.

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