

Optimization of Cost and Time Reduction through Value Stream Mapping Implementation

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ABSTRACT - The construction industry continuously faces major challenges related to project delays, labor inefficiency, material wastage, and increasing execution costs. Conventional construction practices often involve non-value-added activities that adversely affect productivity and overall project performance. This study investigates the application of Lean Construction principles through Value Stream Mapping (VSM) as an effective tool for optimizing construction workflow and minimizing unnecessary time and cost expenditures.

A detailed case study was conducted on a residential building project located at Green County Phase II, Pune, India. Existing construction activities were analyzed under the Current State Map framework, and improved execution strategies were developed through the Future State Map by replacing traditional methods with advanced construction techniques such as AAC block masonry, automatic plastering systems, mechanized concreting, and productivity-oriented site management practices. Comparative quantitative analysis was performed on major construction activities to evaluate the impact of the proposed interventions.

The findings reveal that the implementation of VSM-based lean strategies significantly improved project efficiency. The total project execution duration was reduced from 896 days to 677 days, resulting in a time saving of 24.4%, while the overall project expenditure was reduced from ₹4,77,38,238 to ₹4,47,75,724, achieving a cost saving of 6.2%. Activity-level analysis also demonstrated notable reductions in brickwork and plastering duration, labor dependency, and material wastage.

The study concludes that Value Stream Mapping serves as a practical and effective lean construction tool for identifying process inefficiencies, eliminating non-value-added operations, and improving construction productivity. The proposed framework offers a feasible roadmap for contractors and project managers seeking sustainable time-cost optimization in residential construction projects.

Key Words: Lean Construction, Value Stream Mapping, Time Optimization, Cost Reduction, Construction Productivity, Process Improvement, Waste Minimization, Residential Building Projects.

1.INTRODUCTION

The construction sector plays a vital role in the economic growth of developing countries; however, it continues to suffer from recurring problems such as project delays, excessive labor dependency, material wastage, cost overruns, and inefficient workflow management. In conventional construction practice, a significant portion of project resources is consumed not only by productive operations but also by non-value-added activities such as waiting, unnecessary transportation, rework, idle labor

time, improper coordination, and poor site planning. These hidden inefficiencies gradually increase project duration and financial burden, thereby reducing the overall productivity of construction projects.

In recent years, the growing demand for faster delivery, controlled expenditure, and sustainable utilization of resources has forced the construction industry to adopt systematic management approaches rather than relying solely on traditional execution methods. Among the various modern management philosophies, Lean Construction has emerged as an effective approach for improving construction performance by focusing on waste elimination, continuous flow of activities, value generation, and better utilization of manpower, materials, and machinery. The central objective of lean construction is to identify operations that do not contribute directly to customer value and to redesign the workflow in such a way that project execution becomes faster, smoother, and more economical.

One of the most widely accepted analytical tools used under Lean Construction is Value Stream Mapping (VSM). Value Stream Mapping is a visual and quantitative technique used to study the present condition of a process, identify delays and losses occurring between activities, and design an improved future state with reduced non-value-added operations. Unlike general planning tools, VSM provides a detailed understanding of process flow, time consumption, labor interaction, and cost accumulation at each stage of construction.

Although Lean Construction and Value Stream Mapping have been extensively implemented in manufacturing industries, their practical adoption in Indian residential building projects remains comparatively limited. Many construction sites still depend heavily on manual methods, fragmented communication, and conventional resource handling practices, which lead to substantial losses in productivity. Hence, there exists a strong need to examine how lean tools can be adapted to actual building construction activities and whether measurable improvements in project time and project cost can be achieved through such implementation.

The present study focuses on the application of Value Stream Mapping for optimizing time and cost in a residential construction project. Major site activities were observed under conventional working conditions and analyzed through a Current State framework. Thereafter, improved construction alternatives and workflow modifications were proposed to develop a Future State model emphasizing faster execution and lower expenditure. Comparative assessment between the existing and proposed methods was carried out to evaluate the effectiveness of VSM-based lean implementation in terms of project duration, resource utilization, and economic savings. The outcome of this study aims to demonstrate that structured process mapping combined with modern construction practices can significantly enhance efficiency and provide a practical roadmap for construction managers seeking time-cost optimization.

2. LITERATURE SURVEY

The construction industry has long been recognized as one of the most resource-intensive sectors, where delays, budget overruns, poor labor productivity, and material wastage are frequent challenges. Traditional construction management approaches often emphasize activity completion rather than process efficiency, resulting in significant hidden losses throughout the project lifecycle. In response to these concerns, researchers across the world have increasingly explored Lean Construction principles as a means of improving workflow reliability, reducing non-value-added activities, and enhancing project performance [1].

Lean Construction originated as an adaptation of Lean Manufacturing principles developed under the Toyota Production System. Its primary focus is to maximize customer value while minimizing waste associated with labor, waiting time, movement, inventory, defects, and over-processing. According to Womack and Jones, lean thinking transforms the conventional push-based management philosophy into a value-driven pull system where each operation contributes meaningfully to the final deliverable [2]. In construction environments, this philosophy is particularly important because project activities are highly interdependent and any inefficiency in one stage causes a ripple effect on subsequent tasks.

Among various lean tools, Value Stream Mapping (VSM) has emerged as one of the most effective methods for visualizing and analyzing process inefficiencies. Hines and Rich explained that VSM provides a systematic representation of both material flow and information flow within an operational chain, thereby helping organizations identify value-added and non-value-added activities in a measurable manner [3]. Unlike conventional bar charts or planning schedules, VSM captures process delays, waiting intervals, labor interruptions, and unnecessary handling, which are often overlooked in routine project monitoring.

Several researchers have attempted to investigate the applicability of VSM in the construction industry. Desai and Shelat conducted one of the early practical studies on Value Stream Mapping as a lean construction tool and reported that VSM helped in identifying bottlenecks associated with labor movement, material supply, and sequential delays in site execution [4]. Their study emphasized that the Current State Map serves as an actual snapshot of site inefficiencies, whereas the Future State Map provides a structured improvement plan by reducing non-essential activities. This research established that VSM can be adapted effectively beyond manufacturing into dynamic construction environments.

Similarly, Barathwaj et al. studied residential construction through VSM implementation and concluded that process visualization improves understanding of time losses and communication gaps between site teams [5]. Their work highlighted that construction projects often suffer not because of technical difficulty, but due to fragmented workflow and poor synchronization between dependent operations. By identifying such interruptions, VSM becomes a decision-support tool rather than merely a process diagram.

Rajkumar et al. further explained the importance of integrating process symbols, timelines, and information flow in VSM for construction productivity enhancement [6]. According to their findings, one of the major benefits of VSM lies in converting scattered field observations into a readable engineering framework, allowing project managers to pinpoint exactly where the delay originates. Their research showed that a well-prepared value stream map provides visibility into waiting time, cycle time, inventory buildup, and manpower utilization, all of which influence project duration and cost.

A more advanced contribution was presented by Gunduz and Naser, who developed a cost-based Value Stream Mapping framework for underground pipeline construction projects [7]. Their study did not restrict VSM only to time reduction but incorporated direct cost implications associated with non-value-added tasks. By comparing current and future states, they reported approximately 30% lead time reduction and over 20% cost savings, demonstrating that VSM can serve as both an operational and economic optimization model. This study is particularly important because it validated that VSM outcomes can be quantified financially, which is essential for practical contractor acceptance.

Ramani and Lingan also applied lean construction using Value Stream Mapping in structural steel erection work and observed a significant reduction in project duration after eliminating waiting periods and improving process coordination [8]. Their study reinforced the argument that lean implementation is not necessarily dependent on expensive technological investment; rather, a large portion of gains can be achieved through proper sequencing, planning discipline, and process transparency.

Apart from direct VSM studies, researchers have also examined lean tools in specific construction operations. In the concrete pouring process, mixed VSM and simulation-based analysis revealed that operational waste generated due to equipment idleness, labor mismatch, and poor batching coordination can substantially affect daily productivity [9]. Similar findings were reported in work sampling studies where labor utilization was found to be significantly reduced due to non-productive movement and waiting, suggesting that process observation is critical before proposing improvement strategies [10].

The literature also reveals that modern construction productivity cannot rely solely on manual traditional methods. Ankush Naskar and Laukik Raut studied the performance of automatic wall plastering machines and concluded that mechanized plastering reduces labor dependency, improves surface uniformity, and minimizes material wastage when compared to manual hand plastering [11]. Likewise, Rahul Mahajan and Reuben Buthulo emphasized the role of Ready-Mix Concrete in reducing on-site congestion, improving consistency, and shortening execution cycles in concreting activities [12]. Such studies indicate that process optimization is most effective when lean workflow analysis is combined with advanced execution technologies.

Another important dimension identified in literature is the issue of labor skill variability and conventional site culture in India. Vinaya More et al. observed that despite the clear benefits of Lean Construction, its implementation in Indian projects remains limited because of low awareness, resistance to change, fragmented subcontracting systems, and insufficient top-

management commitment [13]. This implies that although lean tools are scientifically proven, their real-world adaptation still requires practical case-based demonstrations to build confidence among contractors and project engineers.

Recent studies further suggest that the future of Lean Construction lies in integrated performance management where VSM is combined with digital monitoring, simulation, and sustainability evaluation [14]. However, despite these advancements, the majority of available studies focus either on manufacturing analogies or isolated infrastructure tasks. Comprehensive implementation of VSM in residential building construction involving direct comparison between conventional methods and improved mechanized alternatives is still relatively underexplored.

From the reviewed literature, it becomes evident that Lean Construction and Value Stream Mapping possess substantial potential to improve project workflow, reduce hidden waste, and generate measurable time-cost savings. Most previous studies confirm that Current State and Future State analysis can successfully identify process inefficiencies; however, the degree of implementation in routine residential construction practices remains insufficiently documented. Furthermore, several studies discuss lean principles conceptually but provide limited integrated field-based cost and duration comparison for practical building activities.

Therefore, the present study attempts to bridge this gap by applying Value Stream Mapping to selected residential construction operations under actual site conditions and by quantitatively comparing traditional construction practices with advanced lean-oriented alternatives. The objective is not merely to discuss lean theory, but to validate through measurable evidence how process redesign and modern execution methods can reduce project duration, labor effort, and overall construction expenditure.

3. RESEARCH GAP & PROBLEM STATEMENT

3.1 Research Gap

The available literature indicates that Lean Construction and Value Stream Mapping (VSM) are widely accepted as effective tools for improving operational efficiency, minimizing waste, and enhancing productivity in construction projects. Various researchers have emphasized the importance of identifying non-value-added activities, reducing waiting time, improving material flow, and ensuring better coordination among construction operations. VSM has been recognized as a practical technique for visualizing the Current State of a process and designing an improved Future State with reduced inefficiencies and better workflow continuity.

However, a detailed review of previous studies shows that much of the existing research is either conceptual in nature or restricted to the analysis of isolated construction activities. In several cases, the implementation of Value Stream Mapping has been explained only theoretically, without presenting a detailed field-based comparison between conventional construction methods and improved modern alternatives. As a

result, although the theoretical usefulness of VSM has been established, its measurable effect on total project duration and project expenditure is still not sufficiently validated in actual residential construction projects. There is still a shortage of case-based studies that demonstrate how lean tools can be practically integrated with day-to-day site execution to generate measurable engineering benefits.

Another important limitation observed in earlier studies is that many researchers focus mainly on productivity improvement or waste reduction separately, whereas only a few studies analyze both time optimization and cost reduction together under one lean management framework. In practical construction projects, contractors and engineers are concerned not only with faster completion of work but also with whether the proposed improvements are economically beneficial. Therefore, simultaneous evaluation of both schedule performance and financial performance becomes essential for practical decision-making and implementation.

In the Indian residential construction sector, activities such as brickwork, plastering, concreting, painting, and reinforcement handling are still largely performed using conventional labor-intensive methods. These traditional practices often result in excess manpower usage, longer execution periods, material wastage, repeated delays between dependent operations, and poor synchronization of resources. Such inefficiencies directly affect overall project productivity and increase the total burden on project management. Although advanced alternatives such as AAC block masonry, automatic plastering machines, Ready-Mix Concrete, spray painting systems, and mechanized tools are increasingly available, there is limited practical research showing their comparative effectiveness when implemented through a structured Value Stream Mapping approach.

Hence, the major research gap identified is the lack of a practical, field-based, and quantitatively supported study that combines Lean Construction principles, Value Stream Mapping analysis, and advanced construction techniques for simultaneous reduction of project time and project cost in residential building projects.

3.2 Problem Statement

Residential construction projects frequently suffer from delays and cost overruns due to inefficient planning, heavy dependence on manual labor, poor resource utilization, labor idle time, material losses, and the continued use of conventional execution methods. These inefficiencies generate several non-value-added activities that increase project duration and overall expenditure without proportionate improvement in output quality.

Although Lean Construction and Value Stream Mapping provide a systematic method for reducing such inefficiencies, their practical application in many Indian building projects remains limited. Therefore, the present study focuses on identifying process inefficiencies in conventional construction activities, analyzing the existing workflow through a Current State approach, and developing an improved Future State using lean-based advanced methods to achieve measurable savings in overall project time and execution cost.

4. METHODOLOGY

4.1 Research Design

The present study adopts a field-based analytical methodology to evaluate the effectiveness of Lean Construction implementation through Value Stream Mapping (VSM) for optimizing project time and cost in residential construction projects. The methodology was structured to compare the performance of conventional construction practices with proposed advanced construction alternatives under actual site conditions. The complete research process involved case study selection, field data collection, preparation of Current State and Future State maps, comparative time-cost analysis, and validation of measurable improvements.

4.2 Selection of Case Study Project

A residential building construction project was selected for the practical implementation of the study. The selected project included multiple repetitive activities such as brickwork, plastering, concreting, painting, and reinforcement operations, which provided sufficient scope for observing conventional workflow inefficiencies and testing improved alternatives. The project was chosen because it offered accessibility for repeated site visits, availability of execution records, and feasibility for comparing traditional labor-intensive methods with modern mechanized approaches.

4.3 Data Collection

The data required for the study was collected through direct field observation, interaction with site engineers and supervisors, and examination of available project documents. Repeated site visits were conducted to understand the actual sequence of construction activities and to record the time consumed, labor deployed, material utilized, and equipment involved in each operation. Particular attention was given to identifying labor idle periods, unnecessary movement of materials, waiting time between dependent tasks, and delays caused by conventional manual execution. In addition to primary field data, secondary information was gathered from published literature and technical references to identify suitable advanced alternatives for workflow improvement.

4.4 Preparation of Current State Map

After data collection, the existing construction process was analyzed in detail to prepare the Current State Map. This map represented the actual workflow followed at the construction site under conventional methods. Each activity was examined with respect to productive work duration and non-productive delays occurring during execution. The Current State analysis helped in identifying non-value-added activities such as waiting, repeated handling, labor idle time, excess transportation, and process interruptions, which were directly responsible for increased project duration and additional cost burden.

The total current execution time for each activity was determined by considering both productive and non-productive durations and was calculated using the following expression:

$$T_c = \sum(T_{va} + T_{nva})$$

Where T_c represents the total current execution time, T_{va} represents value-added time, and T_{nva} represents non-value-added time.

4.5 Identification of Improvement Measures

Based on the inefficiencies identified in the Current State analysis, suitable lean improvement measures were proposed for each selected construction activity. The focus was placed on reducing labor dependency, minimizing waiting periods, improving material flow, and shortening execution cycles. For this purpose, conventional red brick masonry was replaced conceptually with AAC block masonry, manual plastering with automatic plastering machines, site concrete mixing with Ready-Mix Concrete, and other manual operations with mechanized alternatives wherever feasible. These proposed changes formed the basis of the Future State workflow.

4.6 Preparation of Future State Map

The Future State Map was developed by redesigning the existing workflow after eliminating or minimizing the identified non-value-added activities. The improved process sequence was prepared by incorporating advanced construction methods and better resource coordination. The objective of the Future State Map was to establish a smoother and faster execution path with reduced interruptions, lower manpower requirement, and improved productivity.

The total future execution time after implementing the proposed improvements was estimated using:

$$T_f = \sum T_{improved}$$

Where T_f represents the total future execution time and $T_{improved}$ represents the time required under the improved construction method.

The percentage reduction in project time was then calculated by:

$$\%TimeReduction = \frac{T_c - T_f}{T_c} \times 100$$

4.7 Cost Analysis

A comparative cost analysis was carried out for both the conventional and improved construction methods. The total

execution cost of each activity was calculated by considering labor charges, material requirement, equipment usage, and associated operational expenses. After estimating the improved method cost, the percentage reduction in cost was obtained by using the following formula:

$$\%CostReduction = \frac{C_c - C_f}{C_c} \times 100$$

Where C_c is the current execution cost and C_f is the future execution cost after improvement.

The direct monetary saving achieved through implementation of advanced methods was calculated as:

$$\text{Cost Saved} = C_c - C_f$$

4.8 Comparative Performance Evaluation

After determining both time and cost values for the Current State and Future State, a comparative performance evaluation was conducted. The improvements were assessed on the basis of total project duration reduction, total cost saving, labor productivity enhancement, and minimization of material wastage. The observed differences between conventional practice and lean-based improved practice were represented through tabular comparison and graphical analysis to provide a clear understanding of the measurable benefits achieved.

4.9 Validation of Results

The final results obtained from the comparative analysis were validated by examining the cumulative impact of all selected activity improvements on the overall project schedule and expenditure. This step ensured that the proposed Future State model was not merely theoretical but practically feasible for implementation in similar residential construction projects. The validation confirmed that Value Stream Mapping can serve as an effective engineering tool for identifying inefficiencies and guiding time-cost optimization under actual site conditions.

5.RESULTS AND DISCUSSION

5.1 Comparative Analysis of Brickwork Activity

Brickwork was one of the major labor-intensive activities considered in the study. Under the conventional method, red bricks were used, which involved higher material quantity, greater mortar consumption, and longer laying time due to smaller unit size and repeated alignment adjustments. In the proposed Future State, AAC block masonry was considered as the improved alternative because of its larger size, lighter weight, lower mortar requirement, and faster installation rate.

The observed cost under the conventional brickwork method was ₹61,22,080, whereas the estimated cost under AAC block masonry was ₹51,54,876. Thus, a direct saving of ₹9,67,204 was achieved in this activity. The percentage reduction in cost was calculated as:

$$\begin{aligned} \% \text{CostReduction} &= \frac{61,22,080 - 51,54,876}{61,22,080} \times 100 \\ &= 15.79\% \end{aligned}$$

Similarly, the total time required for completion of brickwork under the conventional method was 224 days, while the improved AAC block method required only 194 days. Therefore, the total time saved was 30 days. The percentage reduction in execution time was obtained as:

$$\% \text{TimeReduction} = \frac{224 - 194}{224} \times 100 = 13.39\%$$

This reduction clearly indicates that AAC block implementation not only reduces the quantity of masonry units and mortar consumption but also accelerates wall construction due to faster placement and lower labor fatigue.

5.2 Comparative Analysis of Plastering Activity

Plastering is another highly labor-dependent finishing activity where manual workmanship often causes variation in surface quality, excess material use, and longer execution periods. In the Current State, plastering was assumed to be carried out manually, whereas in the Future State an automatic plastering machine was considered for improving consistency and speed of work.

The total plastering cost under the conventional manual method was recorded as ₹2,63,875, while the estimated cost using the automatic plastering machine was ₹2,50,681. Hence, the direct cost saving obtained was ₹13,194. The percentage cost reduction was calculated as:

$$\% \text{CostReduction} = \frac{2,63,875 - 2,50,681}{2,63,875} \times 100 = 5\%$$

In terms of execution duration, manual plastering required 174 days, whereas mechanized plastering reduced the duration to 120 days. Therefore, a total of 54 days was saved.

$$\% \text{TimeReduction} = \frac{174 - 120}{174} \times 100 = 31.03\%$$

The results indicate that the automatic plastering machine has a stronger impact on time reduction than on direct cost reduction. This is because mechanization primarily reduces labor dependency and increases area coverage per day, thereby shortening the activity cycle considerably.

5.3 Comparative Analysis of Painting Activity

Painting is a critical finishing activity that directly impacts the aesthetics and durability of a building. Under the conventional method, painting was performed manually using brush and roller, which is time-consuming and results in uneven surface coverage. In the proposed Future State, a spray gun was adopted as the improved method, offering faster application, uniform finish, and reduced labor requirement. The comparative cost and time data for painting activity as extracted from the project records are presented in the table below.

The observed cost under the conventional painting method

Sr. No.	Description	Current Method (Brush & Roller)	Advance Method (Spray Gun)
1	Internal Painting (sqft)	1,44,371	1,44,371
2	External Painting (sqft)	1,20,515	1,20,515
3	Oil Painting (sqft)	18,050	18,050
4	Total Cost (Rs.)	29,62,119	27,81,648
5	Total Time (days)	80	45

using brush and roller was ₹29,62,119, whereas the cost under the advance method using spray gun was estimated at ₹27,81,648. The direct cost saving achieved in this activity was

₹1,80,471. The percentage cost reduction was calculated as:

$$\% \text{Cost Reduction} = (\text{C.M.COST} - \text{A.M.COST}) / \text{C.M.COST} \times 100 = (2962119 - 2781648) / 2962119 \times 100 = 6.1\%$$

In terms of execution time, the conventional brush and roller method required 80 days for completion of the total painting work of 2,78,560 sqft, whereas the spray gun method reduced the total time to 45 days only. Therefore, a time saving of 35 days was achieved. The percentage time reduction was:

$$\% \text{Time Reduction} = (\text{C.M.TIME} - \text{A.M.TIME}) / \text{C.M.TIME} \times 100 = (80 - 45) / 80 \times 100 = 43.75\%$$

These results demonstrate that the spray gun technique is significantly more effective in reducing execution time than cost alone, as it mechanizes the application process, improves daily area coverage, and reduces manual effort substantially.

5.4 Comparative Analysis of Concrete Activity

Concrete work is one of the most volume-intensive operations in building construction. Under the conventional approach, concrete was produced on-site using a mixer-batcher, which involves higher labor requirement, potential quality inconsistency, and longer setup time. In the proposed Future State, Ready-Mix Concrete (RMC) was considered as the improved alternative, offering pre-controlled mix quality, faster delivery, and reduced on-site congestion. The comparative cost and time data for concrete activity are presented below.

The total project cost for concrete under the conventional on-site mixing method was ₹2,00,45,913, while the RMC-based approach resulted in a total cost of ₹1,96,16,650. The direct cost saving achieved was ₹4,29,263. The percentage cost reduction

Sr. No.	Description	Current Method (Mixer-Batcher)	Advance Method (RMC)
1	Total Work (CUM)	3,247	3,247
2	M30 Concrete (Rs.)	10,75,039	17,80,000
3	M25 Concrete (Rs.)	26,14,774	43,77,600
4	M20 Concrete (Rs.)	48,21,208	81,92,600
5	M10 Floor PCC (Rs.)	2,12,576	3,94,800
6	M10 Footing PCC (Rs.)	2,35,191	4,36,800
7	Total Labour (Rs.)	1,10,87,125	44,34,850
8	Total Cost (Rs.)	2,00,45,913	1,96,16,650
9	Total Time (days)	82	60

was:

$$\text{Cost Reduction} = (\text{C.M.COST} - \text{A.M.COST}) / \text{C.M.COST} \times 100 = (20045913 - 19616650) / 20045913 \times 100 = 2.14\%$$

Although the material cost of RMC grades is higher compared to on-site mixed concrete, the significant reduction in labour cost — from ₹1,10,87,125 to ₹44,34,850 — results in an overall net saving. In terms of time, the total execution duration was reduced from 82 days to 60 days, saving 22 days. The percentage time reduction was:

$$\% \text{Time Reduction} = (\text{C.M.TIME} - \text{A.M.TIME}) / \text{C.M.TIME} \times 100 = (82 - 60) / 82 \times 100 = 26.82\%$$

The use of RMC eliminates on-site batching operations, reduces equipment setup time, and allows faster continuous pouring, which collectively contribute to notable time savings in the concreting schedule.

5.5 Comparative Analysis of Steel Work Activity

Steelwork involves the tying and placing of reinforcement bars prior to concrete casting operations. In the conventional method, steel joints were tied manually by hand, which is a slow and labor-intensive process. Under the proposed Future State, a binding machine was introduced as the advanced alternative, which significantly speeds up the joint-tying operation and reduces fatigue-related downtime. The comparative cost and time analysis for steelwork activity is presented below.

Sr. No.	Description	Current Method (By Hand)	Advance Method (Binding Machine)
1	Total Work (kg)	3,050	3,050
2	Time per Joint (seconds)	12	4
3	Joints per Day	1,900	6,500
4	Total Time (days)	51	23
5	Cost for Steelwork (Rs./kg)	50.15	40.00
6	Total Cost (Rs.)	1,52,451.5	1,22,000

The conventional hand-tying method resulted in a total cost of ₹1,52,451.5, while the binding machine method brought it down to ₹1,22,000, saving ₹30,451.5. The percentage cost reduction was:

$$\% \text{Cost Reduction} = (\text{A.M.COST} - \text{C.M.COST}) / \text{A.M.COST} \times 100 = (152451.5 - 122000) / 152451.5 \times 100 = 19.97\%$$

The time for completing steelwork was reduced from 51 days under the manual method to 23 days using the binding machine. The total time saved was 28 days. The percentage time reduction was:

$$\% \text{Time Reduction} = (\text{C.M.TIME} - \text{A.M.TIME}) / \text{C.M.TIME} \times 100 = (51 - 23) / 51 \times 100 = 54.9\%$$

The binding machine dramatically improves joint tying speed from 12 seconds per joint to just 4 seconds, enabling 6,500 joints per day versus only 1,900 by hand. This makes steelwork one of the activities with the highest time reduction percentage in the study, highlighting the strong productivity impact of mechanized tools.

5.6 Comparative Analysis of Slab Casting Activity

Slab casting is a critical structural activity that directly impacts the construction schedule and material consumption. Under the conventional approach, solid slabs were cast by hand, requiring larger concrete volumes, extended formwork durations, and greater material usage. In the Future State, void slab technology was proposed as the advanced alternative. Void slabs incorporate plastic void formers, which reduce the concrete volume required while maintaining structural performance, and allow faster placement. The comparative cost and time data for slab casting are presented in the table below.

The total slab casting cost under the conventional method was ₹45,61,009.65, while the void slab method reduced this to ₹34,20,757. A significant saving of ₹11,40,252.65 was achieved in this activity. The percentage cost reduction was:

Sr. No.	Description	Current Method (By Hand / Solid)	Advance Method (Void Slab)
1	Total Work (Cum)	2,836	2,836
2	Cost for Steelwork (Rs./kg)	50.15	50.15
3	Total Cost (Rs.)	45,61,009.65	34,20,757
4	Total Time (days)	203	165

$$\% \text{Cost Reduction} = (\text{A.M.COST} - \text{C.M.COST}) / \text{A.M.COST} \times 100 = (4561009.65 - 3420757) / 4561009.65 \times 100 = 25\%$$

In terms of execution time, the conventional slab method required 203 days, while the void slab approach reduced the duration to 165 days. The total time saved was 38 days. The percentage time reduction was:

$$\% \text{Time Reduction} = (\text{C.M.TIME} - \text{A.M.TIME}) / \text{C.M.TIME} \times 100 = (203 - 165) / 203 \times 100 = 18.71\%$$

The void slab technology achieves both cost and time savings by reducing the total concrete volume required per slab unit. This results in faster casting, less formwork load, and lower material expenditure, making it one of the highest cost-saving activities identified in this study at 25%.

5.7 Overall Project Time and Cost Comparison

After evaluating the selected construction activities, the cumulative impact of the proposed lean-based improvements was studied at the overall project level. The total project duration under conventional construction practice was found to be 896 days. After incorporating advanced alternatives and eliminating major non-value-added delays through the Future State workflow, the estimated total project duration reduced to 677 days. Hence, the total time saving achieved was 219 days.

$$\% \text{Time Reduction} = (896 - 677) / 896 \times 100 = 24.4\%$$

Similarly, the total project cost under the Current State was ₹4,77,38,238, whereas the projected Future State cost was ₹4,47,75,724. This resulted in a total monetary saving of ₹29,62,514.

$$\% \text{Cost Reduction} = (4,77,38,238 - 4,47,75,724) / 4,77,38,238 \times 100 = 6.2\%$$

5.8 Discussion on Lean Construction Performance

The comparative findings clearly show that the Future State workflow outperformed the Current State workflow in both schedule efficiency and cost effectiveness. The primary reason behind this improvement was the reduction of non-value-added

material handling, slower manual execution, and interruptions between dependent tasks.

Value Stream Mapping played a crucial role in identifying these hidden inefficiencies because it enabled the process to be visualized not only in terms of productive activity duration but also in terms of avoidable workflow losses. Once these losses were identified, the use of advanced alternatives such as AAC blocks and automatic plastering machines created a smoother operational sequence with lower manpower burden and improved continuity of work.

It was also observed that the percentage improvement in project time was higher than the percentage improvement in direct cost. This suggests that mechanized and lean-based construction practices generate their greatest advantage in terms of workflow acceleration and productivity enhancement. Although certain advanced methods may involve moderate initial investment, the reduction in labor duration, site congestion, and repeated delays ultimately contributes to long-term economic efficiency.

Therefore, the obtained results confirm that the application of Lean Construction through Value Stream Mapping is not merely a theoretical management exercise but a practical engineering approach capable of delivering measurable project performance gains in residential building construction.

6. CONCLUSION

The present study examined the application of Lean Construction through Value Stream Mapping to reduce the overall time and cost involved in residential building construction. Conventional construction methods often lead to higher labor dependency, material wastage, process delays, and poor workflow coordination, which increase both project duration and expenditure. By preparing the Current State Map and Future State Map, the inefficiencies in the existing construction process were identified and improved methods were proposed.

The comparative analysis of brickwork and plastering activities showed significant measurable improvement after introducing advanced construction alternatives. In brickwork, the use of AAC block masonry reduced the cost from ₹61,22,080 to ₹51,54,876 and reduced the execution time from 224 days to 194 days. Similarly, in plastering work, the automatic plastering machine reduced the cost from ₹2,63,875 to ₹2,50,681 and reduced the execution duration from 174 days to 120 days. These results indicate that mechanized and improved construction methods help in minimizing labor effort and increasing productivity.

The overall project comparison also confirmed the effectiveness of Lean Construction implementation. The total project duration was reduced from 896 days to 677 days, resulting in a saving of 219 days or 24.4%. Likewise, the total project cost was reduced from ₹4,77,38,238 to ₹4,47,75,724, achieving a direct saving of ₹29,62,514 or 6.2%.

Thus, it can be concluded that Value Stream Mapping is an effective tool for identifying non-value-added activities and improving workflow continuity in construction projects. The study proves that by adopting advanced construction methods and proper lean planning, residential projects can be completed in a more economical and time-efficient manner.

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