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Research article

Reducing non-value added (NVA) activities through lean tools for the precast industry

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ABSTRACT

Lean management is a strategic approach that is used in construction industry, specifically aims at minimizing and ultimately eliminating non-value-adding activities, commonly referred to as waste, within construction projects. However, an increase in non-value added (NVA) activities within the precast industry has the potential to diminish both productivity and efficiency. The aim of this paper is to investigate the use of lean tools for minimizing NVA activities in the construction industry. A comprehensive literature review, the study identified Unnecessary Inventory (UI), Waiting Time (WT), Overproduction (OP), and Unnecessary Movement (UM) as major NVA activities that affect the precast industry. A structured questionnaire was designed and conducted among precast industry professionals and lean experts to collect data. The data was then analyze using partial least square test–structural equation modelling, including reliability and validity tests, to ensure data quality. Results indicated that the precast industry professionals widely utilized Just-in-time (JIT), Continuous Improvement (CI), and Total Quality Management (TQM) as lean tools to reduce NVA activities. A conceptual path model was developed to assess the impact of Lean tools on NVA activities. The results of the analysis reveal a strong positive relationship between Lean tools and NVA activities, with a β value of 0.654. The findings of this study can be used for improving the productivity of construction projects by focusing on how to minimize NVA activities using lean tools in precast industry.

1. Introduction

The construction industry plays a vital role in a nation's development and progress, providing essential needs such as housing and transportation. According to Demirkesen and Bayhan [1], the construction industry contributes 35% to net-value growth, which amounts to 7.4 trillion dollars in 2010 and 10.3 trillion dollars in 2020. As a significant industry, its success directly impacts the national economy. However, despite its size, the construction industry faces several challenges and poor performance. The construction industry is actively addressing these challenges by implementing new theories, methodologies and technological aspects.

Lean construction (LC) has been emerged as an effective management philosophy with the objective of waste reduction, controlling

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variation within construction, maintaining flow, value generation, improving safety and quality of the construction products. Industrialized Building Systems (IBS) refer to construction methods and techniques that involve the use of prefabricated components and systematic assembly processes in building construction. These both approaches are highly regarded in the construction industry for reducing resource waste and maximizing available resources ([2]; Zakaria et al., 2018; [3]). These two approaches share similar goals for improving the building sector. Lean is a philosophy that originated from the Toyota Production System in Japan and was initially implemented in the automotive industry to increase production efficiency by reducing waste. Lean focuses on delivering what the customer values in a product [4]. Lu et al. (2020) noted that lean prioritizes maximizing productivity while using fewer resources to meet customer demands by minimizing non-value-added activities. Further, by reducing waste, minimizing pollution, and adding value to owners, the lean approach has demonstrated its effectiveness in providing environmental benefits [5]. LC is fostering better collaboration among stakeholders through commitment, respect, and accountability. Howell [6], as cited in Mossman [7], emphasized that lean construction emerges as a contemporary approach to production management applied specifically to the construction industry. This methodology revolves around maintaining a consistent set of priorities throughout the delivery process, with a key focus on maximizing customer efficiency at the project level. Noteworthy aspects of lean construction include the simultaneous consideration of product and process design, along with the strategic implementation of production management spanning the entire product lifecycle—from initial design to final delivery. There are a lot of popular definitions that articulated the concept of lean construction. Lean construction serves as a project delivery methodology with a concentrated emphasis on effective production management, proving particularly advantageous in scenarios characterized by dynamism, unpredictability, and fast projects. Over the recent years, there has been notable enhancement and widespread adoption of lean construction practices. Empirical findings by Babalola et al. [8] indicate that the foremost practitioners of lean construction are observed in countries such as the United States, United Kingdom, and Brazil such as last planner production management system and concept of target value [9]. Therefore, it becomes crucial to explore inventive and creative solutions aimed at enhancing management, minimizing non-value-added (NVA) elements, and improving overall construction processes and performance, as highlighted by Bajjou et al. [10].

IBS a building technology that can be implemented on-site or off-site in controlled environments (Alaloul et al., 2021; [11]), precast technique is a sub-domain of IBS technology. It is a broad system that incorporates or is similar to various construction technologies such as prefabrication, cast in-situ framework, composite system, precast, off-site construction (Kadir et al., 2006; Zakaria et al., 2018). Among the different construction techniques utilized by IBS in controlled environments, precast is one of the most common methods [12]. The primary advantages of IBS include reduced labour requirements, faster completion, less waste, improved safety, cleaner construction sites, greater efficiency, superior products, fewer on-site materials, reduced worker use on the job site, adaptable design, and resistance to weather changes ([13]; Zakaria et al., 2018; [11,14]). Ahmad et al. [12] suggested that incorporating the lean methodology is critical to enhancing the effectiveness of IBS's work processes, as shown by assessing key success factors, motivators, and obstacles.

The construction of precast structures using precast components presents an ideal opportunity for implementing lean construction practices. However, increasing construction complexity may hinder the adoption of lean practices in the precast industry [2]. To successfully integrate lean production into construction projects, Pasquire and Connolly [15] suggest increasing the volume of structures, components, sections, and parts manufactured in factories. The industrial sector has already experienced significant improvements through implementing lean production, and the precast industry, as a component of IBS, is well-suited to adopt lean practices. By recognizing these connections, the precast industry can be encouraged to adopt lean principles.

Activities that add no value to the process or the end product are referred to as non-value adding (NVA) activities and are viewed as waste. NVA activities are those that take up time, money, and resources but have no positive impact on the quality of the final product or process. NVA operations in the precast sector include, among others, idling, overproduction, transportation, reworking, and false production [16]. These actions may increase expenses, cause delays, and lead to inefficiencies in the production process, which would lower output and profit.

In order to increase productivity and decrease waste, such as rework, delays, and requests for information (RFIs), it is essential to recognize and get rid of vital NVA tasks. Additionally, it may lead to a decrease in the number of employees needed and a quicker turnaround time for projects [17]. The precast sector may optimize resource use, streamline manufacturing processes, and boost operational efficiency by concentrating on NVA activities.

The precast sector may find and remove NVA activities, decrease waste, and improve the entire value proposition of its goods and services by applying Lean methods like Value Stream Mapping, 5S, Kaizen, and Just-in-Time. Over time, various lean tools have been introduced to enhance lean implementation. While these tools have expanded the possibilities for stakeholders, they have to use it properly then it will enhance productivity, improve product quality, and boost customer happiness, which will benefit the precast industry. Overall, the following research gap were observed: (1) Implementation of Lean tools in precast industry (2) and how these tools have effect on each NVA activity has not been revealed. If these two knowledge gaps are not solved, industry may miss out on opportunities for improvement and innovation, potentially falling behind competitors in terms of quality, cost-effectiveness, and customer satisfaction. Thus, to fill these gaps, this study aims to investigate the implementation of Lean tools in the precast industry and their effects on each non-value-added (NVA) activity. This research shows how each lean tool influences each NVA activity. A comprehensive literature study used to pinpoint NVA activities, and structured questionnaires used to verify. A path model is created using Partial least square- Structural Equation modelling (PLS-SEM) software to illustrate and analyze the relationship between NVA activities and lean technologies. The path model is further validated for the influence of lean tools on each NVA activity and for validity and reliability to guarantee that data provided by the measurement tool is unbiased.

2. Literature review

2.1. Exploring lean in the construction sector

The construction industry is industry that combines production and service systems. This function is the baseline for adapting lean production theories to the construction industry ([18]; Bygballe et al., 2023). The available literature review on the Lean philosophy in the construction industry focuses on various aspects such as Barriers to implementing lean, critical success factors, limitation of accidents, sustainability aspects, and benefits of lean in construction [1,19–21].

Numerous studies have found that non-value-added work consumes 95% of the time, leaving just 5% for value-added activity, and lean methodology largely focuses on reducing non-value-added activity. Six lean construction tools—the final planner, improved visualisation, huddle meetings, first-run studies, the 5S, and fail safe for quality—are included in an evaluation instrument created by Ref. [18]. Cost reduction, improved subcontractor-manager communication, project completion ahead of time, and accident prevention are all consequences of this evaluation method. The advantages over the long run need more research. Lean has the potential to reduce the frequency of accidents in the construction sector. Table 1. Highlights the literature summary of different lean tools adopted.

2.2. Lean techniques to lower NVA

From earlier works, Koskela [29] claimed that there are 11 fundamental LC principles, which includes (1) Minimize non-value-adding activities (2)Enhance output value by systematically incorporating customer requirements (3) Minimize variability (4) Shorten the cycle time (5) Simplify by reducing the number of steps, parts, and linkages (6)Boost output flexibility (7) Enhance process transparency (8) Concentrate control on the entire process (9) Integrate continuous improvement into the process (10) Strive for a balanced approach between flow improvement and conversion improvement and (11) Utilize benchmarking as a tool for improvement.

Womack and Jones [30] further distill this into five principles: value stream, create value-generating flow, develop customer pull at the appropriate moment, and continue improving, aiming towards perfection. Moreover, it is established that these five principles pertain to the total flow process and its dependent activities in the construction industry [26,31,32]. They concluded these five principles would result in the least amount of work, resources, and materials while meeting demands.

Lim [31] states that properly using resources enables an organization to cut expenses, minimize waste, and complete projects on schedule. LC may be seen as an ongoing process optimization in the building industry that aims to increase customer value while decreasing resource waste. To achieve this, Lim [31] further identified the prime concepts, which comprise Total Quality Management (TQM), Just-in-time (JIT), Total Productive Maintenance (TPM), Employee Engagement, Continuous Improvement, Standardization, Concurrent Engineering (CE), value-based analysis, and Visual Management. Alinaitwe [33] further shortened and illustrated the core ideas of LC, such as JIT, TQM, Business Process Re-engineering (BPR), CE, Value Based Management (VBM), teamwork, and Last Planner System (LPS) [32].

2.3. Application of lean principles in the precast industry: A literature review

Alawag et al. [34] stated that IBS utilization has demonstrated benefits for increasing project value and productivity while lowering project costs and duration. Numerous IBS components are produced nearby, utilizing regional materials in reusable molds or assembly processes. As a result, transportation expenses and traffic congestion are significantly decreased. Additionally, it is possible to

Table 1
Literature summary of Lean tools.

Lean construction tools/ techniques	Brief description	Research/author(s)
5S	Represented by Seiri, Seiso, Seiton, Seiketsu, and Shitsuke (meaning Sort, Straighten, Shine, Standardize, and Sustain), this approach employs visual controls to efficiently eliminate waste from the worksite. It is more applicable to the storage of materials.	Caldera et al. [22] and Ahmed et al. [21]
JIT (Just-in-time)	It aims to decrease the production time flow and minimize the response time from suppliers to end-users. It embodies a mindset, approach, and control system to effectively manage and reduce waste in production. It is more effective in material management.	Bamana et al. [23] and Ahmed et al. [21]
Six sigma	It enhance quality by eliminating defects and minimizing variations in the construction process. Six Sigma boasts the capability to attain a process quality of 99.98%, ensuring virtually defect-free outcomes.	Li et al. [24]; Hussain et al. [25]
LPS (Last planner system)	The Last Planner System (LPS) is a collaborative planning approach that engages various trades in progressively detailed planning as the scheduled work approaches. In the realm of construction, LPS is recognized as a potent tool for managing workflow and curbing project variability effectively. LPS is more closely related to the planning and execution aspect of the project rather than quality or design.	Bashir et al. [26] and Ahmed et al. [21]
Kaizen	It embodies a Japanese production and process philosophy centered on continuous improvement. It is employed to enhance quality and efficiency by systematically minimizing waste in any workflow.	Omotayo et al. [27]; and Ahmed et al. [21]
TQM (Total Quality Management)	This method is designed to align with the organization's objectives and meet customer requirements by integrating all functions within the organization.	Singh and Rathi [28] and Ahmed et al. [21]

minimize construction waste and rapidly recycle off-cut trash. Engineers and contractors will be able to examine concepts crucial to ecological degradation by knowing the IBS capabilities in prioritizing the environment [35]. Improved IBS product quality will assist in achieving consistent insulation standards and decrease operating energy. IBS also has significant environmental advantages, such as resource-saving, waste minimization, and air pollution abatement [36–38].

Lean manufacturing techniques can help the precast sector to cut down on deficit spending and manpower [39]. Even though the initial building cost could be greater, it has the potential to lower long-term construction costs; prefabrication clearly offers an efficient solution to issues with on-site waste creation (Tam et al., 2007a; [38,40]). Luo et al. [41] utilized prefabrication using a lean method, arguing that lean might improve the product, supply chain effectiveness, and resource efficiency. According to Nahmens [42], applying the lean approach to a manufacturing process may cut labor costs from 9 to 6.5 people, a 12% decrease in equipment utilization space, and a 10% reduction in material waste. Defense and Cachadinha (2011) explored that the use of lean in precast sector reduces the space occupied by the inventory by 42%, thereby decreasing the 50% investment on the inventory, enhancing product flow, job satisfaction, and safety. Identifying the sources of waste, suitable steps might be taken to limit the likelihood of these non-value-added activities occurring in the precast industry [43]. Lean concepts are used in a precast component manufacturing facility to shorten processing time and boost output [44].

The insight that all production systems include two components, i.e., conversions and flows, is the basis of lean production philosophy [29]. Conversion activities are actions that add value to the processes or products. Contrarily, flow activities are NVAs that use up time, money, and resources without contributing to the quality or efficiency of the process or the result [5]. Al-Sudairi [45] stated that most building procedures included a significant amount of NVA work, which sometimes approached 50% of the overall workload, reducing productivity. Finding and eliminating the essential NVA operations might increase productivity since it would result in a decline of wastes such as rework, waiting time, and requests of information (RFIs), as well as fewer staff members and/or shorter project completion times [17]. NVA activities involved in the construction process are categorized as Unnecessary Inventory, waiting time, transporting, and overproduction, and investigated how adopting lean thinking may minimize them [16]. Table 2 summarizes the primary Lean tools used to reduce NVA activities within the construction industry.

According to prior research, JIT, CI, and TQM are the most often used lean tools for reducing NVA activities, and it is also clear that NVA activities like Unnecessary Inventory, Waiting Time, Overproduction, and Unnecessary Movement have a greater impact than other NVA activities. A relationship framework between Lean tools and NVA activities (Fig. 1) is developed. The NVA activities are the activities that consumes the resources and doesn't have any added value to the final product or process. Thereby it effects the productivity of the Precast industry. Lean tools are intend developed to ensure the smooth flow of the industry processes. By incorporating these lean tools in the precast industry leads to the efficient use of the resources thereby maximizing the productivity. Unnecessary Inventory results in extra maintenance, storage space, and human resources, which indirectly causes an increase in the industry's expenses. Waiting time causes major damage to the industry's productivity by delay in production. The unnecessary movement in the production process delays the production, wastage of resources, and even complicates the process. Overproduction is not an appreciable practice in the industry, and it is advisable to produce when it is needed rather than wasting resources, money, time, and storage space by overproducing the products. Although not all NVA activities have the same effects on the precast industry, these effects will ultimately cause the excess budget to inventory and the industry's productivity to decline. Lean tools provide the best way in order to cope with the problems caused by NVA activities. JIT enables one to complete or do the tasks at the appropriate time in the proper place, which decreases the maintenance cost and storage area. CI constantly monitors the process and functionality of new methodologies, equipment, or worker performance, and these decrease the flaws, improve productivity, and optimize budget utilization. Whereas TQM will take care of quality-related issues, it could be quality control or quality assurance. These tools balance the budget and productivity. Table 3 highlights the implementation in lean concept.

Table 2
Literature Summary of adoption of lean tools for various NVA activities.

Factors & Sources	Resource Wastage	Unnecessary Inventory	Waiting Time	Overproduction	Unnecessary Movement	Quality & Safety
Kong et al. [46]	-	–	–	–	JIT	–
Nitkakhtal et al., (2015) [16]	-	CF, CI	CF, CI	CF, CI	CF, CI	–
Wu et al. [5]	JIT, CI, CF, TQM	JIT, CI, CF, TQM	JIT, CI, CF, TQM	JIT, CI, CF, TQM	JIT, CI, CF, TQM	–
Singh & Kumar [47]	JIT, VSM, CI, TQM	JIT, VSM, CI, TQM	JIT, VSM, CI, TQM	JIT, VSM, CI, TQM	JIT, VSM, CI, TQM	–
Maharani et al., (2013) [32]	JIT, TQM, VSM	JIT, TQM, VSM	–	–	–	–
Kong et al. [48]	-	–	–	–	JIT	–
Wu & Feng [49]	-	JIT, CF, CI	JIT, CF, CI	JIT, CF, CI	JIT, CF, CI	–
Ahmad et al. [12]	-	JIT, CI, CF, Kanban	–	–	JIT, CI, CF, Kanban	–
Alinaitwe [33]	-	JIT, TQM, VSM	JIT, TQM, VSM	JIT, TQM, VSM	JIT, TQM, VSM	JIT, TQM, VSM
Bashir et al. [26]	CI	–	–	–	CI	–
Deffense & Cachdinha [50]	JIT, VSM, Kanban	JIT, VSM, Kanban	–	–	JIT, VSM, Kanban	JIT, VSM, Kanban

Note: Lean tools- JIT: Just-in-time; CI: Continuous Improvement; TQM: Total Quality Management; CF: Continuous Flow; VSM: Value Stream Mapping; Kanban: Kanban technique.

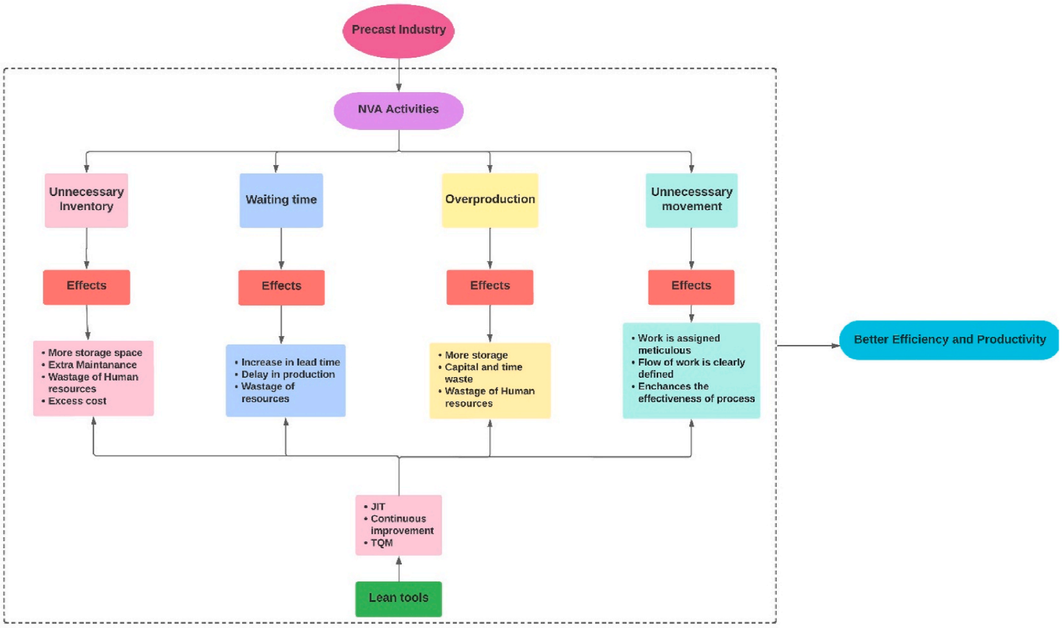

Fig. 1. Relationship framework between Lean tools and NVA activities.

Table 3
Literature Summary of implementation in lean concept.

References	Summary and major findings	Methodology used
Yuan, Z. et al [2]	This study develops the relationship between Lean construction capabilities and benefits of precast buildings under multivariable moderation. Constructtion complexity, construction management and construction policies are the major classification of these variables.	Reliability and validation; scale rational test; theoretical model rationality test
Wu, P., & Feng, Y. (2014).	This study focuses on the identification of NVA that leads to carbon production and implementing Lean tools like uninterpreted workflow, Employee Involvement JIT, TQC & CI are suggested to achieve the low-carbon production.	Case study approach
Wang, S. et al [39]	This study focuses on the process optimization of production line of precast components by value stream mapping.	Case study approach
Panigrahi, S. (2023)[51]	The research focuses on the optimizing the operational performances like cost, delivery, overtime, flexibility, setup, lead time and Business performances like profitability, sale, customer satisfaction by using Lean tools.	Questionnaire survey and Structural Equation Modelling
Demirkesen, S., & Bayhan, H. G. (2019)[1]	The study focusses on critical success factors (CSFs) in Lean implementation for conducting projects more effectively.	Questionnaire survey-factor analysis
Kong, L., (2018)[46]	The Just-in-Time (JIT) strategy for supply chain management of precast construction while considering time-dependent transportation time and on-site assembly time; focusing on the minimization of earliness/tardiness, resource waste and carbon dioxide emission penalties with time constraints.	Multi-objective optimization; a polynomial time algorithm for the optimal solution

Earlier studies have emphasized critical success factors (CSFs) in lean implementation to enhance project effectiveness. Key CSFs include management commitment, raising awareness of Lean principles, effective communication of Lean practices, and ensuring resource availability. Subsequent research has shifted towards sustainability and addressing climate change concerns, such as identifying non-value-added activities leading to carbon emissions and employing Lean tools to minimize carbon production. Additionally, there's a focus on resource management in construction, encompassing time, cost, raw materials, and human resources. Furthermore, studies have targeted process optimization in the precast industry through techniques like value stream mapping and implementing Lean tools such as small lot production and quick setups to enhance operational and business performances. Despite contributing to industry growth, these studies have certain limitations in scope.

Furthermore, it is increasingly acknowledged that optimizing managerial performance is paramount, especially within the realm of precast component manufacturing. The effectiveness of management directly influences crucial aspects such as the quality, timeliness of delivery, and overall production efficiency of precast components. A well-performing management team can streamline processes, allocate resources effectively, identify and rectify potential bottlenecks, and foster a culture of continuous improvement. Conversely, suboptimal managerial performance may lead to inefficiencies, delays, quality issues, and ultimately, hinder the overall competitiveness and success of the precast manufacturing operation. Therefore, investing in enhancing managerial capabilities and fostering a proactive management approach is essential for achieving sustained excellence in precast component production.

As a result, Accordingly, the following objectives were set for the study: (1) to examines the necessity to reduce NVA activities in the precast industry. (2) To evaluate the impact of Lean tools on major NVA activities independently.

2.4. PLS-SEM analysis in construction management

The Partial Least Squares (PLS) approach has gained popularity among researchers in recent years due to its use of variance-based relationships instead of covariance-based ones. PLS also enables the validation of alternative models for identifying the optimal connections between latent variables [52]. This study employs PLS-SEM to investigate the effects of Lean social and technical techniques on organizational performance. The analysis clearly indicates that these techniques positively impact organizational performance, and Lean Social Practices (LSP) facilitate establishing these relationships [53]. According to the results of the PLS-SEM analysis, two out of eight techniques exhibit the most significant effects on productivity [51]. The research suggests that while Lean Manufacturing practices can explain operational performance, they may not benefit all aspects of productivity.

A Barrier Analysis for Lean Implementation in Manufacturing Industries is also conducted using the PLS-SEM technique. The findings from this analysis reveal that the most significant obstacle to implementing Lean is a lack of knowledge [54]. Furthermore, the study examines the impact of Lean Six Sigma (LSS) on sustainability using PLS-SEM. The results demonstrate that LSS practices favorably impact 78% of environmental, 83% of economic, and 70% of social indicators [55]. The existing literature indicates that PLS-SEM can be effectively used to analyze the application of Lean tools in the precast industry.

PLS-SEM analyzes the structural model and path coefficients. In accordance with Ingle and Mahesh [56], Structural Equation Modeling (SEM) was developed as a tool for testing theories and concepts. PLS-SEM further extends this capability by evaluating comprehensive theories, intricate concepts, and complex models through the estimation of composite relationships among identified variables. PLS-SEM is well-suited for research in strategic management, providing researchers with the capability to evolve and fine-tune concepts and theories. Particularly beneficial for exploratory research purposes (Hair et al., 2014), PLS-SEM is employed in this study for several reasons. Notably, PLS relaxes distributional assumptions, making it suitable for smaller sample sizes. Moreover, PLS is recommended when the study's focus involves testing causal relationships and developing theories.

2.5. Conceptual model

A conceptual model (Fig. 2) is created to emphasize the significance of lean tools in mitigating the consequences of NVA activities in the precast industry. NVA activities are classified as Unnecessary Inventory (UI), Waiting Time (WT), Overproduction (OP), and Unnecessary Movement (UM), and by analyzing the outcomes of the application of Lean tools, JIT, Continuous Improvement, and Total Quality Management (TQM) are utilized to improve efficiency in the precast sector by reducing NVA operations. The lean tools are implementing to the precast industry and their impact on the NVA activities are evaluating. This states that the optimization of NVA activities is dependent on Lean tools. Thus, Lean tools are independent variables and NVA activities are dependant variables.

Much research focuses on the precast industry's NVA activities and lean tools. However, researchers have not illustrated the prime

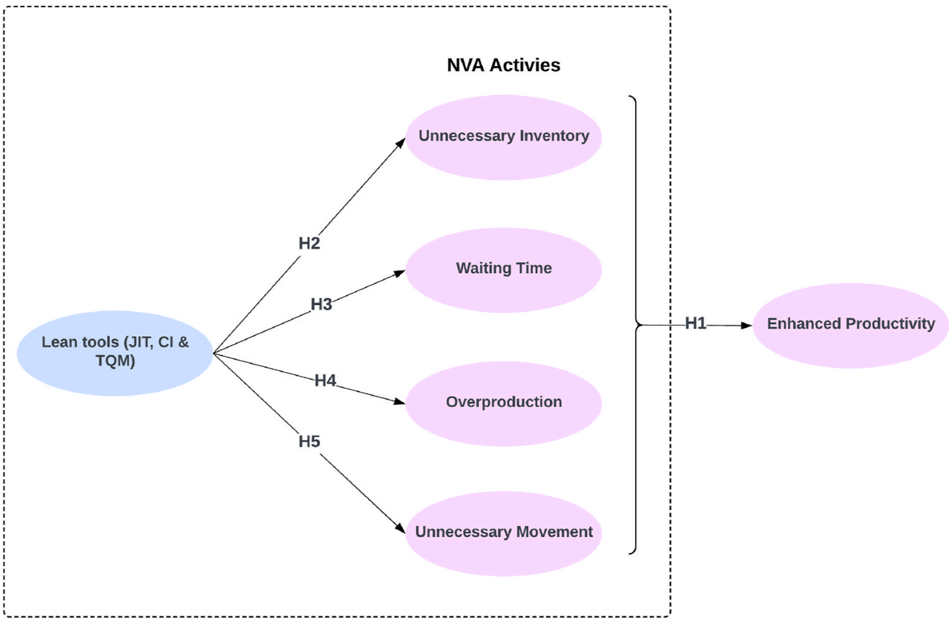

Fig. 2. Representation of conceptual model.

NVA activities that are necessary to be minimized. Lean tools such as 5S, value stream mapping, just-in-time production, kanban systems, and total productive maintenance (TPM) are commonly utilized in the manufacturing industries industry to streamline workflows, optimize resource utilization, and enhance overall performance by optimizing the NVA activities [57,58]. Embracing these Lean tools can significantly enhance productivity in the precast industry, aligning it with manufacturing best practices.

H1. The implementation of Lean tools in the Precast industry reduces the impact of non-value added (NVA) activities.

Excessive inventory leads to increased maintenance, storage requirements, and labor allocation, posing a challenge to the precast industry. Manufacturing firms employing Lean methodologies typically maintain optimized inventory levels, resulting in higher turnover rates. This optimization is facilitated by Lean tools such as just-in-time (JIT), kaizen, and total quality management (TQM) [59,60]. Thus, in the precast industry, Lean tools effectively streamline inventory management, eliminating unnecessary stockpiling.

H2. Incorporating lean tools will address the issue of unnecessary inventory in the precast industry.

Equipment malfunctions, staff shortages, processing delays, bureaucratic hurdles in document approval, late material deliveries, and transportation issues contribute to prolonged waiting times in workflows. Introducing process modifications, such as implementing Lean tools, can effectively minimize the duration of each work sequence, thus enhancing process flow and expediting operations [61].

H3. Lean tools can be utilized for tackling the issues with waiting time between various stages of the process as well as dispersion phases in the precast industry.

The primary challenge confronting our manufacturing and service sectors is overproduction, which occurs when the quantity of goods produced exceeds current or anticipated demand. Simply put, it involves manufacturing products at a rate or quantity that surpasses market needs. A fundamental aspect, often observed in manufacturing, is producing without existing customer orders. The adoption of lean tools facilitates a better comprehension of customer demand and market requirements [62,63].

H4. Lean tools assist with keeping tabs on the production processes, which reduces overproduction in the precast industry.

Unnecessary movement can encompass the movement of people, documents, resources, and equipment, resulting in wastage of time, effort, and human resources. Such inefficiencies often arise from the lack of method in task execution. The application of lean

Fig. 3. Flowchart of research methodology.

tools in manufacturing industries aids in the establishment and standardization of work methods, particularly those pertaining to bottleneck stations [64,65], thereby mitigating these challenges.

H5. Through the incorporation of lean tools in the precast industry, unnecessary movement of people, equipment, and work documents can be decreased.

Also, researchers have worked with various types of lean tools, but most of these tools are used in the name of sustainability and environmental perspectives. Thus, this supports that there is a need to explore the wastes that affect the project's time, cost, and budget. Therefore, this study aims to make up for the gap caused by the NVA activities that affect the productivity of the precast industry and to enhance productivity Lean tools.

3. Research Methodology

This section covers the study's research methodologies, which are presented in Fig. 3. The steps are concisely described below.

3.1. Distinguishing NVA activities and Lean tools

The study examines the necessity to reduce NVA activities in the precast industry. In accordance with the literature review, it is observed that NVA activities are classified into different types based on perspectives like productivity, environmental, customer value, etc. After thorough research, the NVA activities that are considered for this research include unnecessary inventory, waiting time, overproduction, and unnecessary movement. A hypotheses model is developed by understanding the effects of these NVA activities and the lean tools (JIT, CI&TQM) that are selected which are fit to reduce these effects. According to the conceptual model, a questionnaire survey is done for data gathering. The content validity test was conducted to understand the adoption of lean tools for NVA activity. The feedback obtained by these experts was followed, and the survey instrument was changed for data collection.

3.2. Enactment of questionnaire survey

A five-section questionnaire was employed. For easier comprehension, the first portion includes questions about the overall demographics of the respondents and the research's purpose. The questions in the second portion concern unnecessary inventory and adopting lean tools for that NVA activity. The third section covers the question of waiting time and adoption of lean tools for that NVA activity. The fourth section's questions are about overproduction and the NVA activity's lean tools. The final section is for unnecessary movement and lean tools for that NVA activity. The five-point Likert scale used as a data collection instrument, (1) strongly disagree, (2) disagree, (3) Neither disagree nor agree, (4) agree and (5) strongly agree. Respondents asked to select the scale based on their level of agreement with the questions asked. To pretest the questionnaire, content validity was accomplished with professional experts. In order to know whether the adapted questionnaire is valid or not, a pilot study is conducted. Five experts participated in the pilot study is conducted among 8 years' experience in the precast construction and lean fields. Then, the questionnaire was redesigned for the suggested errors and passed on for the main survey.

The questionnaire is set up to connect each factor to each lean tool. In this way, the influence of each lean tool on each NVA activity can be known. For accurate data, the questions are asked so that appropriate results will be obtained. Each factor consists of 8 questions that are related to the causes related to NVA activities and the lean tools influence on those factors. This makes answering the questionnaire take less time and increases the quality of responses.

3.3. Sample population

The intended sample size unclear, and research employed a purposive sample instead of non-probability sampling. Collecting data from an extensive population for the study poses significant challenges in terms of time, cost, and geographical constraints. So, it is important to select a sample that will appropriately represent the population being studied. This approach is predominantly applied in qualitative studies and involves the selection of units (such as individuals, groups, or institutions) based on specific purposes aligned with addressing the research questions. This study targeted different stakeholders having at least two years of experience in the construction industry. The population participated in the study were precast managers, construction business managers, lean associates, academics, project managers, etc. The reason for choosing the industry professional is because their input will help to strengthen and understand the perspectives of lean tools for that NVA activity. The selected experts held senior management positions and possessed a track record of successfully overseeing diverse precast projects. This choice enhances the credibility and reliability of their insights, as their roles underscore a high level of responsibility in offering valuable insights into the impacts of these NVA activities and the efficacy of lean tools. The survey was administered after obtaining informed consent from all participants involved in the study.

The formula that is used to estimate the sample is adopted by Hair et al. (2006) as calculated in Equation (1). A confidence level of 95% and 8% error value are considered to calculate sample size [66]. Based on this formula

$$n = \frac{z^2 * p * q}{e^2} \tag{1}$$

Where, n = sample size.

z = 1.96 @ 95% confidence level

p = estimated fraction of the population with a specified standard

q = 1-p

e = desired margin of error, i.e., 0.08.

3.4. Respondent profile

This study employed a web-based survey methodology to reach maximum responses and achieve high response rate. In this study, the finished questionnaire was distributed to 150 participants in the precast managers, construction business managers, lean associates, academics, project managers. In return, 99 of them answered, yielding a response rate of 66%. For construction research, the obtained response rate is significant [67]. Respondents having two years of experience were considered for research. The obtained data is analyzed through WarPLS Smart PLS 4.0. The questionnaire survey conducted in the month of January 2023 and it took 3 months to collect the data from respondents.

3.5. Minimum sample size for smart PLS analysis

The required minimum number of samples for PLS-SEM analysis can be obtained using a variety of techniques. Among them are the 10-times rule approach is the basic approach. The sample size should be more than 10 times the inner or outer model linkages pointing at any latent variable, according to the 10-times rule approach [68]. The maximum number of linkages that can point at any one latent variable in the current investigation is 5. Consequently, the sample size ought to be bigger than 50. Since the sample size collected is 99, it is greater than the minimal sample size needed for analysis.

3.6. Method of statistical data analysis

Based on 5-point Likert scale used in the questionnaire, the descriptive statistical was analyzed to check the overall distribution for all responses in the questionnaire survey. Next, reliability of the survey instrument was measured using Cronbach's alpha test. The author determines 4 NVA activities impacting the lean tools as shown in conceptual model. Next, a factor analysis was conducted to assess the appropriateness of the lean tools under consideration. The validation of model is done through partial least squares–structural equation modelling (PLS-SEM) technique using Smart PLS 4.0. PLS was used to estimate measurement and structural model parameters.

3.7. Application of smart PLS

Across numerous data analysis methodologies, the present study uses Partial Least Square Structural Equation Modeling (PLS-SEM) since it evaluates the measuring tool and conceptual model in addition to the necessary data analysis. Smart PLS 4.0 is the tool utilized for this purpose, which allows to perform Higher Order Construct testing [69]. In the current research, Lean tools and NVA are conceptualized as higher-order constructs (Fig. 4) with 7 lower-order constructs, i.e., JIT, CI, TQM, UI, WT, OP, and UM (3 for lean tools and 4 for NVA, respectively). Modeling of Lean tools and NVA as higher-order constructs is advantageous as it decreases the number of interactions among the constructs and eases the understanding of the analysis process and interpretation.

There are four different forms of higher-order construct models: reflective-reflective, formative-formative, reflective-formative, and formative-reflective. Among these models, Reflective-Reflective and Formative-Formative are widely used in different domains. Based on the prior study of these models, the Reflective-Reflective model is used in the present research [70]. Strategies like the two-stage method (embedded two-stage and disjoint two-stage) and repeated indicators approach are frequently utilized to assess the validity and assuring the path model. In this paper, a Disjoint two-stage approach is utilized to develop and estimate the path model,

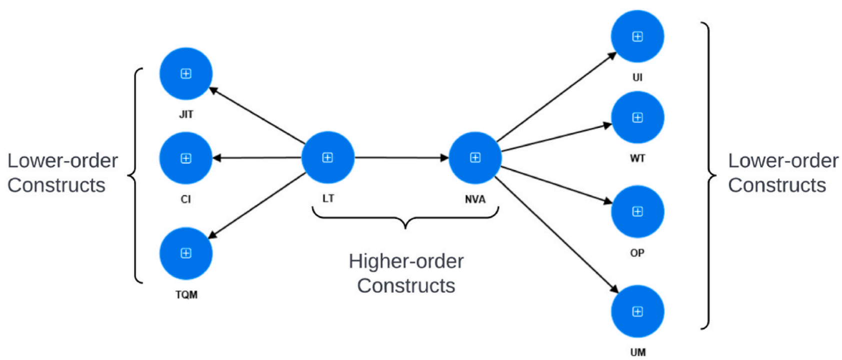

Fig. 4. Lower-order and higher-order constructs representation.

enabling precise results while using higher-order constructs [71]. The lower-order elements of higher-order constructs are only taken into account in the first stage of the two-stage methodology, leaving out higher-order constructs from the route model. The Latent Variable scores of lower-order elements are used as the input for higher-order constructs in the phase two-path model to execute a disjoint two-stage method.

The measurement model evaluation for lower-order elements is performed based on the phase one path model (Fig. 5) during the first stage of the disjoint two-stage method. As the two-stage approach recommends in stage two Latent Variable scores for (JIT, CI, TQM, UI, WT, OP, and UM) collected in phase one were included in the original data file, and analysis was repeated (Fig. 6). The model was developed and estimated, and this method tested the hypothesis.

Two steps make up the PLS model assessment and interpretation: (1) examining the measurement model's reliability and validity and (2) analyzing the structural model. To examine the measurement model, the phase one path model is used (Fig. 5). The values for Outer loadings, LVs, Convergent validity, ' 'Cronbach's alpha, composite reliability (CR), and Average Variance Extracted (AVE) are obtained while assessing the measurement model. After it has been shown that the measurement model was adequate, the structural model is examined, and the hypotheses are tested. The phase two-path model is used to test the structural model (Fig. 6). The path is assessed during the structural model, and all the path values should be less than 0.05 (as per confidence level); then, the model is valid.

4. Results and discussion

4.1. Evaluation of measurement model

Data gathered through the questionnaire can be analyzed in numerous ways. It is important to ensure that the collected data is valid or not. Reliability and Validity analysis will be assessed to determine the validity of the data. This section emphasizes the study's Reliability and Validity analysis, which is represented in Fig. 7.

4.2. Reliability analysis

In essence, the phrase "reliability" serves as a catch-all for dependability, consistency, and repeatability over time, over a variety of instruments, and over populations of respondents [72]. The split-half approach and Cronbach's alpha coefficient are two measures of internal consistency that can be employed to determine reliability in quantitative analysis. Cronbach's alpha is the often-utilized

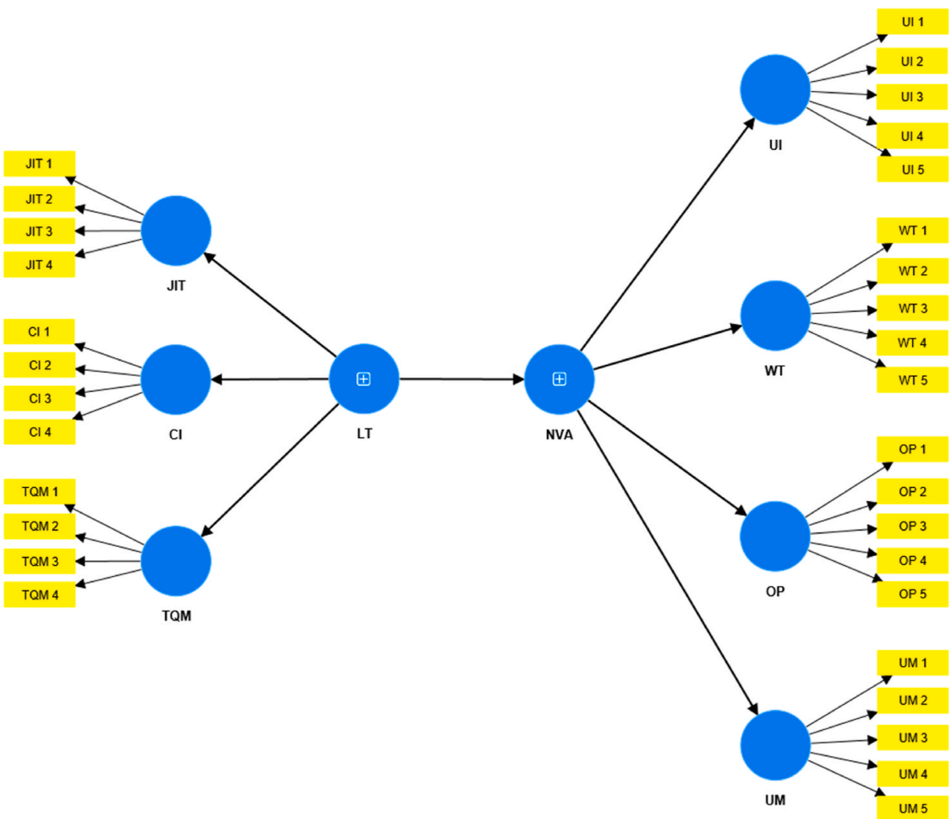

Fig. 5. Phase one path model (measurement model).

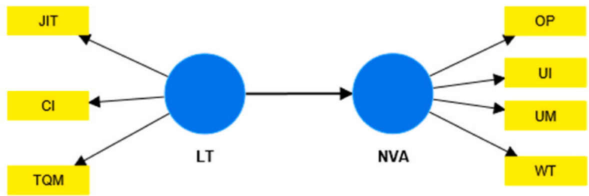

Fig. 6. Phase two-path model (structural model).

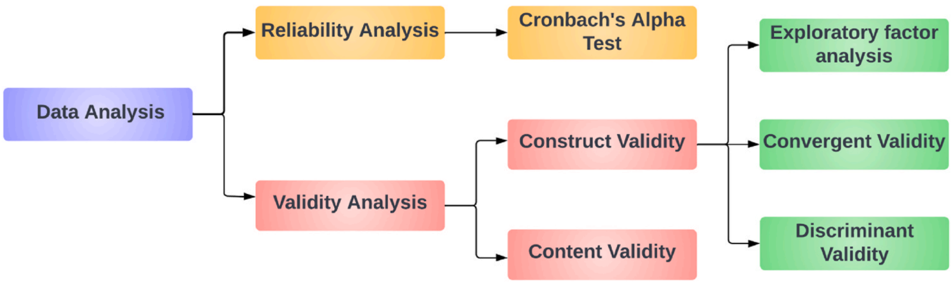

Fig. 7. Flowchart of data analysis.

reliability metric [73]. The estimated ' 'Cronbach's alpha and Composite reliability for each factor are listed in Table 4.

According to Bryman and Cramer (1990, p. 71), the reliability value is satisfactory at 0.8, whereas some believe it is acceptable at 0.67 or higher. Table 4 shows that every Cronbach's alpha coefficient is higher than 0.8. Composite reliability is also considered for assessing the reliability along with ' 'Cronbach's alpha. Based on the internal consistency of the indicators of the latent variables, composite reliability is determined. The composite reliability is significant if the values are more than 0.7 [74]. It demonstrates that the information gathered via the questionnaire has strong internal consistency and is unbiased. Additionally, it shows that uniformity is upheld throughout the whole questionnaire.

4.3. *Validity analysis*

4.3.1Content validity

Content Validity is a non-statistical test that is conducted before the questionnaire is circulated. To establish content validity, the instrument must show that it fairly and fully covers the area or topics it purports to cover [72]. The formulated survey instrument is sent for the expert review to perform this test. Five academics and industrial specialists were asked to conduct the expert evaluation. The feedback obtained by these experts was followed, and the survey instrument was changed accordingly.

4.3.2. *Construct validity*

Construct validity is measured by conducting Exploratory Factor Analysis (EFA) [72] and is determined by two factors: convergent validity and discriminant validity [75].

4.3.3. *Exploratory Factor Analysis (EFA)*

Factor analysis is a method for assembling variables that share a characteristic. It is a method that allows the researcher to take a collection of variables and simplify them down to a manageable amount of underlying (latent) elements that can explain as many variables as feasible. It is done by using Exploratory Factor analysis and Confirmatory factor analysis [72]. The results of Kaiser-Meyer-Olkin (KMO) and ' 'Bartlett's test are shown in Table 5.

The result of the Kaiser-Meyer-Olkin test for sample adequacy should be higher than 0.500 (Tzivinikou et al., 2020). and Bartlett's

Table 4
Reliability Analysis results.

	Cronbach's alpha	Composite reliability
CI	0.927	0.927
JIT	0.936	0.937
OP	0.814	0.843
TQM	0.925	0.927
UI	0.825	0.849
UM	0.833	0.85
WT	0.811	0.818

Table 5
KMO and ' 'Bartlett's results.

Kaiser-Meyer-Olkin measure of sampling adequacy		0.891
Bartlett's test of Sphericity	Approx. Chi-Square	2909.312
	[a]df	496
	[b]Sig.	<0.001

[a] df-degrees of Freedom.
[b] Sig.- Significance.

test should have a significance of ($p < 0.05$) [72]. From Table 5 and it is clearly observed that the obtained values are quite higher than the limitation values. This confirms that the study's data are appropriate for principal component analysis. The Principal Components Analysis extraction method with Varimax Rotation is utilized for Exploratory Factor Analysis (Tzivinikou et al., 2020). According to Table 6, all the variable factor loadings are more than 0.5. Therefore, all the variables are desirable. The test reveals that the grouping of various questionnaire questions under each factor is satisfied, i.e., the questions in the Unnecessary Inventory section are specific to that section only, and the same is true for the other three factors.

4.3.4. Convergent validity

Two related or comparable factors or components of a given construct are proved to be connected to one another (e.g., by measurements or indicators); it is said that the results have converged or are consistent [72]. In quantitative research, convergent validity is frequently shown using correlation, factor analysis, or regression measures. Factor analysis is used to assess the convergent validity of the questionnaire data. The obtained Average Variance extracted (AVE) values for all factors are listed in Table 7.

Fornell and Larcker [76] claim that the data will satisfy convergent validity whenever the AVE and CR values are more than 0.7. Table 7 shows that all AVE values are higher than 0.5, and all CR values are higher than 0.7 (Table 4). The outer loadings and AVE are shown in Fig. 8, along with path coefficients. It demonstrates that the Convergent validity for each construct is satisfactory. It shows that the variables of each construct are correlate to each other and independent from the other variables, i.e., the variables considered for the Unnecessary Inventory is correlate to each other, and they are independent of the variables associated with other constructs like Waiting time, Overproduction and Unnecessary Movement.

Table 6
Factor loadings.

Indicators	Variables	Factor Loadings
Unnecessary Inventory (UI)	UI1	0.630
	UI2	0.873
	UI3	0.869
	UI4	0.810
	UI5	0.643
Waiting Time (WT)	WT1	0.702
	WT2	0.741
	WT3	0.794
	WT4	0.703
	WT5	0.829
Overproduction (OP)	OP1	0.509
	OP2	0.861
	OP3	0.838
	OP4	0.814
	OP5	0.748
Unnecessary Movement (UM)	UM1	0.600
	UM2	0.860
	UM3	0.833
	UM4	0.854
	UM5	0.720
Just-in-time (JIT)	JIT1	0.903
	JIT2	0.910
	JIT3	0.943
	JIT4	0.910
Continuous Improvement (CI)	CI1	0.879
	CI2	0.909
	CI3	0.921
	CI4	0.913
Total Quality Management (TQM)	TQM1	0.866
	TQM2	0.919
	TQM3	0.937
	TQM4	0.890

Table 7
Convergent Validity results.

Indicators	Average variance extracted (AVE)
CI	0.82
JIT	0.84
OP	0.585
TQM	0.816
UI	0.597
UM	0.608
WT	0.571

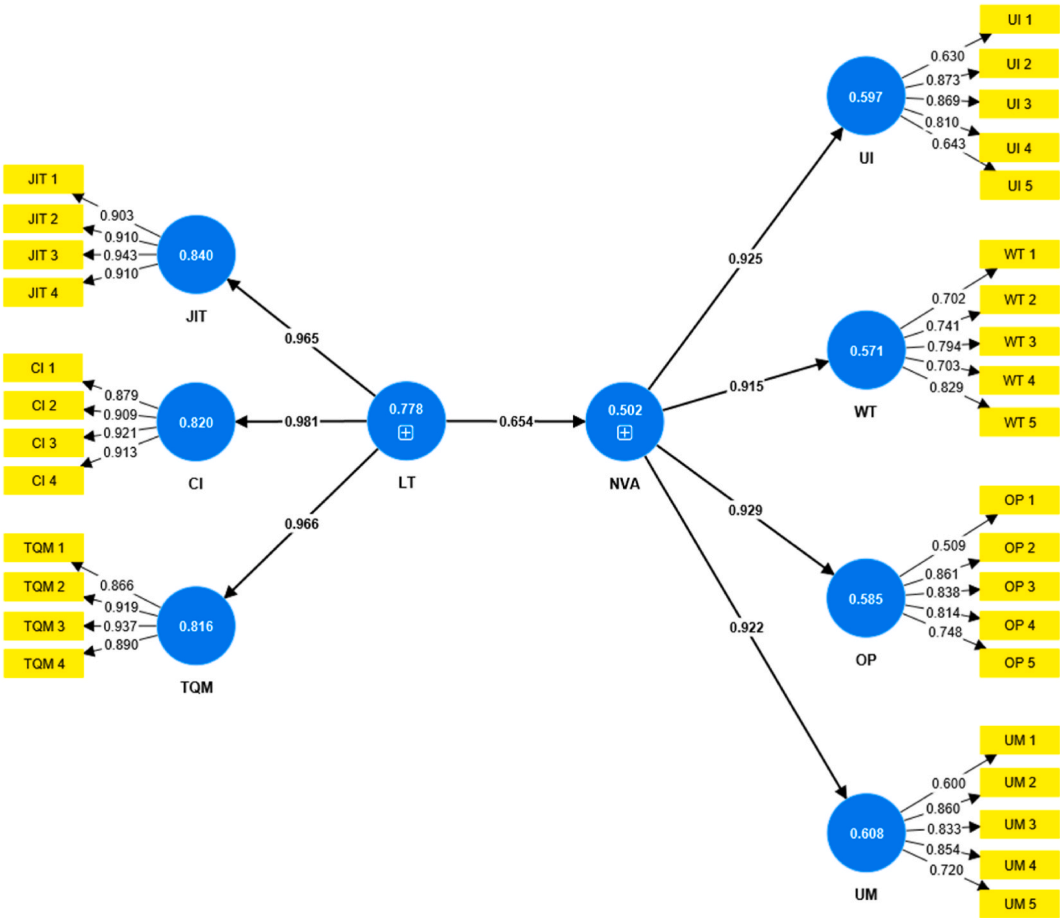

Fig. 8. Average Variance Extracted (AVE), Outer loadings, and Path coefficients of the measurement model.

Table 8
Heterotrait-Monotrait ratio of correlations.

	CI	JIT	OP	TQM	UI	UM	WT
CI							
JIT	0.792						
OP	0.693	0.652					
TQM	0.684	0.695	0.677				
UI	0.664	0.615	0.627	0.649			
UM	0.693	0.637	0.653	0.655	0.642		
WT	0.669	0.691	0.673	0.696	0.699	0.649	

As a result, it ensures that variables for one factor only reflect that factor and have no relation to any other factors. For example, the variables for Unnecessary Inventory only reflect Unnecessary Inventory and have no connection to other factors like Waiting time, Overproduction, and Unnecessary Movement.

4.3.5. Discriminant validity

The level of distinctiveness among measurements of various latent variables is known as discriminant validity. A measure must solely represent the variation related to its target latent variable and not to any other latent variables for it to be considered valid [77]. In this research, the Heterotrait-Monotrait ratio of correlations (HTMT ratio), which is an advanced method than the Fornell and Larcker criterion, is used to calculate the discriminant validity. The correlation among the variables is obtained by analysis, and the HTMT ratio is calculated for the obtained values. According to Ref. [78], HTMT ratios must be lower than 0.9. The data has discriminant validity, as evidenced by the results in Table 8.

4.3.6. Evaluation of structural model

The structural model is then tested by means of the suggested Hypotheses once the measurement model has been evaluated. The Structural path model was bootstrapped in 5000 replications. The results obtained from the bootstrapping analysis are presented in Table 9, which displays that H1 was supported ($\beta = 0.654$; $t = 10.761$; $P = 0.000$), indicating that Lean Tools has a positive effect on minimizing the impact of NVA activities in the precast industry. Secondly, H2 was supported ($\beta = 0.605$; $t = 9.778$; $P = 0.000$), which indicates that Lean tools like JIT, CI, and TQM have a significant effect on decreasing the Unnecessary inventory in the precast industry. Theoretically, Unnecessary Inventory involves the consumption of more storage space, time, and resources, which can be minimized by adopting the Lean tools. Further, H3 was supported ($\beta = 0.599$; $t = 9.409$; $P = 0.000$), which implies that Lean tools like JIT, CI, and TQM have a prominent impact on decreasing the Waiting Time. Waiting time consumes more time and tends to increase the process time, ultimately leading to the delivery delays of products. The fourth hypothesis, H4, is supported ($\beta = 0.608$; $t = 9.667$; $P = 0.000$) demonstrating that Lean tools adoption will tend to cut down the overproduction in the precast industry that promotes the effective use of resources. The last hypothesis, H5, is supported ($\beta = 0.603$; $t = 9.438$; $P = 0.000$), which displays that Lean tools will decrease the Unnecessary Movement between the various processes or back and forth of steps in the process. Fig. 9 demonstrates the β values and P values.

The JIT forces the industry to purchase the goods when it is necessary at the appropriate time and at an appropriate place which helps the precast industry to reduce unwanted purchases, dead stock, significant use of resources, unwanted movement, and excess production. The Continuous Improvement enables the industry to redevelop and re-read their process. By continuous improvement, the resources are used effectively, unwanted steps can be eliminated, and there is a better allocation of time to every process. Total Quality Management improves the overall quality of the process resources and tends to increase the industry's productivity.

5. Interpretation of results

The primary hypothesis tested in this research is whether implementing Lean tools significantly impacts reducing non-value added (NVA) activities in the Precast industry. The analysis results reveal a strong positive relationship between Lean tools and NVA activities, with a β value of 0.654. The Lean philosophy emphasizes maximizing productivity while minimizing resource usage and prioritizing customer value. Implementing Lean tools in the Precast industry can improve sales and productivity by aligning with customer values. This study considers Just-in-Time (JIT), Continuous Improvement (CI), and Total Quality Management (TQM) as the specific Lean tools used to achieve these results. Several NVA activities plague the Precast industry, often viewed as waste, and can decrease overall efficiency. The most significant NVA activities include unnecessary inventory, waiting time, overproduction, unnecessary movement, reduced productivity, improper resource utilization, increased storage space, higher maintenance costs, and ineffective use of human resources. To address the negative impact of NVA activities and compete effectively in the market, implementing Lean tools is crucial. Following the fulfillment of the basic hypothesis, the model is subsequently evaluated to see how these tools independently alter the impediments generated by different NVA activities.

At first, the model is analyzed for the hypothesis that incorporating lean tools will address the issue of unnecessary inventory in the precast industry. With a β score of 0.605, the research results demonstrate that selected lean tools positively impact the Unnecessary Inventory. Unnecessary inventory results from various actions like improper planning and scheduling, unawareness of the demand and supply of the product, and improper use of management tools. Lean tools aim to address the underlying issues that cause unnecessary inventory. JIT optimizes the inventory by increasing the flexibility of the schedule, minimizing the maintenance, improving the equipment arrangements, supplier relationships, encouraging the pull systems and tiny batch sizes. Employing JIT shows its impact on procurement management and product management [59,79]. CI strives to have steady improvement in planning, scheduling, and manufacturing processes, allowing the management team to devote time to evaluate their proposals. TQM makes the management use statistical process control methods, error-proofing procedures, and equipment problem controls, resulting in less unnecessary inventory [59]. All of these lean tool practices are aimed at stimulating their use in order to optimize the inventory.

Second, the hypothesis was predicted that Lean tools could be utilized for tackling the issues with waiting time between various stages of the process as well as dispersion phases in the precast industry. Equipment breakdowns, personnel unavailability, processing waits, document approval, material deliveries, and transportation problems are the underlying causes of waiting times [80–82]. The analysis shows that lean tools have a tangible influence on waiting time, with a β score of 0.599. JIT ensures transportation and material delivery issues through effective supplier contacts and schedule optimization. JIT deliveries enable the timely delivery of the material, reducing waiting times. CI focuses on enhancing the procedures employed to carry out a certain process to minimize waiting times brought on by processing delays, document approval delays, and staff shortages. TQM primarily addresses quality, employee working conditions, and equipment, which aids in dealing with downtime caused by equipment malfunction [59].

Further, the model is evaluated for the hypothesis that Lean tools assist with keeping tabs on the production processes, which reduces overproduction in the precast industry. The model analysis yields a score of 0.608, confirming that lean tools eliminate

Table 9
Hypothesis test results.

Hypotheses	β Values	t values	P values	Results
H1: LT - > NVA	0.654	10.761	0	Supported
H2: LT - > UI	0.605	9.778	0	Supported
H3: LT - > WT	0.599	9.409	0	Supported
H4: LT - > OP	0.608	9.667	0	Supported
H5: LT - > UM	0.603	9.438	0	Supported

Significance at $p^*<0.05$.

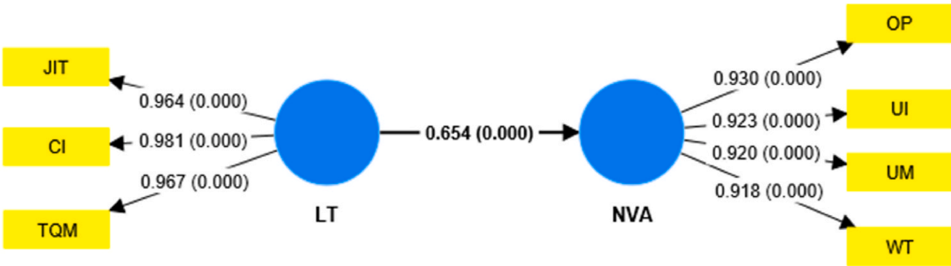

Fig. 9. β values and P values of the structural model.

overproduction. The primary causes of overproduction are early product production, ambiguous market forecasts, and surplus production against demand [82,83]. Pull methodologies of JIT enables the industry to manufacture the products when there is adequate demand [59,79]. The irregularities in the forecasting can be optimized through CI methodologies adopted for market analysis [84]. Using TQM focuses primarily on client values, which reduces extra production by detecting consumer requests [82].

Finally, the model is tested to verify the hypothesis that incorporating lean tools in the precast industry can decrease unnecessary movement of people, equipment, and work documents. The analysis yielded a β value of 0.603, indicating that Lean tools strongly impact Unnecessary Movement. Unnecessary movement might involve people, documents, resources, and equipment, wasting time, effort, and human resources. JIT aims to reduce unnecessary movement by streamlining schedules, processing times, and task categorization [59]. Continuous seeks to raise performance standards by increasing process efficiency, profitability, and demand while lowering unnecessary movement [84]. TQM may aid in enhancing coordination and communication amongst many construction players, including contractors, engineers, and architects. This can lessen the possibility of delays and mistakes that can cause unnecessary movement.

6. Practical implications

Embracing Lean practices holds immense potential for the Precast industry, particularly in the realms of waste reduction and impact the productivity. By incorporating lean principles, the industry can streamline processes, minimize inefficiencies, and foster a more efficient and productive project environment. It gives reference for industries who are implementing lean for first time. Directly adopting lean into the industry is impractical. The shift towards lean methodologies stands to be highly rewarding, paving the way for enhanced sustainability and improved overall project performance in the construction sector of India. Before actual execution of lean principles in the construction industry it is necessary to train all the stakeholders and organised a seminar to understand in depth knowledge of lean principles.

By fostering awareness and understanding, the production team gains the capacity to discern between Value-Added (VA) and Non-Value-Added (NVA) activities within the work process. This non-value added (NVA) activities do not contribute value to the final product, yet they often consume a significant portion of project resources. For instance, industries may stockpile inventory to ensure uninterrupted workflow, but this can result in unnecessary accumulation leading to increased storage costs, maintenance expenses, and resource utilization in terms of both personnel and time. To address such challenges, the Just-In-Time (JIT) approach can be implemented. JIT facilitates the efficient management of inventory by ensuring that materials are procured and utilized precisely when needed, thus promoting a smoother workflow while minimizing resource usage associated with inventory management. There are different lean tools available this research will help to select the appropriate tools for a particular problem. The application of lean tools and techniques, such as JIT with Kanban, and continuous flow, can support the work process.

7. Limitations and future study

Although this research demonstrated various notable results, it has some limitations, too. The study is reserved for a limited number of samples and is purely based on the perspective of the people present in the sample size. The present study only concentrates on the implementation of lean tools in the Precast industry, but it is not particularly mentioned at which stage of manufacturing these implications are prominent. Further, this study can be carried out by performing a case study on any particular precast industry and considering more NVA activities and other lean tools' role in the precast industry. Future studies may focus on region-specific and longitudinal studies that could provide more insights related to precast industry in different contexts. Future works can extend the application of this methodology to other precast projects such as buildings and railways to explore how construction firms can effectively adopt lean construction methodologies. Future the study should be conducted on the implementation of lean principles, waste management, and the sustainable integration of these practices.

8. Conclusion

To summarize, the construction industry is a prominent industry that is spreading its wings towards the product-based approach. Lean Construction (LC) principles can help streamline processes, reduce waste, and enhance overall efficiency. Industrialized Building Systems (IBS) are fetching more attraction. IBS empowers the construction industry to deliver productive work to a greater extent. The Precast Industry is a part of this IBS, which is on top of coming up with these product-based approaches, and that too with high quality and efficiency. In spite of the fact that it is highly effective, the Precast industry bottles up various non-value-added activities, which declines the productivity of the industry. NVA activities are commonly regarded as waste. The study has carried out for the four NVA activities in the precast industries. Unnecessary Inventory (UI), Waiting Time (WT), Overproduction (OP), and Unnecessary Movement (UM). The three lean tool JIT, CI, and TQM were considered and the does it impact on the NVA activities was examined. Conceptual model was developed and data was collected through questionnaire survey. PLS-SEM was used to validate the model and test the hypothesis.

The study revealed that the analysis of the path model justifies that Lean tools can eliminate these NVA activities. Just-in-time (JIT) increases scheduling flexibility, lowers maintenance requirements, and strengthens supplier relationships to maximize inventory. Small batch sizes and pull systems are also encouraged, which assist in minimizing waiting periods and Unnecessary movement. The benefits of JIT may be evident in product management and procurement, with strong supplier relationships and efficient schedules guaranteeing on-time material delivery. Streamlining schedules, processing times, and task categorization through JIT reduces non-value-added activities in the industry. Continuous Improvement (CI) attempts to consistently improve planning, scheduling, and production processes, allowing management to evaluate suggestions. By streamlining processes, CI seeks to reduce wait times brought on by bottlenecks in staffing, delays in document approval, and processing delays. Additionally, CI can enhance forecasting through improved market analysis techniques, ultimately leading to a decrease in non-value-added activities in the precast industry.

Total Quality Management (TQM) approaches in the precast sector could address quality, employee working environment, and equipment to reduce downtime caused by equipment breakdown. Prioritizing customer values lets TQM recognize customer needs, reduce overproduction, and identify customer demands. Better coordination and communication between various construction stakeholders, including contractors, engineers, and architects, can be facilitated by TQM. In general, TQM implementation in the precast industry will result in a reduction in non-value-added activities. Future studies can compare several cases to explore the impacts of other lean tools in the different precast industries. This study contributes to the existing body of knowledge within the construction management in the concept of LC. On a worldwide scale within the construction realm, the study results would enhance our existing understanding of engineering management. It lays the groundwork for future investigations into in determining where to commence the implementation process, emphasizing that systematic identification and elimination of non-value-added activities can lead to significant process improvement.

CRediT authorship contribution statement

Haritha Malika Dara: Writing – original draft, Methodology, Investigation, Formal analysis. **Ashwin Raut:** Writing – original draft, Supervision, Methodology, Investigation. **Musa Adamu:** Visualization, Investigation, Data curation. **Yasser E. Ibrahim:** Writing – review & editing, Visualization, Supervision, Resources. **Prachi Vinod Ingle:** Writing – original draft, Methodology, Investigation, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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