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Lean Construction 5.0: A Framework for Collaborative Decision-Making Powered by Artificial Intelligence and Intelligent Parametric Modeling

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Abstract
The construction industry is going through a historic transformation driven by the need to overcome a chronic stagnation in labor productivity, which has averaged only 1% annual growth in recent decades. This article proposes a conceptual framework called Lean Construction 5.0, which transcends the digitalization of Construction 4.0 to integrate a human-centric, resilient and sustainable vision. The synergy between third-generation BIM, Artificial Intelligence (AI) and parametric modeling allows data capture and predictive analysis to be automated, optimizing decision-making in environments of high uncertainty. Through a review of recent scientific evidence, 30% reductions in design times and an improvement in weekly planning (PPC) reliability are documented from 50% levels to a range of 70-90% through the use of smart tools. The proposed framework emphasizes that technology should serve as an enabler of Lean principles (specifying value, constant flow, and perfection), operating under collaborative contracting models such as Integrated Project Delivery (IPD). The results indicate that the strategic integration of these components not only increases profitability by 13-21%, but also reduces environmental impact through the optimization of resources and energy. It is concluded that the transition to Lean 5.0 is inevitable to guarantee the competitiveness and sustainability of the sector in the 2025-2035 horizon.

Keywords: Lean Construction, construction, BIM, Artificial Intelligence

1. Introduction

While sectors such as manufacturing and automotive have multiplied their productivity through Lean management and digitalization, construction has remained stagnant in artisanal processes. Historically, the production model has been based on the "conversion" of inputs ignoring the value stream, which generates hidden waste that reaches 57% of the time and material invested.

Today, in 2025, the landscape changes radically with the maturity of BIM 2.0, Artificial Intelligence and international standards such as ISO 19650. The evolution towards Lean Construction 5.0 represents a quantum leap: it is no longer just about optimizing isolated tasks, but about using AI for generative design and risk prediction, allowing the professional to focus on strategic decisions while technology manages complexity. This article explores how intelligent parametric modeling, being pulled by construction, revolutionizes operations planning and control.

2. Methodology

For the development of the Lean Construction 5.0 framework, a robust research methodology has been designed that integrates academic rigor with practical validation in environments of high construction complexity.
The methodology used for this scientific article is detailed below:

2.1. Research Design

The research adopts a mixed methodology approach, combining the quantitative analysis of magnitudes and counts with the qualitative depth provided by the interpretation of the context and the unique experiences on site. The design is experimental and quasi-experimental, structured chronologically with multiple control groups to evaluate the impact of Lean philosophy tools and disruptive technologies on infrastructure projects.

Sources of Knowledge and Data Integration

The proposed framework is based on the integration of four fundamental pillars of knowledge:

1. Longitudinal Research: It is based on a foundational research initiated in 2007 on productivity and measurements of productive times, contributory and non-contributory (TP/TC/TNC).
2. Recent Scientific Evidence: Validated quantitative data from eight scientific articles published between 2024 and 2025 in journals indexed in Scopus Q1 and Q2 are incorporated. These studies specifically address BIM-Lean integration, AI applied to decision-making, and the use of *Digital Twins*.
3. International Standards: The methodology is aligned with current regulations, particularly the ISO 19650 series for information management and ISO 16739-1:2024 (IFC 4.3) for data interoperability.
4. Global Case Studies: Fully documented cutting-edge projects, such as the *Celsius* project in Sweden and *HMP Five Wells* in the UK, are analyzed to validate real-world performance metrics.

2.2. Analysis and Validation Procedure

The methodological process follows a sequence of six phases to ensure the maturity of the proposed system:

- Phase 1: Scope and Thematic Fusion: Dispersed concepts are reorganized into coherent axes, eliminating redundancies between traditional management and the 5.0 paradigm.
- Phase 2: Modeling and Simulation: Modeling of construction operations (using languages such as CYCLONE) is used to represent systems of interest and perform computational flow processing.
- Phase 3: Real-Time Data Capture: The use of Computer Vision, IoT and LiDAR technologies is proposed to automatically feed productivity functions and detect waste on the construction site.
- Phase 4: Maturity Assessment (MMLPS): A maturity model is applied to the Last *Planner System* (LPS) based on questionnaires that assess specific process areas and practices of the team.
- Phase 5: Validation through PDCA Cycle: A systematic cycle of learning and continuous improvement (Plan-Do-Check-Act) is implemented to measure the Percentage of Plan Completed (PPC) and analyze the causes of non-compliance.
- Phase 6: Collaborative Decision Making: Intelligent parametric modeling pulled by the construction is used to simulate the virtual prototype as many times as necessary before physical execution.

2.3. Measuring Instruments

To quantify the impact, statistical sampling tools and balance charts are used to evaluate the percentage of time spent on productive activities by each crew. The accuracy of risk predictions (delays, cost overruns) using *Machine Learning* is calibrated to reach confidence ranges between 70% and 85%

3. Results

The integration of digital technologies with the Lean philosophy has generated quantitative results superior to traditional methods (CPM/WBS). Data from recent research (Scopus Q1/Q2, 2023-2025) and global case studies such as the *Celsius* (Sweden) and *HMP Five Wells* (UK) projects demonstrate substantial improvement in key performance indicators.

Technology / Methodology	Key Benefit	Magnitude of Improvement	Source (Evidence)
BIM + Lean	Reduced errors and rework	25% - 30%	
AI in Design	Reduction of documentation times	Up to 30%	
Digital Twins	Operating Cost (O&M) Savings	20% - 30%	
AI + Urban Planning	Improved energy efficiency	20%	
Last Planner (LPS)	Reliability Enhancement (PPC)	40%-> 70-90%	
3D BIM	Reduced interference in design	85% - 90%	

Table 1: Documented Benefits of Lean-BIM-AI Integration

Project Indicator	Traditional System	Marco Lean 5.0 (IA+BIM)	Final Impact
Cost Control	Variation >10%	Cost reduction 13-21%	Increased profitability
Compliance with Deadline	Late delivery (frequent)	Time reduction 15-25%	Expedited delivery
Labor Productivity	Growth <1% per year	50-100% improvement	Industrial transformation

Table 2: Economic and Timeline Impact on Complex Projects

4. Discussion

The research underscores that technology alone does not solve the productivity crisis; non-Lean BIM can generate "beautiful but useless models." The key to success lies in the Lean-BIM-IPD Synergy, where BIM visualizes the flow that Lean optimizes, and IPD aligns the incentives of all actors from early stages.

The introduction of AI in collaborative decision-making (Lean 5.0) poses ethical and societal challenges. It is imperative that AI acts as a Decision Support System (DSS) based on Lean tools such as Choosing by Advantages (CBA), while maintaining human trust and algorithmic transparency. In addition, the transition to Industry 5.0 requires these innovations to be human-centric, prioritizing worker well-being and environmental sustainability. The integration of AI makes it possible to automate repetitive tasks (clash detection, automatic measurements), freeing engineers to solve problems with greater added value through "visual management" and sessions

5. Conclusion

Lean Construction 5.0 is not a utopia, but an operational necessity in the face of the increasing complexity of modern assets. The integration of AI and parametric modeling allows the prototype to be digitally built as many times as needed, eliminating uncertainties before physical execution.

Recommendations:

1. Adoption of Collaborative Contracting: Implement IPD models to mitigate supply chain fragmentation and foster trust.
2. Standardization of Information: Mandatory use of ISO 19650 to ensure that the right information reaches the right people.
3. Continuous Training: Closing the digital and philosophical skills gap in current and future professionals.
4. Technology Scalability: Invest in AI and Digital Twins to close the asset lifecycle, turning data into operational intelligence for the maintenance phase

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