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ACCELERATING CONSTRUCTION OF PUBLIC INFRASTRUCTURES LEVERAGING LEAN CONCEPTS: A CASE STUDY

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ABSTRACT

Public infrastructure projects often face schedule overruns due to fragmented planning, poor coordination, and weak workflow reliability. This paper presents a Lean Construction case study from India involving the construction of a 650-bed government teaching hospital, developed as an academic extension to an existing medical college. The project was part of a programme comprising four identical hospital facilities. After delays of nearly fifteen months, a pilot Lean intervention was initiated on one hospital.

The intervention shifted project control from traditional quantity-based monitoring to modular and sub-modular workflow planning using physically measurable work packages. Constraint management was prioritised, and repetitive work patterns across floors and building zones were systematically analysed. Lean planning was implemented through structured monthly, weekly, and daily collaborative planning cycles involving contractors, the Project Management Office (PMO), and client representatives, aligned with the Last Planner System®.

The outcomes included improved workflow reliability, effective debottlenecking of critical finishing activities, and enhanced coordination across project stakeholders. The pilot hospital was completed nearly three months ahead of the remaining projects without any increase in budget. The study demonstrates the practical applicability of Lean principles in public sector infrastructure projects characterised by complexity and multiple interfaces.

KEYWORDS

Collaborative Planning System, Last Planner System®, workflow, constraint management, production.

INTRODUCTION

Public infrastructure projects in developing economies rarely move in a straight line. They face uncertainty at every stage, disjointed governance that slows decisions, and design changes that arrive late but carry heavy consequences like cost escalation, delays, and, too often, compromised quality. Traditional methods such as CPM schedules or quantity-driven reviews have been tried, but they fall short; they cannot capture the real constraints of workflow or the

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tangled interdependencies between trades (Ballard & Howell, 1998; Howell, 1999; Koskela, 2000).

India's infrastructure sector offers many such examples. A public programme of four identical teaching hospitals ran into delays, and one facility was already 15 months behind schedule when the authorities decided to launch a Lean pilot. The question was simple but urgent: could Collaborative Planning System push delivery without stretching the budget higher?

The pilot started with introduction of Collaborative Planning System (CPS), adapted from the Last Planner System®, with emphasis on physical modular unit-based planning with systematic removal of constraints, and collaborative handovers. The floor layouts repeated across 48 levels, so successful sequences could be repeated, embedding learning cycles directly into production (Andersen et al., 2012; Gutiérrez Alvarez et al., 2025). This paper presents that case study and asks: how can CPS improve constraint-focused workflow management and delivery performance in a complex public hospital project? The contribution is threefold. First, it documents one of the pioneering applications of CPS in Indian public infrastructure. Second, it shows how physical unit-based planning can overcome the blind spots of quantity-driven monitoring. And third, it highlights the role of collaborative governance in aligning approvals, materials, and work-front readiness: the often-invisible factors that decide whether projects succeed or stall.

Although Lean Construction concepts have been explored in several Indian private sector projects, systematic implementation in public infrastructure programmes remains limited. Government projects often operate within complex multi-agency governance structures where planning reliability is difficult to achieve. This context makes the present case particularly relevant for examining how Lean collaborative planning approaches can improve workflow coordination and delivery outcomes.

PROJECT DESCRIPTION

The government teaching hospital at Balangir, Odisha, stands out as one of the state's most ambitious healthcare undertakings. It was launched in December 2019 with a 30-month schedule for a 500-bed facility. Soon after, regulations changed, and the scope was raised to 650 beds. And that expansion was not a minor adjustment; it pushed the Floor Area Ratio to 61,600 square metres, representing a 67 percent rise in scope and an 80 percent escalation in cost with a linear shift of 13 more months in delivery; a sharp reminder of how statutory changes can ripple through design, finance, and delivery. Revised GFC drawings, expanded services, and new contractual obligations followed, stretching this timeline and shifting the completion deadline to October 2023. Actual construction, however, could begin only in February 2021, once the approvals were in place and the updated drawings were approved for construction.

FINANCIAL PROGRESS AND WORK SPEED DYNAMICS

By December 2022, the project had recorded 49 percent financial progress over 23 months. Of this, 37 percent came from on-site execution and 12 percent from off-site advance payments. The numbers looked steady, but they were not enough. At the prevailing pace, another 24 months would have been needed to finish the remaining works, which meant delays in installing and commissioning several long-lead items. These components carried lots of uncertainties. They accounted for nearly 30 percent of the total project cost and were highly vulnerable to schedule slippages. Any delay in their delivery or integration threatened not only cost escalation but also demurrage charges, extra maintenance expenses, and even the loss of warranty coverage.

Faced with this reality, the project team turned to Lean Construction. Could its principles provide a way forward? The central question was clear, urgent, and practical: how might Lean

methods be applied to raise field productivity while ensuring the timely delivery and commissioning of those critical long-lead items?

LITERATURE REVIEW

Lean Construction has evolved from Lean Production, emphasising waste elimination, value maximisation, and workflow reliability (Koskela, 2000). Unlike traditional CPM approaches that focus on activities, Lean prioritises flow and reduction of variability. The Last Planner System® (LPS) remains a widely adopted framework for improving planning reliability through collaborative and commitment-based processes (Ballard & Howell, 1998; Ballard & Tommelein, 2016).

International studies demonstrate its effectiveness in healthcare infrastructure. Andersen et al. (2012) reported improved workflow reliability in hospital projects, while recent work by Gutiérrez Alvarez et al. (2025) highlights the integration of Lean with Virtual Design and Construction (VDC) to enhance coordination between design and execution. These studies underline Lean's strength in repetitive environments, where standardised layouts enable learning cycles and continuous improvement.

Recent research has further emphasised the importance of constraint management and short-term planning in improving workflow predictability (Hamzeh et al., 2020; Daniel et al., 2021). In developing economies, fragmented governance and delayed approvals continue to challenge traditional planning approaches (Sarhan et al., 2023). Lean-based collaborative planning frameworks such as CPS address these gaps by integrating constraint management, multi-level coordination, and physical unit-based planning into project governance.

Despite these advances, empirical evidence from public healthcare infrastructure in developing economies remains limited. This study contributes by presenting a practitioner-led case demonstrating the application and impact of CPS in such a context.

Adoption in developing economies, however, is not straightforward. Ajaelu et al. (2025) pointed to fragmented governance, approval bottlenecks, and contractor capacity constraints. In India, multi-agency oversight, frequent design changes, and delayed GFC drawings weaken CPM-based planning, which fails to reveal workflow constraints. The literature on Lean in Indian public healthcare remains thin, leaving a research gap. Yet CPS — Collaborative Planning System — builds on LPS while introducing context-specific adaptations for Indian projects. Distinctive features include physical unit-based planning, multi-level collaborative cycles, embedded constraint management, and Big Room decision making. By tackling fragmented interfaces and governance complexity, CPS offers more than a toolset; it represents a novel contribution to Lean literature, a replicable framework for accelerating public healthcare delivery.

METHODOLOGY

This study adopted a single-case, action research approach to test how Lean Construction principles could be implemented in the pilot hospital project. Action research was chosen deliberately: it allows researchers to step inside ongoing projects, intervene directly, and at the same time generate knowledge (Coughlan & Coghlan, 2002). This project became the pilot case because of its delays, scope escalation, and the potential to replicate lessons across three identical hospitals in the programme.

A Lean expert was embedded for the next eight months wherein his role was not passive; it meant mentoring the Project Management Office (PMO) and contractors, hand-holding as well as ensuring methodological rigour while keeping the insight practitioner-led. This embedded presence offered facilitation and observation together, enabling iterative refinement of CPS practices and capturing real-time data on workflow reliability and constraint management.

DATA SOURCES

Evidence was drawn from multiple streams and triangulated to strengthen validity. These included: (1) Monthly and weekly work planning records documenting CPS cycles (2) Constraint logs capturing approval, material, and design bottlenecks (3) Observational site data from Weekly Work Planning, Daily Huddles and Big Room sessions (4) Comparative performance analysis across the other three hospitals in the programme. Triangulation meant that findings were not just anecdotal; rather they reflected systematic patterns across records, site observations, and comparative benchmarks.

In addition to documentary records, the study incorporated insights from structured site interactions including Weekly Work Planning sessions, Daily Huddles, and Big Room coordination meetings involving contractors, consultants, and client representatives. These interactions served as informal but systematic feedback mechanisms, allowing the research team to validate observations regarding workflow reliability, constraint resolution, and coordination effectiveness.

VALIDITY AND RELIABILITY

The embedded researcher role reinforced internal validity by ensuring interventions were specific to the contexts and adaptive. Reliability was strengthened through consistent documentation of planning cycles and constraint logs. Comparative analysis with the progress of other hospitals provided an external benchmark, showing that CPS outcomes were not simply the result of broader programme dynamics but due to the intervention itself. Ethical considerations were addressed carefully to avoid future litigation and to give respect to each action point: *contractor identities were kept confidential, and analysis focused on systemic processes rather than individual performance*. The practitioner-led nature of the study ensured practical relevance, while systematic documentation and triangulation. Maintained academic rigour.

LINK TO CPS FRAMEWORK

This methodological design created a solid foundation for evaluating CPS impact on workflow reliability, schedule compression, and collaborative governance. By embedding Lean expertise within the project team, the study captured both technical outcomes and cultural shifts, e.g. progress acceleration, timeline compression, and trust in commitments, collaborative decision making. The methodology, in short, set the stage for the detailed CPS framework and implementation analysis that follows.

LEAN INTERVENTION DESIGN FRAMEWORK

Affected by escalating scope, rising costs, and relentless time pressures, the project turned to Lean Construction methodologies: specifically, the Collaborative Planning System (CPS). CPS shifted the focus away from cumulative, quantity-based tracking and toward commitment-driven flow management, synchronizing parallel work fronts. Daily huddles, constraint analysis, and “Big Room” decision-making sessions were introduced to collapse approval cycles and sharpen trade coordination.

Figure 1 shows how the work was divided into eight physical segments across six floors, marked in dark lines. This division was not cosmetic. It was structural, becoming the framework through which CPS enabled reliable handovers and reduced variability. Flow concepts were applied even to micro-activities like false ceiling installation, long-lead procurement ; so that critical services like MEP and HVAC could be integrated seamlessly, without the usual friction between trades.

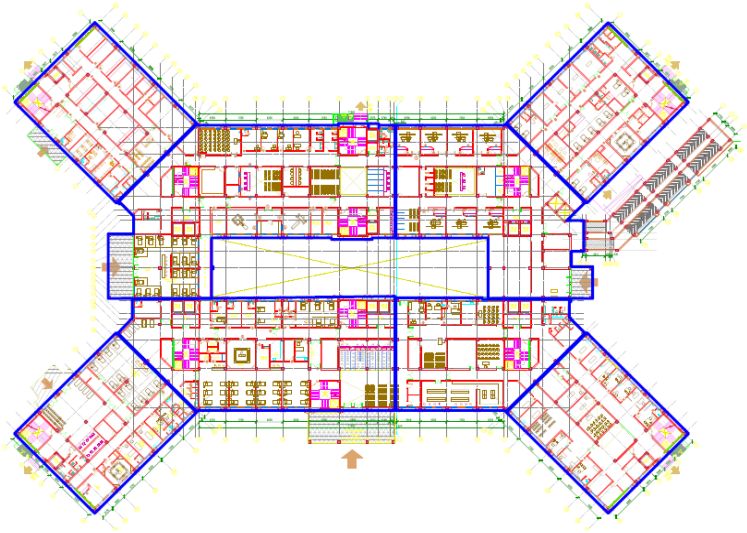

Figure 1: Typical floor plan broken into eight parts across six floors.

The effect was striking. Lean-driven planning allowed the project team to compress the schedule by 14 months, delivering a high-standard medical facility in October 2023, well ahead of the extended deadline, showing clearly that before Lean intervention, the hospital project leaned on conventional CPM schedules and quantity-based progress reviews; and the new methods produced neat cumulative percentages of work completed. However, they failed to capture workflow constraints or the interdependencies between trades, which was one of the difficult parameters.

Between January and October 2023, the schedules were reorganized and the expenditure profile radically restructured. The balance of the project was planned through 33 percent on-site execution and 18 percent off-site recognition. This redistribution compressed what had originally been projected as a 24-month workload into just 10 months, slashing excess time by 14 months. This was not accidental. It was conceived through a deliberate two-pronged approach:

1. On-site works: Field execution to accelerate to sustain higher productivity and raise the direct physical expenditure, while ensuring readiness for installation and commissioning of items and works that can be taken up separately, off-site.
2. Off-site works: Monitoring and fast-tracking long-lead items to guarantee their timely availability at site, payment, and then physical integration into the project.

DIAGNOSIS OF TRADITIONAL PLANNING PRACTICES

Before Lean methodologies were introduced, the project was tangled in systemic bottlenecks that threatened the October 2023 deadline. Traditional practices leaned on quantity-centric tracking, mismatched contractor schedules, reactive quality checks, and slow approval loops. They proved inadequate for a scope that had expanded by 67 percent and nearly doubled in cost; and moreover now on the edge of meeting a timeline. Progress was being measured in abstract volumes rather than functional readiness, which meant no modular management; stalled work fronts, trade stacking, and repeated rework, and with administrative delays piling on, only to create decision paralysis.

To break this cycle, the Collaborative Planning System (CPS) was adopted as a structured adaptation of the Last Planner System®. CPS shifted measurement to physical units, embedded multi-level collaborative cycles, and integrated contractors, the PMO, and client representatives into a unified planning ecosystem.

By naming these weaknesses, it became possible and encouraging to pivot to the CPS model. The transition solved the diagnosis by replacing “Quantity Tracking” with “Commitment

Tracking" and transforming "Disruptive Changes" into "Planned Constraints." Table 1 contrasts traditional practices with CPS resolutions, showing how flow reliability replaced quantity tracking.

- Inversion of Control: The "Big Room" decentralized decision-making. Trade supervisors — the people actually performing the work — dictated the daily sequence based on site reality rather than an outdated office plan.
- Flow Reliability: Weekly Work Planning and Daily Huddles eliminated the "dependency vacuum." Each trade knew exactly what they needed from the preceding team to succeed. This clarity allowed the agency to raise the field delivery rate by over 100 percent, sustaining aggressive monthly financial dynamics consistently for the final ten months.

Table 1: Comparison of Planning Paradigms

Feature	Traditional Practice (Diagnosis)	Lean CPS Practice (Resolution)
Focus	Quantity / Volume	Flow / Physical Completion
Dependencies	Invisible / Isolated	Visible / Collaborative
Quality	Post-execution Inspection	Integrated Workflow
Changes	Disruptive Bottlenecks	Managed Constraints (Look-Ahead)

It is known that CPS draws inspiration from LPS, but its novelty actually lies in contextual adaptation:

1. It embedded multi-level collaborative cycles into structured governance, ensuring fit across strategic, tactical, and operational levels.
2. It provided a third eye for monitoring from modular physical progress to cumulative quantities, enabling reliable handovers.
3. It integrated constraints into the daily/weekly management routine directly and into planning cycles, rather than treating approvals and materials as external dependencies.
4. It triggered the hospital's repetitive floor layouts to replicate successfully sequentially across all 48 floors, embedding learning cycles into production; which increased the team efficiencies multifold.

These adaptations made CPS particularly suited to public projects characterised by fragmented contractor interfaces, complex governance, and frequent design changes.

IMPACT OF CPS FRAMEWORK

The introduction of CPS transformed project delivery in several ways:

1. Workflow Reliability: Daily huddles and physical unit-based planning improved predictability of task completion.
2. Constraint Resolution: Approval and material delays were systematically tracked and resolved, reducing idle time.
3. Collaborative Governance: Big Room sessions fostered trust and transparency, enabling faster decision-making.
4. Schedule Compression: By synchronising parallel work fronts and replicating successful sequences, CPS enabled a 14-month compression of the schedule.

5. Cultural Shift: Contractors and supervisors began to view planning as a collaborative commitment rather than a reporting exercise, strengthening accountability.

IMPLEMENTATION AND OBSERVATIONS

RESOLVING APPROVAL AND DESIGN DELAYS

One of the most stubborn challenges in this project was waiting for approvals and design clarifications. Revised drawings arrived late, leaving contractors idle and sequencing uncertain. To sustain the aggressive work schedule, the team paused standard Lean planning cycles and directly addressed the administrative friction. This "strategic reset" cleared the path for the final ten-month surge:

- **Senior-Level Intervention:** A coordination group was formed to bridge gaps between stakeholders and hold high-frequency meetings to resolve critical design changes and cost deviations triggered by the 67% scope expansion.
- **Stabilizing the "moving target":** By confirming outstanding cost and design approvals within a concentrated window, uncertainty was reduced. This stabilization was essential for Look Ahead Planning to function effectively, enabling subcontractors to commit with confidence.
- **Restoring Trust:** Resolution of approval delays restored confidence across contractors and long-lead suppliers. Waiting times reduced, approvals accelerated, and execution shifted to full-scale, multi-shift operations.

CPS reinforced this reset by embedding constraint logs into weekly planning cycles, making pending approvals visible. Big Room sessions enabled real-time resolution of design queries and collapsed approval cycles from weeks to days (Hamzeh et al., 2015).

These measures stabilized workfront readiness, reduced stoppages, and institutionalized transparency. CPS tools, combined with collaborative governance, safeguarded the ten-month schedule while preserving Lean principles of flow, pull, and reliability.

MATERIAL AVAILABILITY

Material shortages had long disrupted workflow, especially finishing items like tiles, false ceilings, and MEP components. CPS countered this by introducing make-ready planning: material availability was verified before commitments were made. Weekly huddles included explicit procurement checks, and vendors and suppliers were integrated and pulled into Big Room discussions. This proactive stance meant critical materials arrived when needed, reducing variability and avoiding last-minute substitutions that negotiated with quality (Ballard & Howell, 1998).

FLOOR-BASED PLANNING

The hospital's repetitive floor layouts became an opportunity rather than a burden. With 48 floors to deliver, CPS operationalised learning cycles by breaking work into physical units such as floors and sections; and tracking progress accordingly. Once a reliable sequence was proven on one floor, it was replicated across others, embedding lessons into production. Daily huddles reinforced this rhythm, letting supervisors share insights and adjust commitments in real time. Predictable handovers replaced disorder, and overall progress accelerated (Andersen et al., 2012).

FINISHING WORKS DEBOTTLENECKING

Finishing activities such as false ceiling installation, painting, and MEP integration; had historically been coordination nightmares. CPS introduced synchronized parallel work fronts,

allowing multiple trades to work simultaneously without interference. Constraint logs flagged dependencies (like electrical clearances before ceiling closure), and Big Room sessions resolved them before work began. The result was smooth finishing, free of the bottlenecks that had plagued earlier phases (Gutiérrez Alvarez et al., 2025).

CRITICAL ISSUE RESOLUTION & VALUE DELIVERY

To sustain the accelerated pace required for the October 2023 completion, the project team addressed several high-impact challenges through precision management.

- **Chemical Blasting (Non-Explosive Rock Excavation):** As the site was within a functioning medical college and close to existing structures, traditional blasting was not feasible due to vibration and safety risks. Chemical blasting was adopted with rapid administrative approval, avoiding delay from manual excavation or regulatory hurdles.
- **Lean Flow in Metallic False Ceiling Work:** Progress was initially slow due to vendor constraints. The work was subdivided into micro-activities—drilling, framing, tile fixing, and finishing—and cycle times were studied. By increasing workforce and facilities to run tasks in parallel, a continuous production flow was established, converting a bottleneck into a predictable sequence.
- **Streamlining Long-Lead Items:** The 650-bed expansion required extensive specialized equipment. Critical items were integrated into the 6-week look-ahead plan within the Big Room, ensuring alignment between procurement, delivery, and site readiness.
- **Specialized Agency Coordination (OTs):** Operating Theaters required close coordination across civil, medical gas, and sterility systems. Big Room sessions enabled real-time design adjustments and prevented trade stacking.
- **Reduction of Decision Waiting Times:** With consultants and decision-makers present in the Big Room, approval cycles were significantly compressed, eliminating idle time and supporting the 14-month schedule reduction.

Table 2 illustrates how Lean principles were applied to critical activities, showing how CPS solutions accelerated delivery.

Table 2: Lean impact on key activities

Activity	Traditional Challenge	Lean/CPS Solution	Outcome in Project Speed
Excavation	Vibration/Safety risks	Chemical Blasting	Zero disruption to hospital
False Ceiling	Stagnant/Slow progress	Micro-activity Work Study	Continuous Production Flow ensured minimizing delay
Procurement	Delivery delays	Look-ahead Streamlining	Engineering and Procurement were confirmed for Construction
Decisions	7-14 days lag	Big Room Collaboration	Faster Approvals through daily and weekly constraint analysis

This documentation effectively highlighted the transition from a traditional "quantity" focus to a "flow and commitment" focus.

By compressing 24 months of remaining work into just ten, the agency delivered the hospital by October 31, 2023; 14 months ahead of the extended deadline - demonstrating that Lean

principles, when reinforced by senior coordination and transparent planning, can overcome major scope and timeline challenges.

RESULTS

The CPS intervention produced clear quantitative gains. The project could be completed in October 2023, 14 months ahead of the extended deadline of December 2024. On-site monthly expenditure accelerated from 49.3 million INR to 100.9 million INR, reflecting a 105% increase in field productivity. The remaining 51% of project cost was delivered in just 10 months instead of the projected 24, and the pilot hospital was handed over nearly three months earlier than its identical peers that continued under conventional CPM planning.

Beyond these figures, it was seen that CPS could provide qualitative improvements that strengthened overall project reliability. Percent Plan Complete (PPC) rose steadily, approvals and material constraints were addressed consistently, and Big Room governance enhanced transparency among contractors, the PMO, and client representatives. Though initially a hurdle and mental set-back, a cultural shift could be seen as supervisors and contractors began treating planning as a collaborative commitment rather than a reporting exercise. Repetitive floor layouts with the learning cycle advantage, further helped, embedding continuous improvement into production and reinforcing workflow predictability. Table 3 summarises the performance improvements achieved under CPS compared to traditional CPM.

Table 3: Performance summary

Dimension	Traditional CPM (Baseline)	CPS Intervention (Pilot Hospital)
Planned Completion	Dec 2024 (after extensions)	Oct 2023 (<14 months)
Productivity Gain	Baseline	105% post CPS
Workflow Reliability	Low, frequent stoppages	High, predictable
Constraint Management	Reactive, ad hoc	Proactive, systematic logs
Contractor Coordination	Fragmented, siloed	Integrated Big Room
Comparative Outcome	3 months later than pilot	3 months earlier than peers

The performance leap summarized in Table 3 stems from three primary Lean mechanisms, embedded in CPS:

1. Constraint Management: Ensuring work commenced only when drawings, materials, and approvals were secured, minimizing rework and idle time.
2. Collaborative Planning: Increasing commitment reliability among trade contractors, which stabilized workflow and reduced stoppages.
3. Modular Planning & Learning Cycles: Utilizing repetitive floor layouts to allow productivity gains to compound as teams moved across identical building segments.

These mechanisms demonstrate that Lean principles, when adapted to local governance and contractor realities, deliver both schedule compression and systemic transformation. This validates CPS as a replicable model for complex public healthcare infrastructure in India and similar emerging contexts.

DISCUSSION

The CPS adoption demonstrates that Lean principles can be effectively applied in public infrastructure projects. By integrating physical unit-based planning and constraint management into governance, CPS improved workflow visibility beyond traditional CPM methods. The case

shows that significant schedule acceleration is achievable without budget escalation, even under scope changes and multi-contractor interfaces, through improved coordination, reduced waste, and a 'first-time-right' work culture.

The pilot hospital indicates strong potential for replication across large-scale government programmes, particularly in resource-constrained environments. The findings are also consistent with international Lean hospital cases, reinforcing evidence of improved workflow reliability through CPS.

However, the study is based on a single pilot within a four-hospital programme. Variations in site conditions, contractor capability, and institutional support may affect broader applicability. Future research should validate these findings through multiple case studies across public infrastructure projects.

CONCLUSION

This paper presents a practitioner-led case study demonstrating the application of CPS in delivering a 650-bed teaching hospital in a public infrastructure context. Despite an initial delay of over 13 months, the project was transformed through CPS into a reliable and accelerated delivery model.

The shift from quantity-based monitoring to workflow planning, supported by collaborative cycles, constraint management, and Big Room coordination, significantly improved execution reliability. Repetitive floor layouts enabled learning cycles, contributing to productivity gains. The hospital was completed in October 2023, 14 months ahead of the extended deadline, with a 105% productivity increase and delivery three months ahead of peer projects, without budget escalation.

The study contributes to Lean Construction literature by demonstrating:

1. the feasibility of CPS in Indian public healthcare projects,
2. the effectiveness of physical unit-based planning over quantity-driven monitoring, and
3. the critical role of collaborative governance in ensuring workflow readiness.

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