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Developing a Composite Index to Measure the Integration of BIM, IPD, and Lean Construction: Analysis and Framework

Moaaz Munir [1], Usama Khan [2], Dr. Salman Ali Suhail*[3], Dr. Kamran Latif[4], Hafiz Nauman Yousaf[5]
[1] Assistant Professor, The University of Lahore, Lahore, Pakistan; moaaz.munir@ce.uol.edu.pk
[2] Project Manager, Muhriz Infotech, Lahore, Pakistan; usamakhanphd@gmail.com
[3] Assistant Professor, The University of Lahore, Lahore, Pakistan; salman.suhail@ce.uol.edu.pk
[4] PhD Civil Engineer, Hanyang University, Seoul, South Korea; Kamran5latif@gmail.com
[5] Lead Project Planner, EGIS, UAE; Nauman@chohdry.com

*Correspondence: Usama Khan (usamakhanphd@gmail.com)

Abstract: The integration of Building Information Modeling (BIM), Integrated Project Delivery (IPD), and Lean Construction (LC) presents a transformative opportunity to improve collaboration, efficiency, and sustainability in construction projects. However, the lack of a unified metric to evaluate the maturity of this integration limits strategic benchmarking and implementation. This paper introduces a novel composite index, titled the BIM-IPD-Lean Integration Index (BILI), to measure integration maturity across these three methodologies. A structured questionnaire was administered to 27 construction firms, and response data were used to develop and apply the index. The analysis revealed that most firms exhibit high to exceptional integration readiness. To bridge perception with practice, the study also proposes a conceptual framework for practical implementation of the index, enabling real-world auditing based on documented project evidence. The BILI model offers a scalable and replicable approach for evaluating integrated construction practices and contributes a structured tool for industry benchmarking and improvement.

Keywords: Building information modeling, Integrated project delivery, Lean construction.

1. Introduction

The construction industry is increasingly adopting advanced project delivery methods to improve efficiency, reduce waste, and enhance collaboration. Among these, Building Information Modeling (BIM), Integrated Project Delivery (IPD), and Lean Construction (LC) have emerged as transformative approaches. BIM supports accurate visualization, clash detection, and information sharing throughout the project lifecycle. IPD promotes early involvement of key stakeholders, shared risk and reward, and transparent communication. Lean Construction focuses on minimizing waste and maximizing value through tools such as the Last Planner System and Value Stream Mapping. While each of these methods offers clear advantages when used independently, their combined use can deliver even greater project benefits—such as improved safety, reduced delays, enhanced cost control, and better quality outcomes.

Despite growing interest, the combined implementation of BIM, IPD, and Lean Construction remains limited in practice. Existing studies often explore these methods in isolation or in partial integration, with little focus on measuring how well they are applied together. To address this gap, this paper presents a survey-based analysis of industry perceptions and practices regarding these three methods. A composite index, called the BIM-IPD-Lean Integration Index, is introduced to quantify the maturity of integration.

This index is supported by structured scoring logic and applied to responses from 27 construction firms. In addition, a practical conceptual framework is proposed to guide future implementation of the index using real project data. Together, the index and framework aim to support benchmarking, continuous improvement, and strategic decision-making for fully integrated project delivery.

2. Literature Review

The literature review reveals that BIM has transformed how construction information is managed and visualized. It enables the digital representation of physical and functional characteristics of a facility, facilitating better collaboration and decision-making throughout the project lifecycle. BIM can be defined as central platform that supports coordination among architects, engineers, and contractors by integrating geometry, spatial relationships, quantities, and properties of building components [1]. BIM maturity models such as Succar's BIM Framework [2] and the Bew-Richards model [3] are widely used to assess the level of BIM implementation, ranging from simple 3D modeling to advanced 6D and 7D capabilities. Empirical studies confirm that BIM adoption leads to reduced rework, improved visualization, and better cost control [4][5].

Integrated Project Delivery (IPD) offers a collaborative project delivery model that aligns interests, objectives, and practices of key stakeholders through early involvement, shared risk and reward mechanisms, and transparent communication. The American Institute of Architects (AIA) defines IPD as a method that fosters teamwork and mutual respect among owners, designers, and builders through multi-party agreements [6]. Research found that IPD enhances trust, reduces adversarial relationships, and promotes innovation [7]. Studies also link IPD to improved productivity, shorter schedules, and reduced litigation in complex projects [8]. However, the practical implementation of IPD is often limited to large-scale projects due to its contractual and legal complexities [9].

Lean Construction (LC), derived from lean manufacturing principles, focuses on reducing non-value-adding activities and improving process flow. Koskela laid the foundation for Lean Construction by applying production system theory to construction processes [10]. Tools like the Last Planner System, pull planning, and value stream mapping are now widely adopted to manage construction workflow and reduce waste. Lean Construction improves transparency, accountability, and planning reliability [11]. Numerous case studies show that Lean practices significantly reduce lead time, improve quality, and enhance safety [12][13]. Furthermore, research confirms the alignment of lean principles with sustainability goals in construction [14].

While BIM, IPD, and LC each demonstrate value independently, recent literature highlights the growing importance of their integration. Literature review identify a high degree of synergy among these methods, especially when used together on design-build projects [15]. The integration of BIM and Lean, often referred to as Lean-BIM, has been studied for its ability to improve workflow visualization, identify constraints, and support pull scheduling [16]. Likewise, BIM and IPD integration supports real-time decision-making and collaborative design validation [17]. Research also reveals that combining BIM with IPD and Lean results in improved constructability, early clash detection, and better control over project risks [18]. However, these integrations are typically examined in isolation or through case studies without any standard metric for measurement.

There is a growing consensus in literature that a structured evaluation method is required to quantify the level of integration across BIM, IPD, and LC. Existing assessment tools such as BIM maturity indices, Lean implementation scores, and IPD readiness checklists, exist independently but are not unified. Researchers advocate for composite indices in construction to measure complex, multi-dimensional adoption levels, especially in sustainability [19]. Their work supports the development of new indices that incorporate perception, practice, and performance measures.

Despite this academic foundation, no study has yet introduced a composite index to measure BIM, IPD, and Lean integration together. This gap is significant, particularly as industry moves toward digitallyenabled, collaborative project delivery. A single, normalized measure could serve as a benchmark for organizations to assess their integration maturity and guide continuous improvement. Such an index would also enable cross-project comparisons and help identify best practices in the application of modern construction methodologies.

3. Methodology

This research adopted a structured, survey-based methodology to assess how construction professionals perceive and integrate Building Information Modeling (BIM), Integrated Project Delivery (IPD), and Lean Construction (LC) within their projects. The methodology is divided into four key phases: survey design, data collection, data organization, and development of the integration index.

3.1 Survey Design

The study began with the development of a targeted questionnaire aimed at capturing industry practices and perceptions regarding BIM, IPD, and Lean Construction. Questions were prepared, covering themes such as tool usage, project-level experiences, integration awareness, and perceived impact of using the three methodologies. The questionnaire was designed to be practical and easy to interpret for professionals from various construction backgrounds.

3.2 Data Collection and Analysis

All collected responses were compiled into a structured dataset using SPSS. Basic validation was performed to ensure completeness and consistency across all entries. Each firm’s responses were then categorized based on implementation experiences, tool usage patterns, and strategic alignment with BIM, IPD, and Lean practices. Preliminary analysis was conducted to identify general trends in adoption and integration.

3.3 Development of Integration Index

To move beyond descriptive reporting, a composite metric called the BIM-IPD-Lean Integration Index (BILI) was developed. This index was designed to measure the maturity level of a firm’s integration of BIM, IPD, and Lean Construction.

3.4 Framework Proposal for Implementation

In addition to index calculation, the study proposes a conceptual framework to support practical application of the BILI in real-world projects. The framework outlines how integration maturity can be measured using both perceptual insights and implementation evidence. It also suggests ways for firms to benchmark their progress and align their project delivery methods with modern construction practices.

4. Results and Analysis

4.1 Survey Analysis

The survey results offer valuable insights into current industry practices and perceived benefits related to BIM and Lean Construction. Among the BIM tools used, Revit Structure dominated with usage reported by over 70% of respondents, followed by Revit Architecture at 26%, and Site Planning at a minimal 4% (figure 1). This suggests a strong focus on structural modeling within firms, aligning with the industry's emphasis on clash detection, reinforcement detailing, and load coordination during design stages. The limited use of Site Planning tools indicates a gap in preconstruction spatial analysis, which may represent an area for future growth.

Regarding the primary uses of BIM, MEP modeling emerged as the leading application, accounting for approximately 41% of responses, followed by structural design (26%) and architectural design (19%) (figure 2). This reflects BIM's growing role in interdisciplinary coordination, particularly in services integration and clash prevention. Visualization (11%) and scheduling/marketing (4%) were less emphasized, implying that advanced BIM applications such as 4D simulation and stakeholder communication are underutilized.

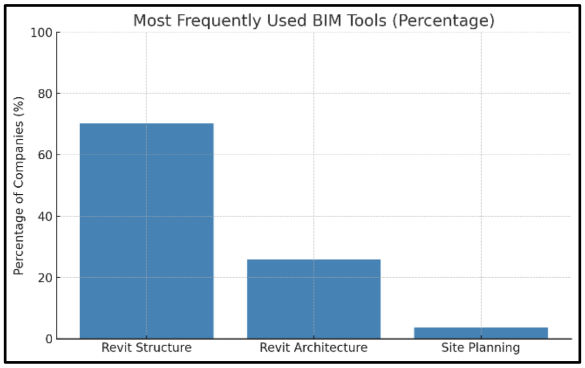

Figure 1 BIM tools

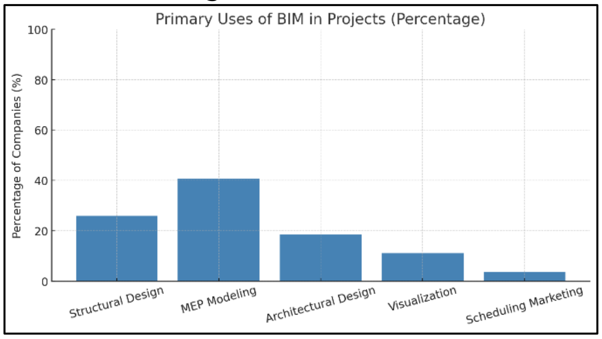

Figure 2: Uses of BIM

In terms of perceived benefits, improved visualization was recognized by 34% of participants, closely followed by enhanced safety (32%) and cost efficiency (31%) (figure 3). These results highlight the industry's recognition of BIM not only as a design tool but also as a driver of project-wide performance and risk reduction.

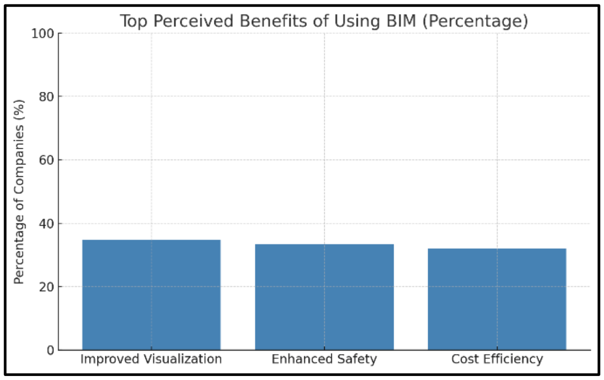

Figure 3: Perceived benefits of BIM

Similarly, in the context of Lean Construction, sustainability (48%) and cost reduction (44%) were viewed as its primary contributions, while only 7% selected healthy environment (figure 4). This indicates that Lean is primarily valued for its measurable economic and environmental impacts rather than softer, health-related outcomes.

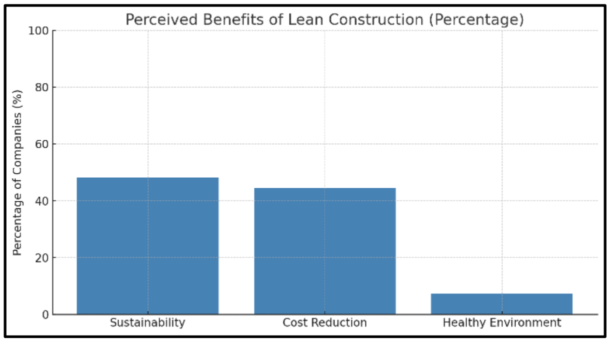

Figure 4 Perceived benefits of Lean

Overall, the findings reflect a mature perception of BIM and Lean as high-impact practices, though also expose underutilized dimensions such as scheduling, site planning, and environmental health, suggesting opportunities for expanded adoption and deeper integration.

4.1 Developing BIL-IPD-LEAN Integration Index

The BIM-IPD-Lean Integration Index (BILI) is designed as a composite metric that quantifies how effectively construction firms integrate BIM, IPD, and LC into their projects. The index is constructed using four weighted components, each representing a distinct dimension of integration maturity as reflected in the questionnaire responses.

BIM dimensions measure the extent of BIM usage in a firm's projects. Based on the response to the question on BIM adoption percentage, companies were assigned scores as follows (Table 1):

Table 1: BIM Scores

BIM Usage Range	Scores	Justification
Less than 30%	1	The scoring reflects BIM maturity as aligned with established BIM implementation models [2][4]. Higher frequency of use typically correlates with higher capability in model coordination, scheduling, and cost estimation.
30% – 50%	2	
50% – 70%	3	
70% – 100%	4	

IPD dimension is based on multiple IPD-related questions from the survey, focusing on collaboration, risk sharing, value creation, and waste reduction (Table 2).

Table 2: IPD Alignment Score

IPD Alignment Score	Scores	Justification
Limited/no alignment	1	A firm was scored **3** if it showed consistent support across all IPD-related questions, **2** if it supported most (3–4 out of 5), and **1** otherwise. This scoring is consistent with IPD literature emphasizing early collaboration and integrated decision-making as core maturity indicators [6][7].
Moderate alignment	2	
Strong alignment	3	

Lean dimension assesses the firm's application of Lean principles. It was derived from survey questions related to Lean implementation and its perceived benefits (Table 3).

Table 3: LC Engagement Score

LC Engagement	Scores	Justification

LC Engagement	Scores	Justification
Weak engagement	1	Firms supporting Lean use for both waste reduction and sustainability received the maximum score. According to Koskela [10] and Ballard [11], practical application of Lean tools such as Last Planner and pull systems significantly improves project efficiency.
Moderate engagement	2	
Strong engagement	3	

Synergy dimension reflects whether the firm believes that integrating BIM, IPD, and Lean offers additional benefits Table 4).

Table 4: Synergy (Combined usage of BIM, IPD and LC)

Combined Usage	Scores	Justification
Does not Support	1	This component emphasizes awareness and strategic belief, which is a precursor to actual implementation. Sacks et al. [15] highlight that such synergy leads to higher productivity and reduced project risks.
Supports Synergy	4	

Each company's BILI score is calculated using the following formula (Equation 1). The result is normalized to a scale of 0 to 100 for easy benchmarking.

$$BILI = (BIM_{Score} + IPD_{Score} + LC_{Score} + Synergy_{Score})/14 \times 100$$

Table 5: BILI Reference Range

BIM Usage Range	Scores
0- 30%	Very Low Integration
31% – 60%	Moderate Integration
61% – 80%	High Integration
81% – 100%	Exceptional Integration

This structured and literature-supported index allows firms to be benchmarked not just on individual practice but on overall integration maturity, filling a notable gap in existing construction evaluation models.

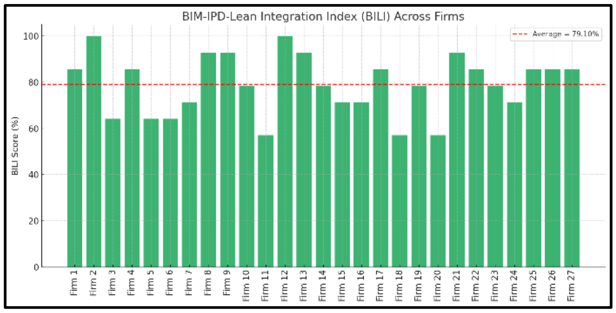

Figure 5: BILI across Construction Firms

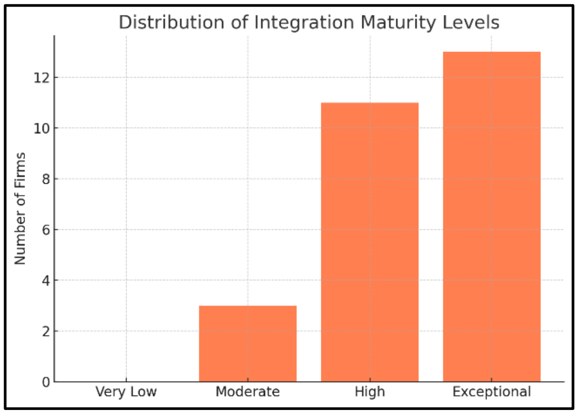

Figure 6: BILI Maturity Levels

The analysis revealed that the majority of firms demonstrate high to exceptional levels of perceived integration (figure 5). Over 85% of the surveyed organizations scored within the "High" or "Exceptional" categories on the BILI scale, reflecting strong alignment with integrated delivery principles (figure 6). Most firms reported frequent use of BIM tools, clear recognition of Lean benefits, and favorable views on IPD practices such as early collaboration and shared value creation.

4.2 Conceptual Framework for Practical Implementation of BILI

While the BILI index provides a perception-based benchmark for integration maturity, its full potential can be realized through a structured, evidence-driven implementation framework. The proposed conceptual model enables organizations to transition from perception to practice by applying BILI as an audit tool within actual construction projects.

The implementation framework is designed to:

- Evaluate real integration performance across BIM, IPD, and Lean Construction.
- Support internal audits, maturity assessments, and benchmarking.
- Link qualitative perception with quantitative project evidence.

To implement BILI practically, the same four components used in the index must be assessed using objective, verifiable data:

Table 6: Dimensions and Evidence Required

Dimension	Evidence Required
BIM Implementation	BIM Execution Plan, Level of Development (LOD), use of 3D–7D models
IPD Application	Type of contract (multi-party or traditional), collaboration records
Lean Practices	Use of tools (Last Planner, Pull Planning), visual management data
Integration Synergy	Case examples where all three methods were applied simultaneously

Each dimension is scored based on the depth, frequency, and quality of its implementation. A weighted scoring rubric is proposed for implementation auditing:

Table 7: Scoring rubric

Componet	Max Points	Weight (%)	Evidence Required
BIM Implementation	10	30%	Depth of BIM usage, dimension modeling, integration into procurement or FM stages
IPD Practices	8	25%	Contract type, early involvement, collaborative tools used

Lean Application	8	25%	Lean tools, training, scheduling alignment, waste tracking
Synergetic Use	4	10%	Instances of combined use and shared value delivery
Documented Impact	4	10%	Project outcomes (time saved, cost reduced, safety improved, quality enhanced)

The maximum score is 34. A normalized score ($BILI_{Real}$) is calculated as:

$$BILI_{Real} = \frac{\sum_{i=1}^{n} Score_i}{\sum_{i=1}^{n} Max_i} \times 100$$

This gives you a normalized percentage-based integration score that reflects actual implementation maturity across multiple verified criteria.

5. Conclusion

The survey results highlighted widespread use of Revit-based BIM tools, strong engagement with MEP and structural modeling, and recognition of visualization, safety, and cost efficiency as primary BIM benefits. Similarly, LC was acknowledged for its role in sustainability and cost reduction, while IPD was valued for its collaborative delivery structure. These findings confirm the growing strategic alignment of firms toward integrated project delivery practices.

To translate perception into measurable implementation, the study proposed a practical framework for applying BILI in real world projects using verifiable documentation and performance data. The framework assesses integration across five core dimensions including BIM, IPD, LC, synergistic use, and project impact, offering a normalized maturity score. This dual layer approach enhances the index's utility by supporting both benchmarking and evidence-based auditing. By linking perception and practice, the BILI framework contributes a scalable and structured model for evaluating and improving integration in modern construction environments. It addresses a significant gap in existing literature and offers a foundation for future research, performance tracking, and digital transformation in the built environment.

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