

ANALYSIS OF SUCCESS FACTORS IN IMPLEMENTING THE BIM-LEAN CONSTRUCTION APPROACH IN CONSTRUCTION PROJECTS IN SOUTH SUMATERA

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ABSTRACT

Building Information Modeling (BIM) and Lean Construction are two strategies that are being used more and more to address these problems in tandem with the advancement of global construction technology. In order to apply BIM-Lean building to building projects in South Sumatra, it is necessary to determine the critical success factors (CSFs). Contractors, consultants, and project owners must understand these success characteristics in order to implement a BIM-Lean approach successfully, sustainably, and with a major influence on project performance. Lean Construction is the application of Lean Manufacturing concepts to construction project management. This strategy focuses on improving workflow, cutting waste, and boosting process efficiency in order to add value for clients. In contrast to traditional management techniques, which frequently place an emphasis on individual productivity, Lean Construction places a strong emphasis on teamwork, planning dependability, process stability, and information transparency throughout the project. The structural equation modeling-partial least squares (SEM-PLS) method is used in this study's quantitative methodology. The research aims of investigating causal links between latent constructs and predicting important factors influencing the success of BIM-Lean deployment are best served by this approach, which is why it was selected. Based on a Google Form questionnaire of 119 respondents, findings indicate strong support for the implementation of BIM-Lean Construction through management policies, HR competency, technology readiness, and communication. A significant 52.6% rated management policies as crucial, while 84.2% affirm teamwork supports continuous improvement. Technology assessments show strong reliability, with effective internet connectivity rated at 89.5%. Collaboration is also highlighted, with 57.9% agreeing on project information accessibility and 79% noting improved teamwork through BIM. Furthermore, a Lean culture is evident, with 57.9% strongly agreeing on adhering to work standards and 52.6% on waste reduction. Overall, the internalization of efficiency principles within the organization supports the effective integration of BIM technology, linking technical tools with a culture of continuous improvement for project success.

Keywords: Building Information Modeling (BIM), Lean Construction, Structural Equation Modeling-Partial Least Squares (SEM-PLS).

1. INTRODUCTION

One area that is essential to the expansion of the national economy is the building industry. Public infrastructure, housing, transportation, energy, and social facilities are all made possible by Indonesia's construction industry, which also makes a substantial contribution to the country's GDP. The national construction industry nevertheless faces a number of fundamental issues despite its strategic position, such as low productivity, excessive project delays, material waste, high rework rates, and a lack of stakeholder integration. The primary drivers of cost and time variations in building projects are process and coordination inefficiencies, according to numerous studies (Fitriani & Bangun, Br, Prasetyo, 2021).

Building Information Modeling (BIM) and Lean Construction are two strategies that are being used more and more to address these problems in tandem with the advancement of global construction technology. BIM reduces design flaws, minimizes coordination conflicts (clash detection), and improves the accuracy of cost and time calculations by enabling the multidimensional and collaborative visualization and integration of building information. In the meantime, Lean Construction, which is based on the Lean Manufacturing concept, concentrates on cutting waste, streamlining the value stream, boosting process effectiveness, and fostering a continuous improvement-oriented workplace culture (Fitriani et al., 2021).

Strong synergies have been demonstrated when BIM and Lean Construction ideas are combined. Lean supports BIM implementation techniques through methodical work process improvements, while BIM offers a digital platform that makes applying Lean concepts simpler and more scalable. Projects that combine these two strategies minimize waste, boost productivity and quality, and speed up decision-making, according to numerous worldwide studies (Fitriani et al., 2021).

Regulations, such as those requiring BIM for specific government projects, have started to promote the use of BIM in Indonesia. Simultaneously, the construction professional community is gradually adopting Lean Construction. Nevertheless, the application of both strategies—particularly their integration—remains inadequate. Inadequate training, reluctance to change, insufficient technology infrastructure, a lack of implementation standards, a weak collaborative culture, and poor human resource readiness are common problems (Fitriani et al., 2022).

The province of South Sumatra, which is seeing substantial infrastructural development, likewise faces this circumstance. Toll highways, bridges, government buildings, industrial facilities, and large-scale housing projects are examples of projects that highlight the critical need for a more effective, integrated, and digitally oriented approach to project management. Despite the fact that a number of South Sumatra construction enterprises are familiar with BIM and Lean, their use is still dispersed and not yet strategically integrated (Fitriani et al., 2019).

In order to apply BIM-Lean building to building projects in South Sumatra, it is necessary to determine the critical success factors (CSFs). Contractors, consultants, and project owners must understand these success characteristics in order to implement a BIM-Lean approach successfully, sustainably, and with a major influence on project performance. The lack of empirical research on BIM-Lean Construction integration in Indonesia, especially in a regional setting like South Sumatra, makes this study pertinent. In addition to offering an implementation model that stakeholders may use as a guide, this study is anticipated to make scholarly and practical contributions about the elements impacting the success of BIM-Lean integration in construction projects.

2. THEORITICAL FRAMEWORK

A digital model-based project management technique called Building Information Modeling

(BIM) combines diverse data into a single, collaborative platform that is available to all parties involved. In addition to creating three-dimensional (3D) geometric representations, BIM also generates non-geometric data, including material specifications, technical characteristics, cost information (5D), project scheduling (4D), and building lifespan projections (6D). With these integrative features, BIM becomes the primary basis for more efficient and uniform asset management, design coordination, decision-making, and building performance analysis.

Because all stakeholders work from a single source of truth, BIM is seen in international literature as a shared knowledge resource that functions throughout the building lifecycle, from conceptualization, planning, analysis, construction, operation, and demolition. This approach allows for a more structured decision-making process; consequently, BIM can lower the possibility of errors, increase data accuracy, improve interdisciplinary coordination, and ensure information consistency across all project phases.

Lean Construction is the application of Lean Manufacturing concepts to construction project management. This strategy focuses on improving workflow, cutting waste, and boosting process efficiency in order to add value for clients. In contrast to traditional management techniques, which frequently place an emphasis on individual productivity, Lean Construction places a strong emphasis on teamwork, planning dependability, process stability, and information transparency throughout the project.

The Lean concept is based on the idea that any activity that does not benefit the customer should be reduced or eliminated. Implementing Lean principles is essential for lowering process variability, enhancing schedule reliability, and maximizing coordination between project stakeholders in the construction industry, which is known for its high levels of complexity and uncertainty. This leads to more effective and efficient work execution.

The structural equation modeling–partial least squares (SEM–PLS) method is used in this study's quantitative methodology. The research aims of investigating causal links between latent constructs and predicting important factors influencing the success of BIM-Lean deployment are best served by this approach, which is why it was selected. This research was carried out in the province of South Sumatra, which is seeing a notable increase in building and infrastructure development. The province is promoting the use

of contemporary construction technology, such as Building Information Modeling (BIM) and the Lean Construction methodology, especially for critical government and industry projects, which is why this site was selected. Companies and organizations that are involved in the planning, execution, and oversight phases of building projects are among the research objects. These include:

1. The physical execution of the work is the responsibility of contractor firms of all sizes.
2. Consultants for planning and supervision are essential to design preparation, technical coordination, and project quality assurance.
3. The policies and tactics for deploying project technology, including BIM-Lean, are set by project owners, both public and commercial.
4. Lean workflows and BIM model coordination are crucial for specialist contractors (MEP, structural, finishing, etc.) who are directly involved in technical work.

The research focuses on the following kinds of projects:

1. Roads, bridges, clean water systems, and drainage are examples of infrastructure projects that are extremely complicated and necessitate interdisciplinary cooperation.
2. Building projects, such as commercial, governmental, educational, and industrial structures, are typically the first industries to use BIM extensively.
3. Large-scale housing projects, which demand time and cost efficiency as well as quality consistency, make them relevant to the Lean approach.
4. Due to the necessity for precise design and interdisciplinary integration, EPC projects and the energy sector (where available) have been global leaders in the adoption of BIM and lean-based management.

3. RESULT AND DISCUSSION

A total of 119 respondents participated in this study, according to the results of data collection using a Google Form questionnaire. The distribution of respondents by gender reveals that the majority of respondents were male, at 84.2%, while female respondents were 15.8%. This dominance of male respondents reflects the actual conditions in the construction industry sector, particularly in areas related to Building

Information Modeling (BIM) and Lean Construction, which are still dominated by male professionals.

This is understandable given the characteristics of construction work that call for technical, operational, and strategic decision-making involvement in project management. Because the respondents are from professional groups that are directly involved in the planning, execution, and management of construction projects, their gender composition is deemed representative to support the analysis of success factors for BIM-Lean Construction implementation using the Structural Equation Modeling (SEM) method. Therefore, it is anticipated that the collected data will be able to characterize respondents' opinions and real-world experiences with respect to the examined research variables.

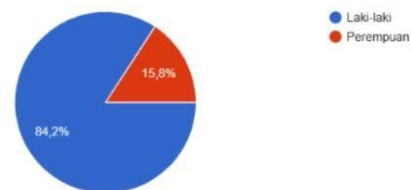


Figure 3.1. Gender graphic response

Source: Google Form Asri Mulyadi

The distribution of responders by job title or position within the project revealed a varied composition, according to data gathered via a Google Form questionnaire. The majority of respondents (52.6%) fell into the "Other" category, which reflects the involvement of a variety of professional roles outside of the primary occupations indicated, such as technical staff, owner representative, implementing contractor, or other supporting positions in building projects.

Additionally, 21.1% of respondents had the title "Project Manager," compared to 10.5% each for Site Manager and Planning/Supervisory Consultant. At 5.3%, the Site Engineer position got the lowest percentage. The categories "BIM Engineer/BIM Modeler," "Quality Engineer," and "Planner/Scheduler" had no responders.

This position composition indicates that the majority of respondents play both strategic and operational roles in construction project management. The involvement of respondents at various management and technical levels provides a comprehensive perspective on the factors contributing to the success of BIM-Lean Construction implementation, from planning and coordination to field implementation.

The variety of respondents' perspectives enhances the quality of the research data in the

context of Structural Equation Modeling (SEM) analysis because the perceptions gathered represent the actual conditions across roles in construction projects. As a result, it is anticipated that the analysis results will be able to more accurately and representatively identify causal relationships between latent variables regarding BIM–Lean Construction implementation practices in construction projects.

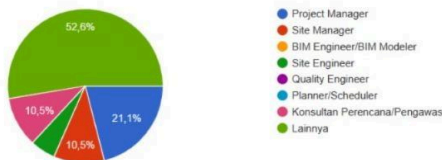


Figure 3.2. Characteristic of response
Source: Google Form Asri Mulyadi

Based on data collected through a Google Form questionnaire, of the 119 respondents involved in this study, the distribution of respondents based on the type of project they frequently handle indicates that the majority of respondents are involved in infrastructure projects, such as roads, bridges, airports, ports, and railways, with a percentage of 52.6%. This indicates that the implementation of BIM–Lean Construction in this study is largely perceived from the perspective of infrastructure projects, which generally have a high level of complexity and require intensive interdisciplinary coordination.

Furthermore, 26.3% of respondents handle educational and government projects (universities, schools, and government buildings). 10.5% of respondents are involved in building projects (offices, shopping centers, hotels, and the like) and residential projects. Meanwhile, no respondents reported frequently handling industrial, factory, or healthcare projects.

The dominance of infrastructure and public projects among these respondents provides a strong context for this research, given that these projects tend to have high demands for time, cost, and quality efficiency, making the application of the BIM–Lean Construction approach highly relevant. From a Structural Equation Modeling (SEM) analysis perspective, this variety of project types enriches respondents' perspectives on the success factors for BIM–Lean Construction implementation, including technology, process, management, and organizational aspects.

Thus, the results of this study are expected to comprehensively describe the key success factors for BIM–Lean Construction relevant to various types of construction projects, particularly infrastructure and public projects, which were the primary focus of respondents.

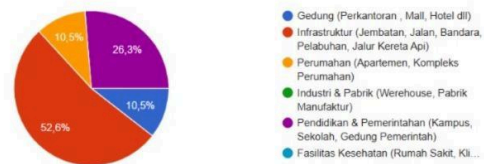


Figure 3.3. Type of projects response

Source: Google Form Asri Mulyadi

3.1. Management Supportting Response

Based on the results of a Google Form questionnaire completed by 119 respondents, responses to indicator X1.1: "Management provides formal policies to support BIM–Lean implementation" showed a very positive trend. The majority of respondents (52.6%) rated the policy on a scale of 5 (strongly agree), indicating that more than half of respondents considered the existence of formal management policies to be a very important factor and were already perceived in the implementation of BIM–Lean Construction.

Furthermore, 31.6% of respondents rated the policy on a scale of 4 (agree), indicating a strong perception that management support through formal policies was working well, although there was still room for strengthening or improvement. Meanwhile, 10.5% of respondents rated the policy neutral (scale 3), and only a small proportion rated the policy slightly disagree (scale 2). No respondents strongly disagreed (scale 1).

This distribution of responses indicates that respondents generally agreed that management support in the form of formal policies is a crucial element in the successful implementation of BIM–Lean Construction. From a Structural Equation Modeling (SEM) perspective, indicator X1.1 has the potential to contribute strongly to forming the Management Support latent variable, as it demonstrates a high level of agreement and consistent perceptions among respondents. Thus, these results reinforce the research's assumption that top management commitment, manifested through formal policies and internal regulations, plays a significant role in driving the successful integration of BIM and Lean Construction in construction projects.

Table 3.1. Management Supportting Response

Variable	Factor	Validation
X1.1	Formal policies are provided by management to facilitate the deployment of BIM-Lean.	Approved
X1.2	A sufficient budget is set aside by management for the use of BIM technology.	Approved

X1.3	The management actively promotes HR development and training linked to BIM-Lean.	Approved
X1.4	The project's BIM-Lean deployment is directly assessed by management.	Approved
X1.5	The shift from traditional to digital and lean work techniques is supported by management.	Approved

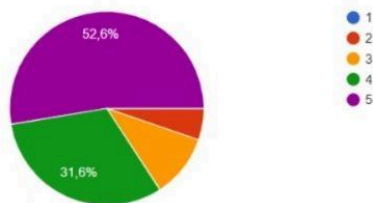


Figure 3.4. Management Supporting Respondence

Source: Google Form Asri Mulyadi

3.2. Human Resources (HR) Competence

Based on the results of a questionnaire with 119 respondents, the analysis of the Human Resources (HR) Competency factor indicates a very good level of readiness in supporting the integration of BIM and Lean Construction. In the technical capability indicator (X2.1), the majority of respondents (52.6%) strongly agree that personnel have mastered BIM software, which technically minimizes the risk of modeling errors. In line with this, in the work process analysis capability indicator (X2.5), there is an accumulation of 84.2% of respondents who assess the team is capable of continuous improvement. Within the Structural Equation Modeling (SEM) framework, high achievements in these two indicators indicate that the HR Competency variable has a strong foundation to support workflow efficiency and waste reduction in the field, so it is predicted to make a significant contribution to the loading factor value and the success of the overall model implementation.

Table 3.2. Human Resources (HR) Competence

Variable	Factor	Validation
X2.1	Project HR is technically proficient in using BIM software.	Approved
X2.2	HR is aware of the Lean Construction project implementation principles.	Approved
X2.3	The organization regularly offers BIM and lean construction training.	Approved

X2.4	HR have the necessary BIM certification or experience.	Approved
X2.5	The project team has the ability to evaluate and constantly enhance work procedures.	Approved

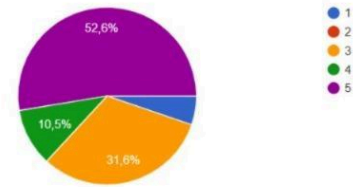


Figure 3.5. Human Resources (HR) Competence
Source: Google Form Asri Mulyadi

3.3. Technology Proficiency

The analysis results of the Technology Readiness variable (X3) show very strong infrastructure support in the implementation of BIM-Lean Construction, where the majority of respondents gave positive assessments on all technical indicators. In depth, the availability of adequate hardware (X3.1) and cloud-based storage systems or easily accessible servers (X3.5) received a strongly agree response of 47.4% and 52.6%, respectively, which are the backbone for massive project data management. Smooth collaboration is also supported by an effective internet connection (X3.4) with an accumulated score of agree and strongly agree reaching 89.5%, as well as the ability to integrate data between platforms (X3.3) which was considered good by the majority of teams (42.1% strongly agree). Although there is a small note on the official software licensing aspect (X3.2) which still recorded 10.5% disagreement, overall this data shows that the technology factor has high reliability in the SEM model. In the context of Lean, this technological readiness plays a crucial role in reducing non-value added activities due to technical constraints and accelerating information flow, thereby strengthening the validity of variable X3 as a significant predictor of project success.

Table 3.3. Technology Proficiency

Variable	Factor	Validation
X3.1	The BIM application can run on the hardware that was used.	Approved
X3.2	The BIM program has an official license and is readily available.	Approved

X3.3	Platforms and software can effectively integrate project data.	Approved
X3.4	Effective BIM collaboration is supported by the network and internet connectivity.	Approved
X3.5	Systems for storing data, including servers and clouds, are widely available and simple to use.	Approved

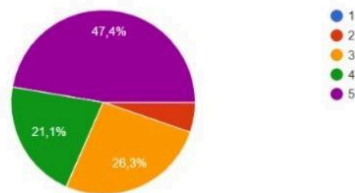


Figure 3.6. Technology Proficiency
Source: Google Form Asri Mulyadi

3.4. Collaboration and Communication

Based on questionnaire data from 119 respondents, the Collaboration and Communication (X4) variable showed very solid performance as a key factor for the success of BIM-Lean Construction integration, marked by the accessibility of project information (X4.2) which reached the highest level of strong agreement at 57.9%. The effectiveness of coordination was supported by the implementation of structured regular meetings (X4.4) where 52.6% of respondents agreed, as well as the collaborative decision-making process (X4.5) which was also agreed by the majority of the team at 52.6% strongly agreed. The use of the BIM model was proven to increase the effectiveness of teamwork (X4.3) with an accumulation of positive responses reaching 79%, while interdisciplinary communication (X4.1) ran smoothly although there were still 21.1% of respondents who were neutral. In the Structural Equation Modeling (SEM) analysis, the high values of these indicators strengthen the validity of the latent variable X4, which indicates that information transparency and synchronization between stakeholders are the main drivers in reducing communication barriers and accelerating the project work cycle according to Lean principles.

Table 3.4. Collaboration and Communication

Variab le	Factor	Validation
X4.1	The project's interdisciplinary communication operates smoothly and successfully.	Approved

X4.2	All pertinent parties have easy access to project information.	Approved
X4.3	Project teamwork is more productive when BIM models are used.	Approved
X4.4	Meetings for project coordination are organized and conducted on a regular basis.	Approved
X4.5	Stakeholders work together to make decisions pertaining to the project.	Approved

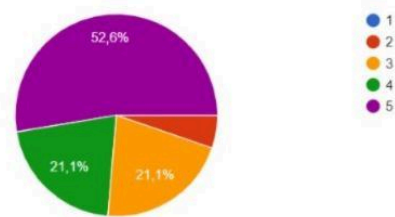


Figure 3.7. Collaboration and Communication
Source: Google Form Asri Mulyadi

3.5. Lean Culture and Continuous Improvement

Based on questionnaire data from 119 respondents, the Lean Culture and Continuous Improvement variables (X5) showed a very good level of internalization of the efficiency philosophy in the project environment, with the indicator of work activities based on clear standards (X5.2) recording the highest level of strong agreement at 57.9%. The organization's commitment to reducing waste (X5.1) and the implementation of periodic evaluations (X5.3) also showed predominantly positive results with a strong agreement figure of 52.6%, supported by management's openness in facilitating input from the workforce (X5.4) which was agreed upon by 47.4% of respondents on the maximum scale. Although the internalization of Lean principles as values and norms of organizational culture (X5.5) had a slightly lower distribution in the strong agreement category (36.8%), cumulatively positive responses still dominated the model. In the context of Structural Equation Modeling (SEM), these data indicate that the Lean Culture variable has strong validity to act as a catalyst in optimizing the use of BIM technology, where successful implementation depends not only on technical tools but also on a structured continuous improvement mentality to achieve overall project success.

Table 3.5. Lean Culture and Continuous Improvement

Variab le	Factor	Validation
X5.1	The company actively incorporates waste reduction techniques into the planning and execution of projects.	Approved
X5.2	Project tasks are completed in accordance with precise, recorded, and uniform work standards.	Approved
X5.3	Periodically, work processes are evaluated in order to find areas for improvement.	Approved
X5.4	Employees are encouraged and assisted in offering suggestions or ideas for enhancing productivity and process effectiveness.	Approved
X5.5	Lean Construction principles have become part of the project organization's values, norms, and culture.	Approved

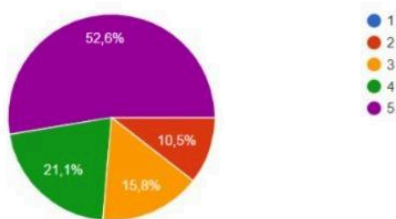


Figure 3.8. Lean Culture and Continuous Improvement
Source: Google Form Asri Mulyadi

3.6. Successful BIM–Lean Implementation

Based on questionnaire data from 119 respondents regarding the Lean Culture and Continuous Improvement (X5) variables, there is a strong internalization of efficiency principles where the indicator of implementing activities based on clear work standards (X5.2) recorded the highest level of strongly agree at 57.9%. The organization's commitment to waste reduction practices (X5.1) and the implementation of periodic evaluations for process improvement (X5.3) showed consistently positive results with a strong agreement rate of 52.6% each. Management support for workforce input (X5.4) was also rated very good by 47.4% of respondents, although the Lean principle aspect as part of the organizational cultural norms (X5.5) had a slightly lower distribution in the strongly agree category at 36.8%. Within the Structural Equation Modeling (SEM) analysis framework, the high trend in scores on these indicators indicates strong construct validity for variable X5 as a key driver of BIM effectiveness, where a

culture of continuous improvement is a crucial foundation for the successful implementation of technology in the field.

Table 3.6. Successful BIM–Lean Implementation

Variab le	Factor	Validation
Y1	Project implementation can be made more cost-effective by implementing BIM-Lean.	Approved
Y2	When compared to traditional approaches, BIM-Lean adoption speeds up project completion.	Approved
Y3	Rework and waste were significantly reduced.	Approved
Y4	Using BIM improves coordination between the design and construction phases.	Approved
Y5	Following the use of BIM-Lean, project team productivity rose.	Approved
Y6	The application of BIM-Lean has enhanced the overall quality of construction outcomes.	Approved

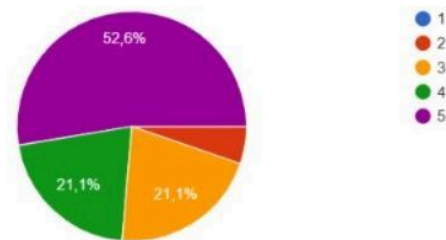


Figure 3.9. Successful BIM–Lean Implementation
Source: Google Form Asri Mulyadi

4. CONCLUSION AND RECOMENDATION

In short, we can conclude that if, based on a Google Form questionnaire of 119 respondents, findings indicate strong support for the implementation of BIM-Lean Construction through management policies, HR competency, technology readiness, and communication. A significant 52.6% rated management policies as crucial, while 84.2% affirm teamwork supports continuous improvement. Technology assessments show strong reliability, with effective internet connectivity rated at 89.5%. Collaboration is also highlighted, with 57.9% agreeing on project information accessibility and 79% noting improved teamwork through BIM.

Furthermore, a Lean culture is evident, with 57.9% strongly agreeing on adhering to work standards and 52.6% on waste reduction. Overall, the internalization of efficiency principles within

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