LEAN CONSTRUCTION, WHERE INNOVATION MEETS EXCELLENCE, TRANSFORMING CONSTRUCTION CULTURE FOR SUCCESS

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Abstract

The Indian Lean Construction sector has experienced substantial growth and development in recent years, owing to the adoption of lean concepts and techniques, however, lean construction practices have been underutilized by Indian construction firms.

The paper aims to investigate the role of lean construction tools in identifying and addressing wastages in the construction industry. Lean construction principles and methodologies have gained prominence as an effective means to improve project efficiency, reduce costs, and enhance overall productivity. The focus area of the paper is to explore how specific lean construction tools can help identify various forms of waste commonly found in construction processes. A systematic approach was adopted to analyze workflow data using three key lean construction tools viz. the Last Planner System (LPS), 5S methodology, and Work Sampling. These tools were selected due to their ability to provide insights into different aspects of construction wastages.

The findings indicated that lean construction tools play a significant role in waste identification within the construction industry. The implementation of the lean tool provided valuable data and visual representations that enabled project teams to identify and address various types of waste, including material waste, excess inventory, unnecessary motion, waiting time, and inefficient processes.

By deploying lean construction tools, it was observed that it can lead to substantial improvements in productivity, cost reduction, and project performance. By identifying and eliminating wastages, construction companies can streamline processes, enhance resource utilization, and improve overall project outcomes. The research outcomes help to derive insights for lean enthusiasts trying to adopt lean principles and tools to optimize construction processes and drive continuous improvement.

KEYWORDS *Lean Project Management, Last Planner System, 5S, Work Sampling, Construction Wastes, Value Stream Method*

INTRODUCTION

The construction sector is one of the important industries responsible for defining our built environment, but it has historically been slower to adopt innovative production philosophies compared to other sectors. In 1993, the Lean Thinking theory was introduced to the construction sector, and several effective applications have occurred. According to the Construction Industry Institute, just 10% are value-added inputs, while the remaining 57% are waste. In comparison, the manufacturing industry has 62% contributed value and 26% waste [1]. The low rate of innovation has been directly tied to the construction industry's lack of performance in comparison to other industries. In today's world the understanding of waste is being redefined, and it is not limited only to material wastage anymore. The goal of lean is to reduce waste, which is defined as everything that does not contribute value. The inventor of the Toyota Production System, Taiiachi Ohno, recognized seven distinct forms of waste (Ohno 1990)[2]. There are eight primary wastes in the construction industry are defects, waiting, transport, motion, inventory, overproduction, overprocessing, and skills on wrong tasks[3]. In an era where sustainable practices and resource efficiency have become paramount, the construction industry faces increasing pressure to minimize wastage and enhance productivity. The quest for leaner construction processes has led to the adoption of various projects management strategies and tools that prioritize the elimination of waste throughout the construction lifecycle. Among these, the integration of Lean Construction Tools has emerged as a transformative approach, enabling construction professionals to identify and address wastages effectively.
We used four essential lean construction tools to identify and remove these wastes: the last planner system (LPS), 5S approach, and work sampling.

The major goal of this research is to investigate the prevalence of waste in the construction industry in India, with a focus on high-rise residential building projects.
This study was conducted on the Joyville Manjari Residential building, which was being constructed for Shapoorji Pallonji Real Estate by Shapoorji Pallonji Engineering and Construction. The project includes 21 towers, each with 22 stories. The monolithic casting method used in the project uses Mivan shuttering-lightweight aluminum formwork designed to comply with a repeating slab cycle, which makes it very suitable for the implementation of these lean tools.

METHODOLOGY

Last Planner System (LPS):

LPS is a tool used in Lean Construction; a method created especially for the building sector by Glenn Ballard in 1992. It is intended to produce more dependable scheduling and improved predictability. The core concept of LPS revolves around active involvement and commitment from the people closest to the work, including those performing the tasks and those supervising or managing them. This can be accomplished by including every stakeholder in the construction process, which improves communication, clarity, and flow. LPS emphasizes strict time management, monitoring, progress tracking, and variation analysis. LPS aims to achieve standardization, quality control, scalability, efficiency, and risk reduction in projects, ultimately improving overall performance and delivering consistent and high-quality products or services.

Key objective to use LPS.

By implementing LPS, the project team can effectively plan and coordinate their activities, minimizing conflicts and delays.
LPS helps to increase the predictability of project timelines and outcomes.
It encourages the use of lean construction principles and techniques to streamline processes, eliminate waste, and optimize resource utilization, leading to improved productivity and efficiency.
LPS promotes a culture of learning and continuous improvement within the project team. By regularly reviewing performance, analyzing deviations, and implementing corrective actions
Improving coordination, predictability, productivity, and quality, LPS ultimately aims to enhance client satisfaction. Delivering projects on time, within budget, and to the desired level of quality helps build trust and positive relationships with clients.

5S Approach:

5S is a technique for arranging, standardizing, cleaning, and consistently enhancing a workplace. 5S is more than a housekeeping technique; it is one of the most powerful Lean tools and easy to adopt. A concept built on five Japanese terms designed to establish and sustain an orderly workplace that is more efficient and productive. It includes Five S words: Seiri, Seiton, Seiso, Seiketsu, and Shitsuke, representing Sort, Set, Shine, Standardize, and Sustain respectively. [13].

Figure 1 describes the schematic diagram of 5S principles

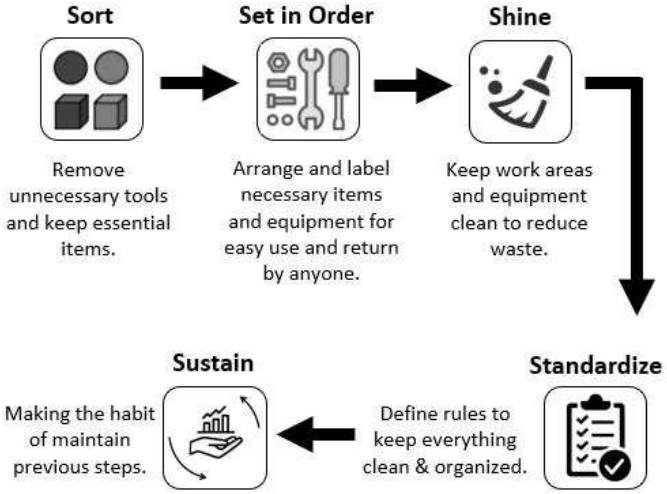

Figure 1: *Schematic Diagram of 5S principles; Source: leanconstruction.org*

Sort focuses on removing items from the workplace that are no longer required for construction.
Set in Order: This refers to arranging the necessary items so that they can be readily grabbed and returned to their original location after use. It involves organizing and storing items in a manner that makes them simple to collect and return to their proper location[14].
Shine, achieved by removing all unnecessary items and debris. Shine: In this stage, smooth-running cleansing is achieved by removing all unnecessary items and debris. This procedure is typically performed after sorting and set in order. All items must be in their designated locations, and work areas must be washed down and routinely inspected in order to improvement[15].
Standardize, means maintaining the first three pillars, establishes a consistent method for performing tasks and procedures. This process consists of integrating 5S responsibilities into daily duties, and monitoring 5S maintenance[16].
Sustain, forming a routine of maintaining correct procedures. Sustain focuses on defining an entirely new paradigm and organizational standard for the workplace. Without the Sustain, the other achievements will not persist. [16]
Key objective to use 5S is to improve safety, efficiency, and quality. By organizing workspaces, identifying hazards, and reducing waste, it fosters a safer environment, enhances employee morale, and increased productivity. Standardization and visual management streamline processes, leading to better teamwork and coordination. The continuous improvement aspect ensures ongoing enhancements, optimizing resources, and reducing costs. Overall, implementing 5S principles creates a well-structured, organized, and efficient construction site, promoting better project outcomes and a positive working atmosphere.

Work Sampling:
Work Sampling is a data-driven tool used to analyze worker productivity and identify potential bottlenecks in construction processes. By gathering and analyzing real-time data, construction managers can make informed decisions to allocate resources effectively, reduce idle time, and optimize labor productivity. Work Sampling is a quantitative technique used to analyze and measure the utilization of resources, particularly labor, in various activities within a construction project. It involves observing and recording the presence or absence of workers in specific tasks over a predetermined period. By capturing data on the frequency and duration of activities, construction managers can gain valuable insights into worker productivity, identify inefficiencies, and optimize resource allocation.
The main objective of work sampling is to acquire a fair and accurate depiction of how labor resources are employed in a construction environment. This data-oriented method is especially beneficial in scenarios where ongoing observation of employees' actions could be unfeasible or overly expensive. Rather than endlessly monitoring every worker, work sampling depends on intermittent sampling periods to collect enough data for evaluation.

A. Implementation of the Last Planner System (LPS):
LPS is utilized to analyze and increase daily worker productivity and accountability. This tool is used to track the daily planned and actual productivity of each work crew. The planning process begins with a "pull planning" session, where key project participants come together to collaboratively develop a reliable and realistic work plan. During this session, tasks are identified, and the team collectively decides on the order in which the work will be executed. Bhadaniya P. and Roy A. created a modified template in line with the principles of Last Planner System for the same site for previous phase buildings [8], refer Figure 2. In which instead of a weekly target plan, they created a holistic target plan with a single 9-day cycle. Whichever stakeholder is responsible for Look-Ahead/Make-Ready Planning must adhere to the cycle plan itself. Thus, it becomes necessary to combine the original LPS components, the look-ahead/make-readiness plan and the weekly task plan, into a single cycle plan. This modified LPS integrates the look-ahead/Make-ready plan and weekly labor plan into a single cycle plan.

Figure 2 describes the LPS framework adopted which included weekly planned Vs achieved data, production and productivity metrics.

In section 1, comprehensive project information, cycle ID, specific work front site, and work quantity across various activity trades are being included.

In section 2, the cycle schedule regarding day-half, day, and dates is incorporated.

In section 3, the activity breakdown for a cycle with the designated trade id is included.

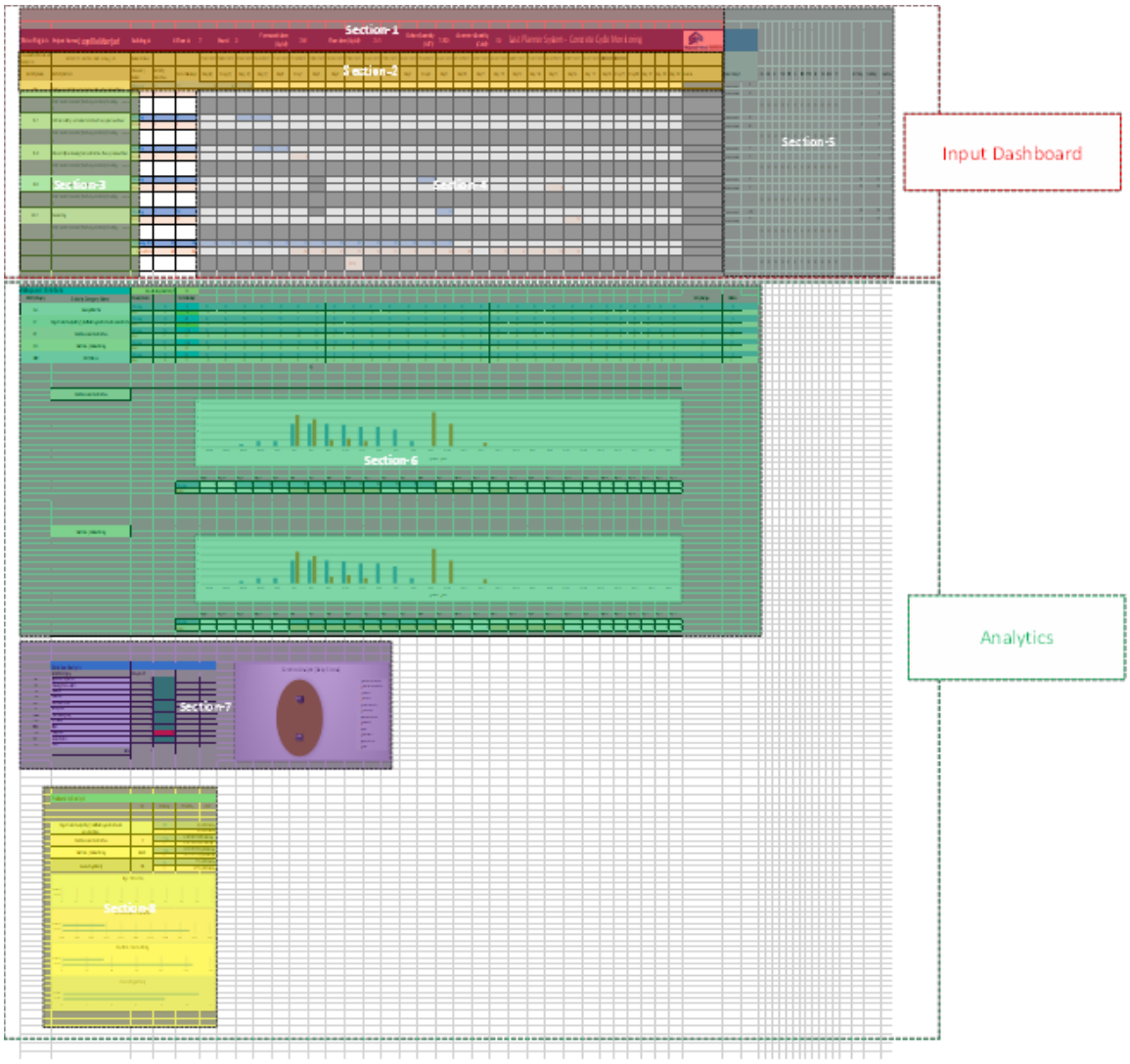

Figure 2: *Modified Activity Cycle Planning & Tracking Framework*

In section 4, arrangements for planning and monitoring spaces for each day-half and for all activities are made such that users must input the necessary manpower in the planning row and the actual manpower in the monitoring row for a specific day-half. This section subsequently generates a bar chart to illustrate planned versus actual data.
In section 5, modifications following execution are noted, and a clause to highlight limitations during the planning phase has also been included.
Section 6 presents an active summary of the intended manpower compared to the actual manpower utilized on a specific day. This part also offers statistical insights that can significantly assist in the equitable distribution of resources both within and among different trades.
In section 7, two pie charts and a detailed table illustrate the influence and probability of various changes noted in section 5.
In section 8, real-time comparisons of planned versus actual productivity are displayed for various activity trades involved in the activity cycles.

B. Implementation of 5's Approach:

The effective implementation of the 5S methodology at a construction site is crucial for maintaining a safe, organized, and efficient working environment. For a particular tower construction project, the responsibility of ensuring 5S compliance has been assigned to tower engineers and supervisors who act as 5S coordinators. Their primary role involves installing and maintaining 5S labeling, overseeing assigned tasks, and fostering a culture where 5S principles are ingrained in daily work. Additionally, the construction team has developed ground level material logistic plans and Workfront logistic plans to further enhance the 5S implementation.

- ***Appointing 5S Coordinators (Supervisors):***

To ensure the success of 5S implementation, the tower in charge and supervisors have been designated as 5S coordinators. These individuals are responsible for spearheading the 5S initiative, guiding their respective teams, and creating a sense of ownership and responsibility towards 5S principles. As 5S coordinators, they spend dedicated time strategizing, planning, and executing 5S-related activities, making it an integral part of their role.

- ***Fostering a Culture of Regular 5S Thinking:***

While 5S coordinators play a vital role in leading the 5S efforts, the success of the methodology relies on everyone's involvement. To instill a culture of continuous improvement and 5S thinking, regular awareness sessions, training workshops, and communication initiatives are conducted for all site personnel. The objective is to encourage everyone to actively contribute to maintaining a clean, organized, and efficient workspace.

- ***Transitioning from Event to Daily Practice:***

Initially, 5S might take place as a formal event to kickstart the process and garner enthusiasm among the workforces. However, the goal is to integrate 5S practices seamlessly into daily work routines. The 5S coordinators play a crucial role in leading by example and ensuring that 5S is not viewed as a one-time activity but rather a daily habit.

- ***Ground Level Material Logistic Plan:***

A well-organized material logistic plan is essential to maintain the principles of 5S effectively. The ground level material logistic plan ensures that construction materials are stored, labeled, and positioned in a manner that promotes efficiency, minimizes wastage, and reduces the potential for accidents. The 5S coordinators work closely with the logistics team to enforce the plan and make necessary adjustments based on project requirements.

Figure 3: Shows the Ground Level Material Logistic Plan

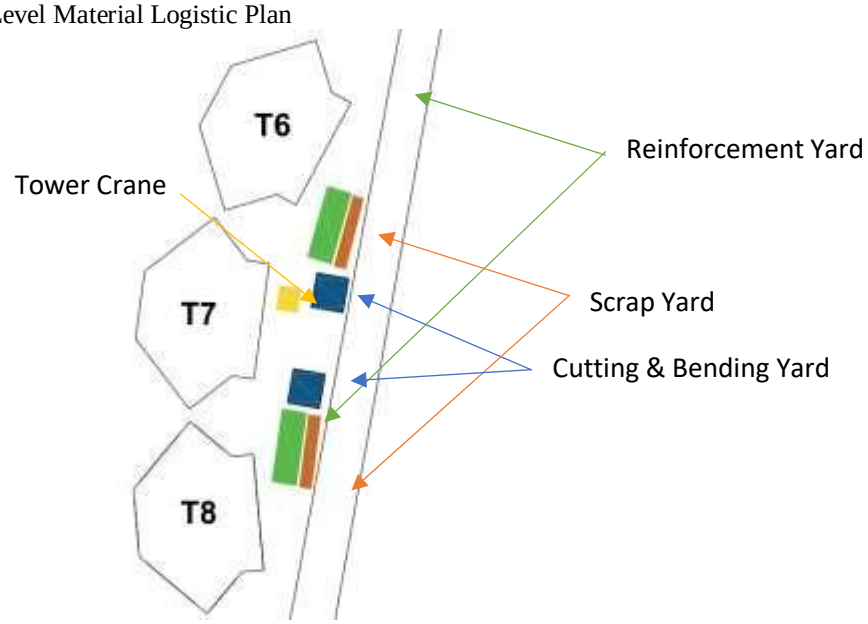

Figure 4: *Ground Level Material Logistic Plan*

- ***Workfront Logistic Plan:***

The Workfront logistic plan focuses on the flow of work and processes on the construction site. It involves streamlining tasks, optimizing workflows, and reducing unnecessary movement, thereby enhancing productivity and adherence to 5S principles. The 5S coordinators collaborate with project managers and supervisors to integrate the Workfront logistic plan into daily operations and ensure consistent compliance.

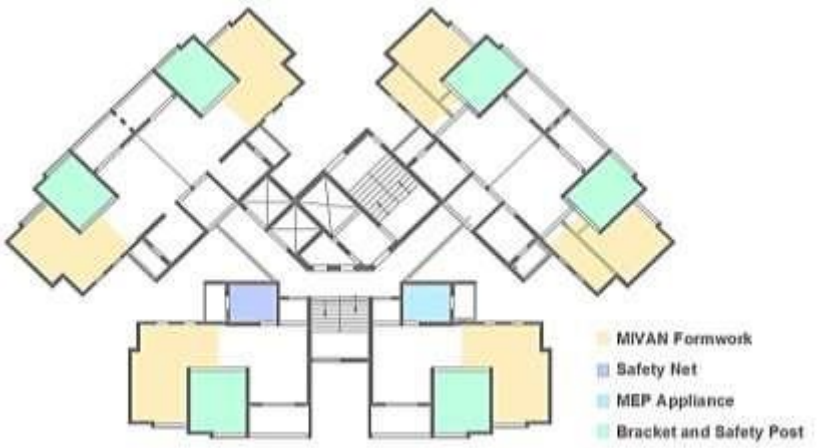

Figure 5: *Workfront Logistic plan for Stacking of Materials at previous level*

C. Adopting Work Sampling Techniques:

Because of the nature of the work, we exclusively use crew-based sampling. The process of conducting work sampling involves the following steps**:**

The first step is to establish clear objectives for the work sampling study. This includes identifying specific tasks or activities to be observed and the reasons for conducting the study, such as improving labor productivity or identifying bottlenecks. For the study, we observed concreting activity.

The next step is to determine the sample size (number of observations) and the sampling intervals (time between observations). The sample size should be statistically significant to ensure the accuracy of the results, while the sampling intervals should be random to avoid bias.

During the designated sampling periods, observers record the presence or absence of workers performing specific tasks. It is crucial to capture data without interrupting or influencing workers, as this could lead to inaccurate results.

Once the data collection is complete, the recorded data is analyzed to calculate the percentage of time workers spend on each activity. This analysis helps in identifying how labor resources are distributed across different tasks and areas of the construction site.

The final step involves interpreting the results and using them to make informed decisions. We identify areas where labor productivity can be improved, allocate resources more efficiently, and implement strategies to optimize project schedules.

D. Result and Conclusion:

By designating specific locations for tools, equipment, and materials, the construction site's workflow was streamlined, and time spent seeking necessary items was reduced. On the construction site, debris, waste material, and potential hazards decreased because of routine cleansing practices. By maintaining a tidy construction site, the project adhered to safety and environmental regulations. The implementation of standardized procedures included training programs for employees to ensure they understood the significance of the new practices. On the construction site, regular audits and evaluations helped identify areas for further advancement and fostered a culture of continuous enhancement. The workers' participation in maintaining the 5S practices fostered a sense of ownership and responsibility for the organization and sanitation of the construction site.

Figure 6: *Effective use of Workfront logistic plane; Source: Joyville Manjari T9 (SPRE)*

Figure 7: *Set in order at site, Source: Joyville Manjari Yard (SPRE)*

The implementation of 5S principles on the construction site led to substantial improvements in organization, productivity, safety, and overall project outcomes. By eliminating waste, improving organization, promoting sanitation, and nurturing a culture of continuous improvement, the construction site saw tangible benefits that positively impacted workers, management, and the overall success of the project. The 5S method proved to be an effective tool for optimizing construction site operations and is likely to continue providing long-term benefits after its initial implementation.
In this investigation, crew-based periodic and continuous work sampling for the Concreting activity was conducted and analyzed. The percentages of time spent on value-added, non-value-added, and necessary but non-value-added activities for Periodic sampling were 39%, 7%, and 54%, respectively. In the continuous sample, the proportions of VA, NVA, and NVAN activities were 39%, 6%, and 55%, respectively. The similarities in the distribution of VA, NVA, and NVAN activities between Periodic and continuous sampling suggest that both processes have similar potential for improvement. Organizations should focus on reducing NVA activities and optimizing NVAN activities to increase overall efficiency and productivity.

Figure 8 Shows The Crew Based Work Sampling

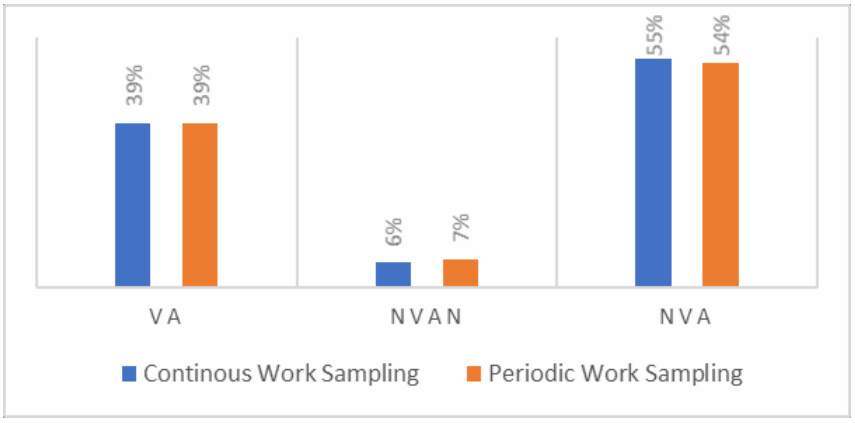

Figure 9: *Crew Based Work Sampling*

To achieve this, process optimization strategies such as lean principles, Six Sigma methodologies, and continuous improvement initiatives can be implemented. Regularly reviewing the work sampling results and identifying specific areas with higher NVA or inefficient NVAN activities can aid in targeted improvements.

Work sampling analysis provides a valuable understanding of the distribution of activities in different work processes. In this study, we found that the proportions of VA, NVA, and NVAN activities were relatively consistent between Periodic and continuous sampling. These findings emphasize the importance of continuously optimizing processes to reduce waste, enhance value-added efforts, and improve overall productivity in the organization.

The implementation of the Last Planner System on the construction site initially resulted in lower productivity than planned. However, through continuous improvement and experience gained in subsequent cycles, productivity significantly improved. The study identified manpower issues from the contractor side as a major contributor to delays, indicating the importance of workforce planning and allocation in construction projects. we made an intriguing observation that the originally planned 9-day cycle could be accomplished in just 7 days by effectively managing and implementing manpower and resources. Overall, the Last Planner System demonstrated its effectiveness in enhancing

productivity and providing valuable insights into the construction process, allowing for better decision-making and timely project delivery.

There were numerous obstacles during the implementation of LPS on site, including**:**

- The lack of communication between subcontractors posed challenges during the implementation of the modified LPS function, making coordination difficult.
- The top management's ability to effectively implement LPS on the project was limited, primarily due to their lack of influence over all parties involved, especially subcontractors.
- The project faced a significant requirement for skilled labor to handle finishing work, but the subcontractor's inefficiency in providing such labor led to changes in priorities and prerequisite work.
- Several unavoidable obstacles were encountered during the implementation process, including a lack of commitment to change and innovation, unrealistic expectations, and the subcontractor's failure to fulfill promises.

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