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Research Article/ Review Article/ Perspective Article (Remove where relevant)

A Study on the Improvement in the Performance of Construction Projects Using Lean Principles

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Abstract

Over the past four decades, the productivity of construction projects has been declining; however, implementing Lean techniques is an effective method for enhancing this scenario. Lean methodology stems from applying a new form of manufacturing control to production. Essential characteristics of lean techniques include a clear set of targets for the construction process, maximizing performance at the project level, concurrent design, and the application of project management throughout the project lifecycle from design to execution. A significant number of construction professionals and specialists have successfully optimized development initiatives using lean construction tools to reduce variability, minimize waste, and eliminate time overruns. This research aims to study the improvement in construction project performance using lean principles. The work is divided into three phases. In the first phase, a questionnaire survey was conducted on Visual Management techniques to enhance performance in construction projects, with nearly 100 responses collected from the industrial professionals. In the second phase, the impact of value stream mapping on a real-time project case study was evaluated, along with its performance in terms of time and cost reduction. In the third phase, the impact of value stream mapping on the project's total cash flow is evaluated and compared by plotting the total cash flow curve using Vico software. As a result, labour costs were reduced by 33%, and the project's duration was cut by 17%, which also improved the overall cash flow by 14% and increased the cash flow from negative 67% to negative 44%

Keywords: Lean Construction, Cost and Time Overrun, Value Stream Mapping, Cash Flow

Highlights

- Lean construction significantly enhances the construction cost and duration
- The stream mapping improves the overall cash flow of the project
- The case study in Kabul, Afghanistan, indicates that lean construction enhances the performance of construction projects.

Introduction

The Toyota Production System is where Lean Manufacturing began, and today it has become a comprehensive project management strategy aimed at improving operations and eliminating waste throughout all sectors. Its applications and effectiveness are well documented in contemporary publications. For example, (Lima, 2023) Defined key considerations for effective Lean project management in the industrial sectors. In construction, (Badran, 2024) Showed that the use of Lean Project Management improved cost effectiveness and enhanced customer satisfaction. Also (Rodrigues, 2025) Put forward a theory-based model on the application of Lean Thinking in IT project management and advocated for its use on the grounds of effective optimisation of processes and resources. These recent studies highlight the shift in focus towards the practicality of Lean concepts in other branches of project management.

An alternative to conventional approaches to management has been developed for managing construction projects that is more accurate and effective. This is especially true for larger and quicker construction projects. There are several key distinctions between traditional construction management and the lean construction management approach that have been discussed in this study. Lean Construction combines operational research and practical development in design and construction with the application of lean manufacturing principles and practices throughout the entire process. Unlike manufacturing, design is a project-based process, whereas Lean construction deals with the coordinated and comprehensive pursuit of simultaneous and continuous improvement in all aspects of the built and natural environment, including design, construction, activation, maintenance, restoration and recycling. (Abdelhamid, 2007.2008). The goal of this approach is to manage and improve the construction process by considering customer needs while minimum cost and maximum value. (Koskela, 2002).The focus is on minimising cost to enhance value and reduce waste while delivering to the customer's requirements to meet the objective of construction goals. This is in alignment with the goals of lean construction, which strives for better productivity by eliminating activities that do not add value during the life cycle of a project. (Al-Mhdawi, 2024).

The primary objective of this research is to adapt lean techniques to enhance the construction project in terms of improvement and performance. Specifically, it focuses on applying visual management and value stream mapping in real-time projects. The specific objectives of the study are: a) To find the effect of visual management LC techniques on improving the performance of construction projects. b) To determine the impact of value stream mapping on real-time projects and evaluate its performance regarding time and cost. c) To assess and compare the impact of value stream mapping on the total cash flow of the project.

The research question aims to explore the economic implications of implementing Lean Construction methodologies in innovative construction projects, concentrating on three key aspects. First, it examines how value stream mapping affects real-time projects. This lean management technique visualises the flow of materials and information, aiding in the identification of waste, bottlenecks, and inefficiencies with project management. Project managers can streamline operations, decrease lead times, and enhance overall project efficiency. Second, it assesses the influence of visual management lean techniques on construction project performance. These techniques strive to improve communication, boost transparency, and facilitate decision-making through tools like Kanban boards, colour-coded systems, performance dashboards, and 5S workplace organisation. Lastly, it investigates how value stream

mapping impacts a project's total cash flow. By identifying and eliminating non-value-adding activities, value stream mapping can enhance a project's cash flow through cost reduction, inventory optimisation, and improved cash flow. It also helps shorten lead times, potentially accelerate revenue recognition, optimise resource utilisation, achieve cost savings, and ultimately improve overall project efficiency while reducing financing requirements. These tools are likely to enhance project performance by promoting team collaboration, minimising errors and rework, increasing productivity, optimising resource allocation, and enabling quicker problem resolution. Reviewing literature, coupled with empirical research, will answer these questions and measure the effects and impacts within different project contexts.

Literature Review

Since the 1950s, the principles of Lean Manufacturing (Toyota Production System) have been developed and successfully implemented by Toyota Motor Corporation. Toyota's production system had two pillar concepts: just-in-time flow (JIT) and automation (intelligent automation). The term "lean" was coined by a groundwork team studying international automobile production to reflect the waste-reducing nature of Toyota's production system and to contrast it with the artisanal types of production. It was done, born out of a desire to cut back machine set-up times and influenced by TQM, an easy set of goals for the look of production systems was developed. This includes identifying value and delivering it to customers, organising the production as an endless stream and perfecting the products and building a trusted flow through information sharing and decision-making. Lean manufacturing develops and manufactures goals and techniques that differ from mass or artisanal kinds of production, optimising the performance of production systems on a full scale to satisfy unique customer needs. Known by various names within the early 1990s, the new manufacturing philosophy and a replacement production system, this philosophy is the new mainstream approach.

Lean Principles and Construction Performance:

Scrutinise the practices of small- and medium-sized construction enterprises through the lens of Toyota Production System (TPS) lean precepts, surfacing inefficiency arising from narrow, episodic targets and segregated initiatives. The authors advance a TPS-centred blueprint designed to harmonise activities, nurture cross-company cooperation, and embed sustainability within the SME. (J. A. Dauda, 2024).present an editorial distilling the evolution of lean practices, underscoring integrated project delivery (IPD), joint-venture-style collaborative planning, and emerging technologies—including BIM and AI—as decisive drivers of enhanced budget, schedule, and quality deliveries (M. Najafi, 2024). Digital Tools and Lifecycle Integration present the "Total BIM" framework, positioning BIM as the singular repository that spans the entire building lifecycle, fortifying trust, operational continuity, and contractual clarity within construction workflows while advancing the principle of digital construction projects in step with lean objectives. (O. Disney, 2024).

Identifying a shortfall in maturity models focuses on synthesising BIM, Integrated Project Delivery (IPD), and lean construction; their investigative findings supply the intellectual basis for the development of instruments that diagnose and elevate performance across these three interconnected areas. (S. Rashidian, 2024). Empirically corroborate a triadic "3D integration" success framework, which consists of value, speed, and impact—thereby furnishing a robust, mixed-method instrument for evaluating project

performance, retains relevance from individual assets to entire programmes. (A. N. Ghanbaripour, 2024).

This systematic review on "Lean Green" in manufacturing SMEs found that a major challenge is the lack of comprehensive metrics. 5S is a common tool, but existing frameworks are often sector-specific and neglect social sustainability aspects. The paper provides a knowledge summary and a model for lean green implementation in SMEs (Siegel, 2019).

Defining Key Concepts

The term Lean con was introduced by the International Lean Construction Group during its inaugural meeting in 1997. Greg Howell and Glenn Ballard, founders of the Lean Construction Institute, state that construction in Lean Construction applies to the whole company rather than just the part where building occurs. As a result, lean construction targets all stakeholders: builders, architects, designers, engineers, suppliers, and end users. In any case, the term lean manufacturing extends beyond its usual definition. Lean strategies are used by manufacturing and service companies to eliminate waste, increase productivity, and save time and value by creating value in their products. Identifying and eliminating waste is essential to the lean construction philosophy, which helps meet customer expectations. (Howell, 1997).

Visual Management

Visual management (VM) is an essential and integral management approach that sets advanced sensory information systems within the Toyota Production System (TPS) in places where employees can access the information to self-manage and self-control. (Ohno, 1988)

Pull System:

The pull system is one of the foundational ideas of Lean philosophy at a strategic level. Pull systems appreciate the necessity of providing products during the precise periods the customers require them. Ordinarily, design processes compel customers to go through extensive, long-term development processes that are riddled with risks and uncertainties. The principle of traction is the skill of promptly flushing out and adjusting to the customer's needs concerning their business, and providing more reliable delivery. (Ohno, 1988)

Just In Time:

Just-in-Time is one of the eff tools in lean construction, to eliminate non-value-added activities and reduce the variability of processes. The just-in-time philosophy highlights the concept of inventories, which do not add value to customers, either internal or external. To avoid waste, these inventories should be minimised, and thus, materials and equipment should only be accessible when necessary. (Ohno, 1988).JIT strives to align supply with demand all the way from the end customer to the sub-supplier; the closer the match, the more efficient the process. This balance comparatively, the need for advantageous first grade, matched with the elimination of scraps.

Kanban Board/Card:

Kanban-based supply management is an effective way to ensure the minimum required materials are met according to site requirements by tracking workspaces. It suggests another solution to the storage problem so that each workspace has its own storage space. A mobile storage block with wheels for easy transport is also available. This solution allows you to physically follow your production flow and effectively reduce many sources of waste, such as shifts, waiting times, and inventory levels. (Ohno, 1988).

Last Planner System "LPS":

The last Planner System, "LPS", is a significant tool for lean construction. A collaborative planning tool that facilitates communication and participation by taking into account the constraints of each stakeholder. The process starts with a master plan. The most important stakeholders, the construction process, and achievable milestones are loosely defined in the planning phase, whereas the goal is to identify possible limitations associated with each task. At the end of this phase, the plan not only becomes more realistic but also includes the order and duration of the side missions as well as all related tasks (Ohno, 1988).

Vico Control Software

The Vico control software is a comprehensive scheduling tool which helps the construction project track the project and budget and create effective schedules with the Schedule Planner module, used with 3D/BIM models, unique location-based segmentation, convenient scheduling to analyse and visualise, especially with project colleagues. (Pučko, 2017).

Existing Theories and Frameworks

Toyota Production System (TPS): The lean philosophy originates from the TPS framework, which aims to eliminate waste, optimise flow, and continually improve processes. In the construction field, the TPS also includes practices like Just-in-Time and the Last Planner System. Total BIM Framework: As stated by Devine et al. (2024), the Total BIM framework focuses on the lifecycle and lean operations, describing gaps in coordination, gaps in lean BIM-based re-work, which is remodelled work. Lean Construction Success Framework: (A. N. Ghanbaripour, 2024).proposed a triadic model focusing on value, speed, and impact as lean adoption's main value drivers. The model works best in combination with the KPIs of SMEs. Integrated Project Delivery (IPD): In the context of SMEs, trust is a concern and is usually low, so the trust that is granted as a result of IPD's enhancement of fragmented planning and contractually driven alignment is extremely valuable. Critical Analysis: While the main focus of the frameworks is on efficiency and collaboration, it is evident that there is a lack of theory in the SME domain. This is particularly the case in Vico-integrated lean construction, where the digital tools are minimal and the resource constraints are maximum. No framework combines Vico and lean construction for SMEs.

Knowledge Gaps and Research Opportunities

The literature review concludes that implementing Lean Construction in the construction industry significantly improves the overall performance of construction tasks. Construction tasks are highly effective in improving production by eliminating non-value-added activities, wasting time, resources,

manpower, and materials, and developing the value of tasks in construction projects. However, this observation is made to determine if the common coin matches the task drift development cost, but not as a form of waste planning for waiting time reduction. Researchers are also trying to understand the impact and importance of the VM and its effects on the production tasks to improve overall performance. Furthermore, this observation identifies the most important limitation to the implementation of lean construction concepts within manufacturing companies.

Proposed Conceptual Model

This model demonstrates the conceptual model and relationship between the independent variables input (visual management and value stream mapping implementation), moderator intervening variables (use of software tools SPSS for analysis, Vico control for visualisation) and dependent variables (improved project performances), and it highlights how lean principles and techniques interact with project cost efficiency.

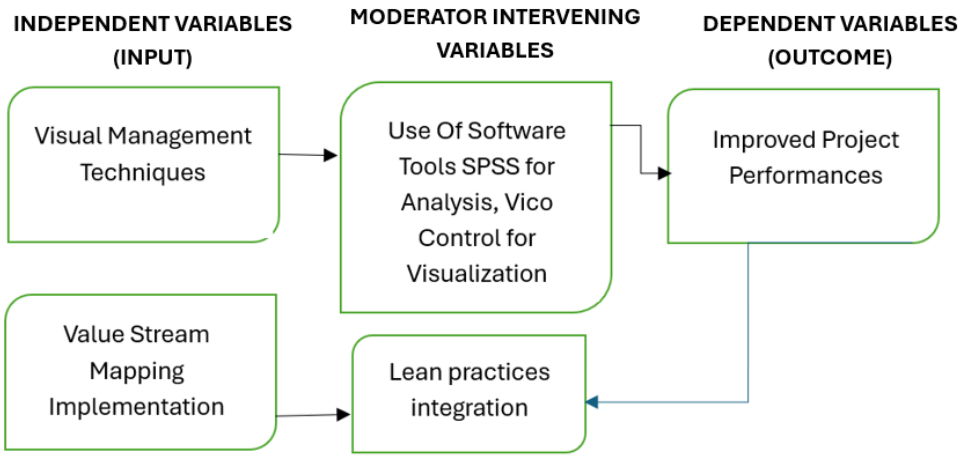

Figure 1. Proposed Conceptual Model

Methodology

The mixed research methods employed for the present study include case studies and a questionnaire survey. A questionnaire survey was conducted on Visual Management techniques in improving the performance of the construction projects. The questionnaire was circulated to civil engineers, architects, site managers, project managers, and full-time executives, and nearly 100 questionnaires were distributed to respondents. The 83 responses received were analysed using SPSS software to determine the reliability of the data. This research is based on a theory of Lean Construction, which seeks to optimise value and improve efficiency at every stage of the project, alongside eliminating waste. VSM, which is a core tool of Lean, is used to analyse current processes to investigate inefficiencies and create strategies for improvement. These concepts inform the reasoning framework to aid both the analysis, design and result analysis of the study. The impact of value stream mapping on the real-time project is determined, and its performance in terms of time and cost reduction is evaluated. The case study considered is a bunker-building project located in Kabul, Afghanistan. It is a military building consisting of a G+2 story. The cost of the building is 17,669,324.97 rupees. The total duration of the project is 12 months. The other data of the project, viz., bill of quantities (BOQ), work plan, etc., is collected from the required contracting company. The project was planned conventionally without considering the concepts of Lean. To

reduce all kinds of waste in the project, a plan was developed using the Vico Control software to visualise the value stream of the project. The impact of value stream mapping on the project's total cash flow is evaluated and compared by plotting the total cash flow curve using Vico software. The combination of a mixed approach assists in capturing all descriptors, making it useful for accomplishing the objectives concerning the assessment of the technical and managerial dimensions of lean implementation. Both methods are combined to construct an explanation, in this case, validating the rationale behind the approach adopted. The case study reveals the rich details of the context within which VSM could be applied to enhance project performance, particularly in terms of time and cost efficiency. In contrast, the questionnaire survey focuses on capturing the opinions of a sector's top experts to obtain broader quantitative evidence, patterns, opinions, and general use of Lean tools in different types of projects. These approaches help in creating a more specialised and technical analysis, as well as general principles useful in evaluating both the strategic and operational aspects of implementing Lean.

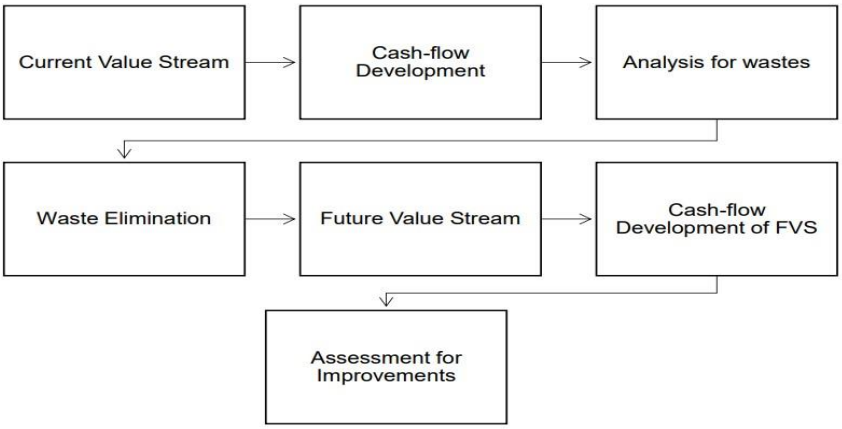

Figure 2. Process of Value Stream Mapping

Results- Key Findings

The value flow of construction projects has yielded positive results, reducing waste of waiting time and having a positive impact on the cash flow of all projects. Additionally, the development of the value stream in Vico Control software enables the visualisation of waiting time between tasks, which is typically not accessible with standard project planning using Excel. From the research, it was found that value stream mapping (VSM) has a positive effect on project duration, expected time wasted and total cash flow. The implementation of VSM in the construction project is very important to improve the project performance in the form of reducing the waste of waiting time, and project duration and improving the cash flow of the projects. The hypothesis that VM use in construction projects is associated with performance improvement is greater than the assumed value of performance improvement. Shows that VM, if used correctly, can increase the performance of construction projects. Construction site, increase safety on site, standardise the construction site, prototype the activity and transfer information to the workforce in a simple way. However, due to a large number of missing responses, the results are reliable enough to be used in future research. Therefore, there is a need for further research to find more reliable results related to the implementation of VM in construction projects and its effects on project performance.

Table 1. Current Value Stream Waiting and Future Value

Task	Current value stream Length		Future value stream Length	
General	14 days	336 hours	14 days	336 hours
Sub-Structure	35	840	35	840
Super-Structure	56	1344	56	1344
Enclosure	46	1104	45	1080
Finishing Plastering Work	81	1944	79	1920
interior	43	1032	42	1008
Mechanical work	29	696	28	672
Electrical Work	32	768	31	744
Water services	30	720	28	696
Duration of the project	366 days		306days	

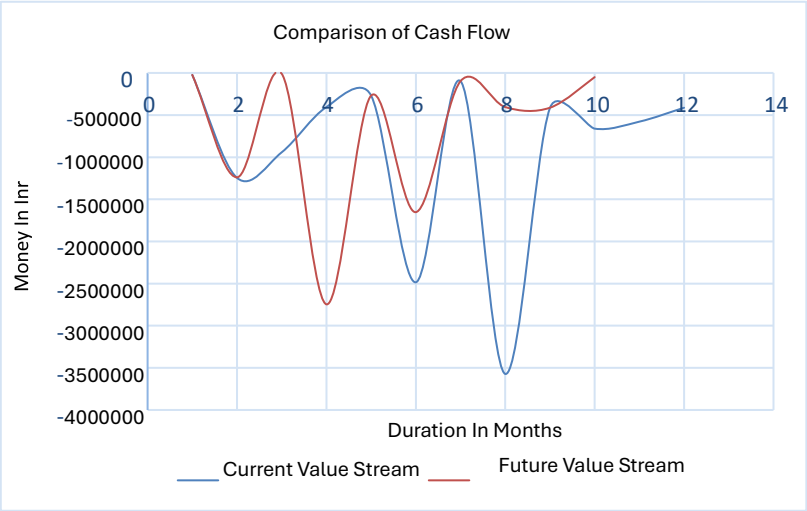

Figure 3.Future Value Stream Cash-Flow Pattern

Figure 4 indicates the total cash flow pattern of present value flow with a negative 67 per cent and future value flow with a negative 44 per cent. In addition, the value stream also had a positive effect on the project duration by reducing the total project duration from 12 months to 10 months.

Discussion

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correctly, can increase the performance of construction projects. Construction site, increase safety on site, standardise the construction site, prototype the activity and transfer information to the workforce in a simple way. However, due to a large number of missing responses, the results are reliable enough to be used in future research. Therefore, there is a need for further research to find more reliable results related to the implementation of VM in construction projects and its effects on project performance.

Conclusions

The primary objective of this research is to investigate the impact of lean construction ideas on the overall performance of a construction project, utilising various lean tools. A detailed study was carried out to confirm the objectives of the study. (1) To find the effect of visual management in improving the performance of construction projects. (2) to determine the impact of value stream mapping on the project in real-time and evaluate its performance in terms of waste reduction; (3) to determine the impact of value stream mapping on the total cash flow of the project. To achieve the above goals, a detailed literature review was conducted and presented in the second chapter, and a case study and a questionnaire were conducted in the third chapter to achieve the above goals. In the fourth and fifth chapters, the results, discussion and conclusion of the current research are presented. Research has been conducted to explore the impact of VSM on total project cost. 5.2 Conclusions 1. Visual management can affect the performance of construction projects by 81%, by reducing waste of time and resources, enhancing the transparency on the construction site, increasing the safety on-site, standardising the construction site, prototyping the activity, and communicating the information to the workforce in a simple way. 2. Due to the reliability test, the Cronbach alpha is more than 0.8, which indicates that the internal consistency of the data is at a high level and is highly acceptable. 3. The value for the regression model is exactly 0.667, which means the result of the data is reliable to be used in future research. 4. Reduced the waste of waiting time between tasks by 33%, which has ultimately reduced labour costs by 33%. 5. The removal of waste of waiting time and the arrangement of the tasks with an early start and early finish technique, the total duration of the project was reduced by 17%. - 76 - 6. Reducing the duration of the project also improved the cash flow of the entire project by 14% and increased the cash flow from negative 67% to negative 44%. 7. The research study showed that with the application of lean construction tools in construction projects, the performance of projects could be improved. 8. The study showed that VSM has a significant impact on the total cash flow of the projects if it is implemented properly for the development of the value stream of the construction projects.

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