From Factory Floors to Construction Sites: The Evolution of Lean Construction Through Six Decades [1]

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Historical perspective of Lean		Impact
Phase I (1970s): Origin of Lean from Manufacturing	Toyota Production System **Taiichi Ohno (1978)**	Introduced lean principles like eliminating waste to improve efficiency, guided by Just-in-Time (JIT), KANBAN and etc.
Phase II (1980s): Introduction of Lean Thinking	Triumph of the Lean Production System **John F. Krafcik (1988)**	Played a crucial role in introducing the concept of Lean Production to the West
Phase III (1990s): Introduction of Lean Philosophy to Construction	The Machine That Changed the World **James P. Womack et al (1990)**	Popularized lean thinking globally
	Lean Production in Construction **Lauri Koskela (1992)**	Formalized lean principles for the construction industry
	Formation of International Group for Lean Construction **(IGLC, 1993)**	Promoted academic research and development of lean tools
	Establishment of Lean Construction Institute **(Glenn Ballard and Greg Howell, 1997)**	Focused on practical implementation of lean principles in construction
	Lean Construction **(Luis Alarcón, 1997)**	Explored how lean methods lead to reduced space, effort, and product development time within construction
	Last Planner System **(Glenn Ballard and Greg Howell, 1990s)**	Improving predictability and reliability, reducing rework, and enhancing project performance
Phase IV (2000s): Test of Applications of Lean Principles on Construction	Transformation Flow Value **(Lauri Koskela, 2000)**	Became the theoretical foundation of LC, emphasizing the balance of transformation, flow, and value
	Target Value Design **(Glenn Ballard et al, 2002)**	Shifts cost control to the design phase, promoting better value and stakeholder alignment
	Building Information Modeling **(Jerry Laiserin, 2002)**	Coined and popularized the term "BIM"
	Integrated Project Delivery **(Dean Reed, Martin Fischer, 2007)**	Changes traditional project delivery by integrating stakeholders early and aligning incentives to project outcomes
Phase V (2010s): Digitisation of LC and BIM Integration	Global adoption of lean construction practices via BIM	Improved productivity and project outcomes worldwide
Phase VI (2020s): LC for Sustainability and Resilience	Focus on digital integration, sustainability and resilience	Lean construction continues to evolve and expand globally

Figure 1: History of LC
(Source: Author's own work)

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The Evolution of Lean Construction: From Factory Floors to Construction Sites

Lean Construction (LC) has not arrived at its current stature by accident, or divine intervention, or coffee-fueled site meetings. Although the latter may have played a role. Instead, LC has journeyed through a rich and structured evolution spanning over five decades, with each phase shaped by prevailing industrial challenges, intellectual breakthroughs, and the universal human desire to "do more with less" (de Oliveira & Loos, 2024; Singh, Kumar, Mittal & Verma, 2024). Figure 1 attempts to summarise this evolution visually, but beware, even a flowchart cannot capture the full drama of transitioning from TPS to AI-enabled LC.

Phase I (1970s): When Lean Was Born in a Car Factory

The LC story begins on the factory floors of Toyota in Japan, where Taiichi Ohno in the late 1970s likely stared at an overcrowded assembly line and thought, "there must be a better way." Thus, was born the Toyota Production System (TPS), a philosophy that revolved around eliminating waste (*muda*), improving workflows via *kaizen*, and redefining value from the customer's point of view (Liker, 2004; Binu & Gupta, 2024; Horsfall & Alaribe, 2024).

TPS's Just in Time (JIT) system and a visual workflow management method namely KANBAN turned the production line from a chaotic sandwich shop during lunch rush into a calm, orchestrated ballet, with each part arriving just in time (Ikuabe et al., 2024; Rajab, 2022). Ironically, while Lean helped Toyota reduce inventory, modern construction sites still hoard materials like they're prepping for an apocalypse. Clearly, the construction industry was late to this party (Dauda et al., 2024; Hyarat et al., 2024).

Phase II (1980s): Lean Gets a Passport

In the 1980s, Lean got on a flight — probably economy class — and made its way to the West. John Krafcik's 1988 paper "Triumph of the Lean Production System" introduced Lean as not just a Japanese quirk but a revolutionary system that made Western manufacturing blush (Aslam et al., 2024). Suddenly, the Western world realised that producing 10,000 widgets before checking for defects was a terrible idea.

Anuar, Sadek & Selvaraj (2021) describe this phase as Lean's transition from a company specific tactic to a global ideology, ripe for adaptation in other sectors. Construction folks, traditionally sceptical of anything that involves change (or paperwork), began to wonder if Lean might just fix their chronic delays and cost overruns. As Wu et al. (2022) pointed out, Lean wasn't just trendy, it was potentially the antidote to an industry known for budget blowouts and timeline chaos.

Phase III (1990s): Lean Enters the Construction Site (Hard Hat On)

By the 1990s, Lean decided it was time to trade its factory uniform for steel-toed boots. The publication of The Machine That Changed the World by Womack, Jones & Roos in

1990 acted like Lean's business card — slick, persuasive, and impossible to ignore (Marhani et al., 2021; Fauzan & Sunindijo, 2021).

Then came Lauri Koskela (1992), the Lean whisperer, who translated Lean from "car-speak" into construction language. His work laid the theoretical foundation for LC (Malla, 2024; Saradara et al., 2024). The 1993 founding of the International Group for Lean Construction (IGLC) and the Lean Construction Institute (LCI) in 1997 were like the Avengers assembling, each bringing unique strengths to face a common challenge, ready to turn chaos into triumph (Jiang et al., 2023).

Luis Alarcón's book Lean Construction (1997) explained how to cut the fluff out of construction with less wasted space, less duplicated effort, and ideally fewer "urgent Request for Information (RFIs)" on Friday afternoons (Shigaki et al., 2024). Meanwhile, the Last Planner System (LPS) by Ballard & Howell arrived like a site foreman with a whiteboard, missioned to educate people on reducing rework, improving task flow, and making planning meetings bearable (Pan & Pan, 2023).

Phase IV (2000s): From Theory to Action (and Digital Disruption Begins)

The 2000s marked Lean's leap from whiteboards to blueprints. Koskela (2000) introduced the TFV model (Transformation, Flow, Value), a trifecta that construction managers suddenly had to remember, along with everyone's coffee order (Silva, Brasil & Pinto, 2022). Lean no longer just told you what not to do (e.g., don't hoard bricks); it began telling you how to build smarter.

Then Glenn Ballard brought Target Value Design (TVD) to the table, telling the industry players not just cutting costs but aligning design with realistic budgets from day one (Desmarais & Alves, 2024). Jerry Laiserin (2002) deserves a digital bow for popularizing Building Information Modelling (BIM), which, like a Global Positioning System (GPS) for projects, helped people stop getting lost in 2D drawings (Ismail et al., 2023; Saputra et al., 2024).

By 2007, Reed and Fischer had championed Integrated Project Delivery (IPD), which asked a radical question: "What if we all worked together for once?" The result was a collaborative model that aligned incentives and outcomes, a bit like splitting the bill without arguing over who had the extra soda (O'Dwyer et al., 2024).

Phase V (2010s): Lean Goes Digital — and Global

If the 2000s were Lean's adolescence, the 2010s were its digital awakening. BIM wasn't just a trendy 3D model; it became Lean's secret weapon for managing real-time construction data with surgical precision (Egbelakin et al., 2024). Fang & Gao (2024) argue that this decade saw Lean evolve into a performance-boosting engine that no longer relied on Excel sheets last updated three months ago.

Tools such as cloud-based project tracking, drones, and Artificial Intelligence (AI) scheduling tools made Lean more than a buzzword, it became a productivity juggernaut

(Bellaver et al., 2022). Suddenly, even small projects could track material delivery and workforce efficiency with the kind of detail previously reserved for NASA missions (Aziz & Zainon, 2023; Velezmoro-Abanto et al., 2024).

Phase VI (2020s): Sustainability, Resilience, and the Rise of Robo-Lean

Today, LC finds itself in a high-stakes era marked by climate concerns, resource constraints, and global unpredictability. Gone are the days when cost and time were the only metrics; now LC is expected to build sustainably, adapt rapidly, and resist disruption, all while staying under budget and within given timeframe (Sánchez et al., 2023; Prasad & Vasuki, 2023).

LC now integrates resilience and sustainability goals through modular design, off-site fabrication, and circular material flows (Tetik et al., 2024). Emerging technologies such as AI, machine learning, and Internet of Things (IoT) devices are not just buzzwords, they're now embedded into LC to predict delays before they happen, suggest improvements mid-project, and, if we're lucky, prevent Friday evening concrete pours (Najafi et al., 2024; Ugural et al., 2024).

Sarhan & Pretlove (2021) and Watfa & Sawalha (2021) describe LC's latest reincarnation as a future-proof, digitally empowered system that not only reacts but anticipates. LC in the 2020s is like having a site foreman, financial advisor, environmentalist, and therapist, all rolled into one with one common goal.

Conclusion

From its humble origins in Japanese car factories to its current role as a globally embraced, tech-enabled construction methodology, LC has undergone a remarkable transformation. It has grown from simple philosophy of eliminating waste on a factory floor to designing intelligent, resilient, and sustainable buildings. And as it continues to evolve, one thing remains clear: Lean isn't just a method; it's a mindset and one that still doesn't tolerate cluttered job sites or vague meeting agendas. The development of Lean in the future is foreseen to be more interesting.

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