Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

p-ISSN: 0972-6268
(Print copies up to 2016)
e-ISSN: 2395-3454

Vol. 23 | No. 4 | pp. 2189-2200 | 2024

Original Research Paper

https://doi.org/10.46488/NEPT.2024.v23i04.023

Open Access Journal

Environmental Monitoring and Assessment for Sustainable Construction Projects: Leveraging Lean Techniques

Ardra Suseelan† and Senthil Vadivel. T.

Department of Civil Engineering, School of Engineering and Technology, Manav Rachna International Institute of Research and Studies, Faridabad, Haryana-121004, India

†Corresponding author: Ardra Suseelan; ardras24@gmail.com

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 21-03-2024
Revised: 09-05-2024
Accepted: 18-05-2024

Key Words:
Construction management
Lean construction
Lean tools
Last planner system
Sustainable project delivery

ABSTRACT

To increase productivity and avoid waste, the construction industry has started implementing Lean ideas and methodologies in construction projects. Due to a lack of awareness of lean practices in the preparation, design, and execution of building and infrastructure projects, lean practices are not very familiar among construction projects, which are most commonly used in the manufacturing industry. Hence, an effort has been made in this paper to provide a comprehensive review of the literature and case studies to analyze the suitability of lean practice in sustainable waste management, increased productivity, and on-time project delivery. It aims to explore the effect of improving communication and fostering collaboration among stakeholders on time, costs, and resource management. The review identified the most commonly applied lean practices, Just in Time (JIT) and Last Planner System (LPS), and linked the adoption of lean techniques within the construction sector to a total of sixteen distinct benefits for the economy, society, and the environment. According to this study, lean techniques have a strong chance of boosting productivity in the construction industry and developing a sustainable built environment, but they also need to be used widely and continuously to achieve these goals.

INTRODUCTION

One of the industries in India with the highest rate of growth is building, which is crucial to the continued growth and development of the nation. It contributes about 8.7% of GDP. Despite the use of several cutting-edge technologies still, the efficiency of the construction sector is relatively very low. In 2015, over 430 million people were living in cities; by 2030, that number is projected to rise to about 600 million, or about 40% of India's population. The Indian government's "Housing for All by 2022" mission is a large-scale initiative that calls for the completion of 20 million reasonable housing in cities by that year. India currently has a shortage of 19 million dwellings in urban areas and 44 million in rural regions, and the number is predicted to reach 114 million by 2022, according to the National Real Estate Development Council, despite our present supply.

The principles of lean are all about maximizing value and minimizing waste. Although it may seem easy, doing so is rather challenging. That is because a variety of waste can sneak into any process, whether it's software development, manufacturing, or something else different. Lean construction helps to reduce waste, maximize the benefits, and deliver a sustainable project at the end of the construction. JIT and Automation, the two pillars of Toyota's manufacturing system, are shown in Fig. 1.

For the design of the Lean Production System, a set of goals was established for the design of the production system influenced by Total Quality Management (TQM). These goals help to maintain Lean Principles and to deliver a product that satisfies consumer needs without keeping any inventory upon request shown in Fig. 2.

Lean is built on a set of guiding principles intended to get rid of waste and help businesses do better at what they do. Five lean principles were outlined by Womack & Jones (1996) as a means of reducing waste in businesses. According to Womack & Jones (1996), one strategy for enhancing organizational performance in terms of value creation is lean thinking. The primary objective is "optimizing the total value," not "minimizing the cost." The literature study helps to identify Lean Principles and their application in the construction sector, identifying the imperatives that bound the application of Lean in the construction sector, the framework assessment process of Lean Principles, model creation, and evaluation of the model. The two sides of the

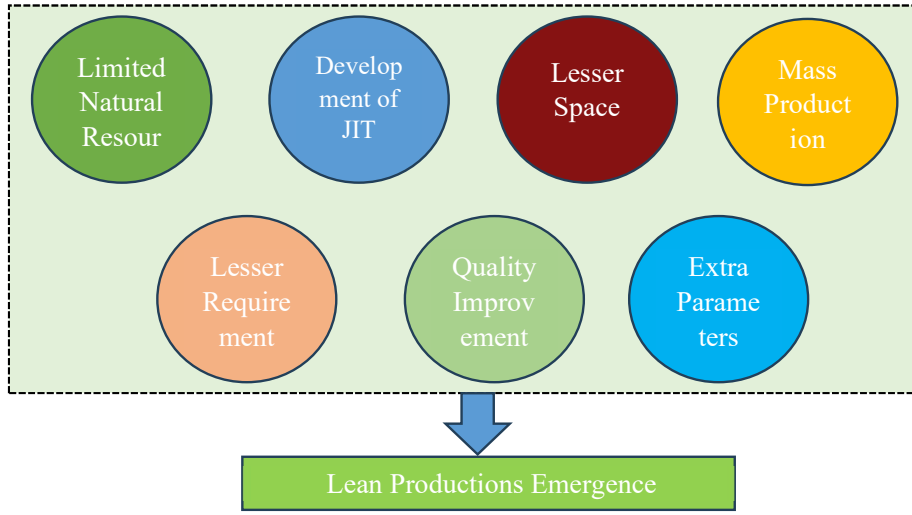

Fig. 1: Lean productions origins (Aziz & Hafez 2013).

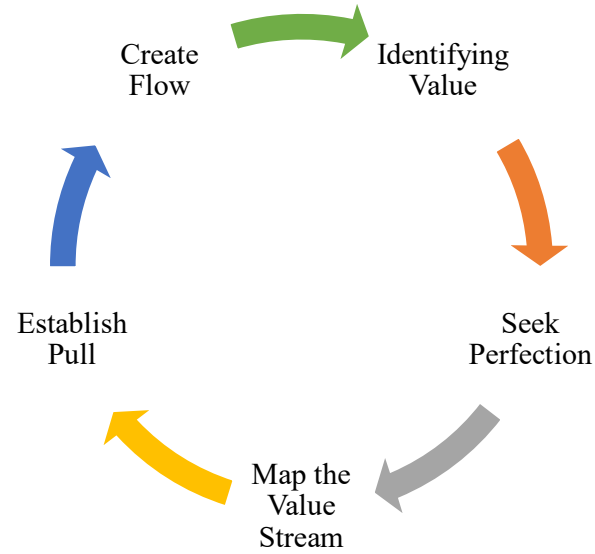

Fig. 2: Fundamentals of Lean.

lean construction coin that keep rotating during a project are (1) Planning and (2) Control. A detailed literature study has been conducted to identify Lean Principles and their application in the construction sector, identifying the imperatives that bound the application of Lean in the construction sector, the framework assessment process of Lean Principles, model creation, and evaluation of the model (Green 2005).

LEAN TOOLS

Adopting a lean strategy inside an organization has the potential to have an impact on productivity, service delivery, and quality, which eventually leads to significant cost savings. Lean construction tools like LPS, improved visualization, and daily huddles were evaluated by "Site Implementation and Assessment of Lean Construction Techniques." Most of the lean tools selected are easily accessible or proposed with slight modifications. The Lean construction methodology and the tools are gives in Tables 2 & 3 respectively.

MATERIALS AND METHODS

A proper systematic literature review of 118 articles was carried out in this study. The following five questions should be considered for a proper literature study, which includes identifying good quality papers, proper research

Table 1: Lean principles' applications.

Lean principles	Applications	Ideas for a deeper and sustainable application of lean principles
Value	Cost-saving enhancements to the construction process. Value, as seen by the client, is not routinely taken into account as a rule.	Recognizing value from the viewpoint of the client. Reviewing the construction process to improve additional willed features while also providing the client with greater value.
Value Stream	Process mapping software	Material and information value stream mapping. Creating a future value stream map and suggesting necessary upgrades
Flow	Applications for specific tools include pokayoke and visual controls. Utilizing work structuring, the last planner identified and reduced process wastes while stabilizing the working flow.	Creating a continuous flow environment by changing how teams and employees divide up their work. Adopting standardized work by specifying rhythm, inventory, and sequence.
Pull	Applications for the supply of specific supplies or tradespeople.	Imagine a vast direct communications system for bringing in services, parts, and supplies just as required.
Perfection	Utilization of Quality Systems, with a primary emphasis on process traits influencing product performance.	Designing procedures for quick problem detection. When differences in standardized work processes are found, establishing systematic procedures for ongoing learning and improvements on the functional hierarchy base are important.

Table 2*:* Lean construction methodology and levels.

Stages	Lean Construction Approaches	Related Lean Manufacturing Methodology
Stage One	Cards for resources Kanban	Kanban system
Stage Two	Visual inspection Tools for monitoring quality	Visual inspection (Poka-Yoke devices) Multifunctional layout TQM Standard operations Single-minute exchange of dies (SMED)
Stage Three	Daily huddle meetings for the last planner's plan conditions of work environment (PCWE)	Kanban system Production leveling Toyota verification of assembly line (TVAL)

Table 3: Lean tools and their benefits in the literature study.

Lean Tools	Benefits	References
LPS, 5S, Poke Yoke	Waste Reduction, Mistake Correction,	Dineshkumar & Kathirvel 2015, Banawi & Bilec 2014, Li et al. 2019, Ngowtanasuwan 2013, Agrawal et al. 2024, Hossain & Purdy 2023)
Continuous Improvement	The drive of the workforce, prompt project completion, and little rework	(Pamfilie et al. 2012, Rahim et al. 2012), (Dunlop & Smith 2004), (Khodeir & Othman 2018), (Dombrowski & Mielke 2013)
Daily huddle meetings, VSM	Minimum Rework, Regular Schedule, and Workplace Cleanliness	(Dombrowski & Mielke 2013), (Martens & Carvalho 2017), (Musa et al. 2016), (Batwara et al. 2023).
Visual inspection, LPS, BIM	Proper site management, prompt project completion	(Singh & Kumar 2016), (Lopez et al. 2021), (Molavi & Barral 2016), (Issa 2013), (Li et al. 2019).

questions, identifying relevant papers, identifying papers with accurate findings and summaries, and interpreting the results, discussions, and conclusions. Papers are identified using the keywords "Lean Construction, Lean tool, Lean Principles" to identify the articles between 1993 and 2024. The databases selected should be among one of the largest online collections of content that have undergone both peer-review and un-reviewed. Fig. 3 represents the methodology used in this study.

Databases include research papers, articles, conference proceedings, books, and reports. About 150 journals, conferences, articles, and books were identified at the initial screening. The second step included the screening and sorting of articles based on their abstract and content and how they are relevant to Lean. The second selection criteria were based on the citations; papers with more citations had given more preferences. After proper screening and sorting, a total of 118 journals were selected over the last 21 years. Among these 118 journals, 33 articles from Scopus, 53 from Science Direct, 16 from Google Scholar, 5 from books, and 11 from conferences. After the chosen articles are examined, the results are presented in the form of charts, tables, Figs, etc. Fig. 4 gives a detailed representation of the total number of articles published and the year. The result identified that 81% of the material was from 2010 to 2024, and most of the studies were conducted in countries such as the USA and

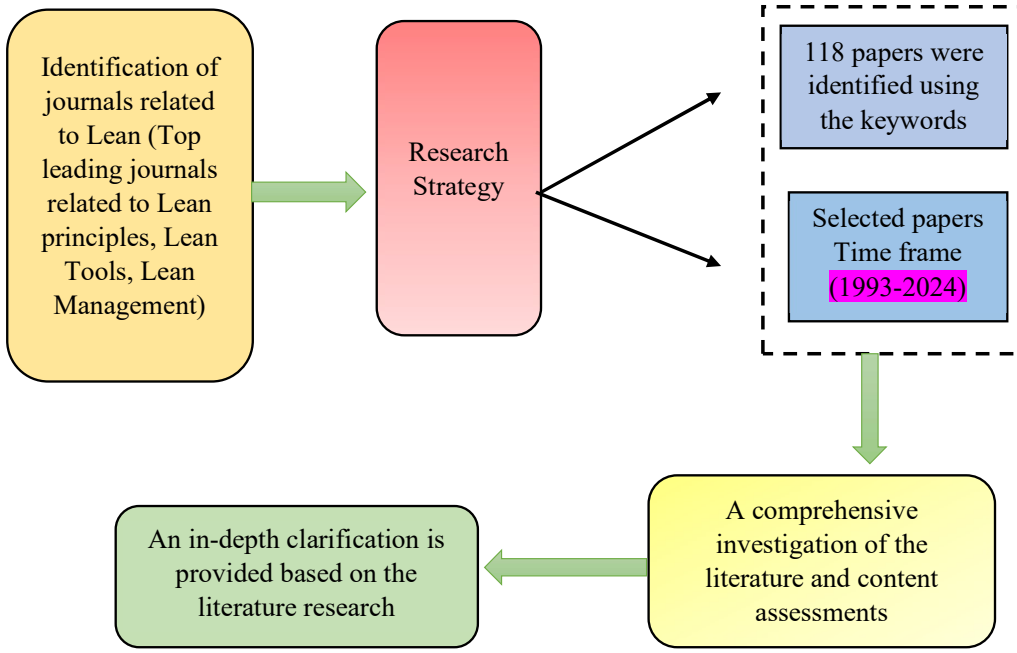

Fig. 3: Flow chart of methodology.

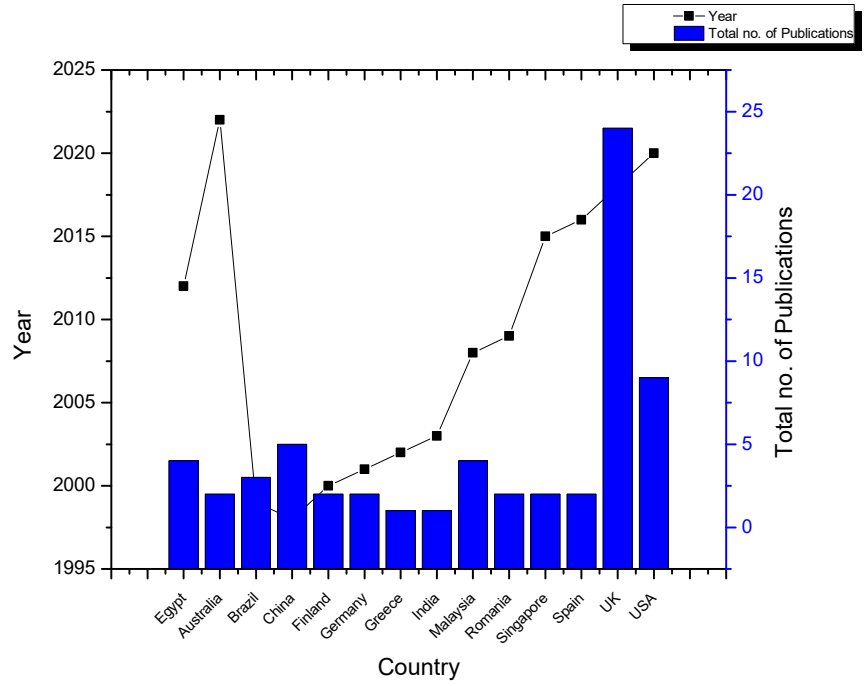

Fig. 4: Total no. of articles referred from different Countries.

the UK, reflecting the dire need for implementation of Lean Principles in the construction sector.

Sustainable Lean Construction Practices

There is a ton of evidence in the literature related to LCPs that makes it possible to achieve lean construction goals. The list of LCPs found in the papers analyzed is given in Table 1. These lean methodologies are based on verifiable proof

of their use at various phases of planning, designing, and building projects for buildings and physical infrastructure in distinct nations. The JIT was the most prevalent JIT discovered in this analysis, as evidenced by the reporting of its application in 108 distinct papers from 14 various countries (sources are included in Fig. 4). The LPS is mentioned adjacent to JIT and has been documented in ten different papers. Integrated project delivery (IPD) and thorough briefing are the two LCPs that have received the least amount of implementation.

CASE STUDY ON LEAN TOOLS

Phaniraj (2015) conducted a case study at the Brigade Orchards Precast Plant near Devanahalli, Bangalore. This project is conducted on 130 Acres of land, which contains small villas, hospitals, stadiums, schools, etc. Various steps included in this case study are recording the current procedure, recognizing wastes, Creating Lean alternatives, and Recording the changes. Kaizen recording is carried out before and after the changes. The output is generated using one of the Lean methods, Kaizen, which helps to reduce non-value-added materials and costs and increase customer satisfaction. The study also gives a brief discussion on employee involvement; labor cooperation is a crucial component of successful Lean Implementation. This study also discusses the barriers to implementing Lean. The Kaizen method helps to maximize the output and minimize the waste.

Gupta & Jain (2014) conducted a case study on 5S and Kaizen and identified that it helps increase process effectiveness and efficiency, better process visibility, improve employee morale and safety and reduce delays and searching time. In this study, company XYZ, a producer of quartz glassware, is selected, which is a small-scale industry in Ambala, Haryana, and recorded observations such as turnover, employees, marketing network, and quality systems. In this study, problem identification is carried out, and training to employees and identified the changes in 1st S, 2nd S, and so on. Both Kaizen and 5S can be used in any organization and any industry, whether it be small or large. Unwanted items are removed by putting the first S into practice. When the second S is used, the working environment is enhanced, and space utilization can be done. Maintaining a safe and cleaner environment can be done with 3rd S. Better workplace and visual control systems by fourth S, foster discipline and team spirit by fifth 5.

Eldeep et al. (2022) conducted a case study at Dammam University, which had 48 classrooms and 8 laboratories, with a total cost of 36 million SAR. The technology used was the standard design-build procurement process. The project took 2 months for the bidding procedure, 4 months for the design stage, and 22 months for execution. The project usually followed a two-dimensional method. In this project, Revit and Navisworks (BIM Software) have been used to redesign the work. With the help of BIM software, the model is prepared within two months and also gives a detailed view of the comparison of 2D works and BIM in detail, which includes increased visual clarity, streamlined process, and information flow.

Rahman et al. (2013) conducted a case study on one of the Malaysian manufacturing Companies that produced a variety of cars, parts, and services and identified that slow staff involvement and less commitment from upper management are the reasons. The study uses a Lean tool known as Kanban**.** The persons included in this study are employees and management staff from different departments such as store, production, logistics, etc. Data collection is done through structured interviews and observation. A structured interview with the managers of the manufacturing organization was undertaken to comprehend the manufacturing processes and acquire precise data on the facility's existing use of the Kanban system.

Vargas et al. (2018) identified defects are one of the major wastes in the manufacturing sector, which affects delivery time, cost, quality, etc. A case study is carried out in a manufacturing company in Tijuana, Mexico. The main aim of this case study is to reduce waste by 20%, and the PDCA (Plan Do Check Act) method is applied. The three product models were examined. Auxiliary tools such as Pareto charts and Flowcharts were used. Hence, faults dropped by 65%, 79%, and 77%. As a result, the case study concluded that PDCA, Pareto Charts, and Flow Charts are the top-quality tools that aid in lowering the proportion of defective components.

Desai & Shelat (2014) conducted a case using VSM to identify the waste and flow of information among people. The study was conducted in a Steel Yard in Mumbai. VSM helps in creating a roadmap to address problem areas and to reduce the gap between the current state and the desired state of various construction operations. For Mapping, the information is collected from contractors, engineers, supervisors, etc. All the data, like types of activities and quantities, are gathered. And the graphical representation helps to identify the data more easily and reduce waste.

Ryan et al. (2019) conducted a case study on Irish case study organization on LPS. The information was gathered using a qualitative online survey, and the secondary data was collected using an examination of a pilot project within the client organization in 2015. For a better understanding of the advantages and difficulties of the LPS in the context of Ireland, the survey included both open-ended and

closed-ended questions. Lack of standardization and lack of customization to a particular client sector were two issues raised by the case study. The study's shortcomings, which include the use of part-time researchers and application to just one case study organization, are acknowledged. It is advised to conduct more research on the Irish background as well as on ways to address the issues raised by the case study.

BENEFITS OF ADOPTING LEAN CONSTRUCTION TECHNIQUES

Lean Construction techniques offer a wide range of benefits in terms of economics, environmental sustainability, and social impact. The review paper identified 16 benefits in the construction industry related to Lean Construction Implementation. Based on their nature, these identified benefits were grouped into three groups, mainly social, economic, and environmental, as shown in Table 4.

INTEGRATION OF DIGITAL TOOLS IN LEAN FOR SUSTAINABLE CONSTRUCTION

Integration of digital tools in Lean Construction practices can significantly enhance project efficiency, reduce waste, improve collaboration, and better project outcomes. BIM and the Internet of Things (IoT) are the two advanced technologies that are widely used in the construction of buildings and infrastructure (Lee et al. 2020, Xu et al. 2018), (Woodhead et al. 2018, Kanan et al. 2018). Lean Construction can benefit from Industry 4.0 in the construction

Table 4: Advantages of Lean principles.

Advantages of Lean Principles	Description	References
Economic	Cost Reduction	Samaila & Hamid 2012, Babalola et al. 2019, Ahiakwo et al. 2013, Ansah & Sorooshian 2017, Bansal et al. 2019
	Improved Profit Margins	Babalola et al. 2019, Ballard & Howell 1998, Alhuraish et al. 2016, Banawi & Bilec 2014, Bansal et al. 2017
	Faster Project Delivery	Bynum et al. 2013, Abdelhamid & Salem 2005, Ansah & Sorooshian 2017, Babalola et al. 2019, Ahiakwo et al. 2013, Brioso 2015, Carvalho & Rabechini 2017
	Higher Return on Investment	Dineshkumar & Kathirvel 2015, Aziz & Hafez 2013, Anvari et al. 2016, Babalola et al. 2019, Eldeep et al. 2022, Gil et al. 2000, Tommelein & Koskela 2002
	Competitive Advantage	Ansah & Sorooshian 2017, Ballard & Howell 1998, Forbes & Ahmed 2003, Dombrowski & Mielke 2013, Tam et al. 2007, Eldeep et al. 2022, Ding et al. 2019
Environmental	Reduced Resource Consumption	Abdelhamid & Salem 2005, Sepasgozar 2020, Singh & Kumar 2016, Zhang & Chen 2016, Rahim et al. 2012, Womack & Jones 1996, Pamfilie et al. 2012
	Lower Carbon Footprint	Anvari et al. 2016, Tam et al. 2007, Lee et al. 2020, Babalola et al. 2019, Jiang et al. 2016, Kamara 2003, Jamil & Fathi 2016
	Sustainable Practices	Ansah & Sorooshian 2017, Li & Froese 2016, Forbes & Ahmed 2003, Kelly & Male 1992, Lakmal 2014, Koskela 1992, Eldeep et al. 2022, Lakmal 2014, Lodgaard et al. 2016
	Waste Reduction	Andelin et al. 2015, Alhuraish et al. 2016, Babalola et al. 2019, Shirowzhan et al. 2020, Issa 2013, Marhani et al. 2012, Kazaz et al. 2015, Moser & Santos 2003
	Energy efficiency	Andelin et al. 2015, Kanan et al. 2018, Phaniraj et al. 2015, Ministry of Finance 2022, Martens & Carvalho 2017, Kumar et al. 2022,
Social Benefits	Safe Work Environment	Pheng & Hui 1999, Sepasgozar 2020, Picchi & Granja 2004, Sapuay 2016, Ryan et al. 2019, Kanan et al. 2018
	Job Creation	Alhuraish et al. 2016, Rahman et al. 2013, Mohammad et al. 2016, Sarhan et al. 2018, Rahman et al. 2013, Mossman 2009, Li et al. 2019, Lakmal 2014
	Enhanced Collaboration	Abdelhamid & Salem 2005, Alhuraish et al. 2016, Babalola et al. 2019, Ballard & Howell 1998, Anvari et al. 2016, Carvalho & Jr 2017, Dulaimi & Tanamas 2001, Eldeep et al. 2022, Gran & Picchi 2004
	Community Engagement	Zhang & Chen 2016, Abdelhamid & Salem 2005, Alhuraish et al. 2016, Anvari et al. 2016, Aziz & Hafez 2013, Babalola et al. 2019, Ballard & Howell 1998, Banawi & Bilec 2014, Brioso 2015
	Improved living and working spaces	Rahim et al. 2012, Zhang & Chen 2016, Zhang et al. 2020, Womack & Jones 1996, Xu et al. 2018, Ying, et al. 2020, Woodhead et al. 2018
	Stakeholder Satisfaction	Paez et al. 2005, Salem et al. 2006, Picchi & Granja 2004, Molavi & Barral 2016, Vargas et al. 2018, Ballard & Howell 1998

Table 5: Digital tools.

Digital Tools	Advantages	References
BIM	It allows for better visualization and coordination of construction projects. BIM can detect clashes and conflicts in design early on, reducing rework and waste.	Abdelhamid & Salem 2005, Ahiakwo et al. 2013, Ansah & Sorooshian 2017, Babalola et al. 2019, Ballard & Howell 1998, Anvari et al. 2016
Lean Construction Software	Specialized Lean Construction software can help teams implement Lean principles more effectively. Helps to facilitate pull planning, production control, and the LPS enabling better collaboration and task scheduling.	Li et al. 2019, Banawi & Bilec 2014, Banawi & Bilec 2014, Bynum et al. 2013, Alhuraish et al. 2016
Kanban Cards	Helps in visualizing team workflow, tracking progress, and managing tasks efficiently.	Mostafa et al. 2017, Issa 2013, Jamil & Fathi 2016, Jiang et al. 2016, Jørgensen & Emmitt 2008,
Cloud- Based Platforms	Cloud-based platforms enable real-time collaboration and information sharing among project teams. Field workers can access up-to-date project data, drawings, and documents from anywhere, reducing delays and errors.	Rahman et al. 2013, Ngowtanasuwan 2013, Koskela 1992, Mostafa et al. 2017, Lopez et al. 2021, Pheng & Hui 1999
Digital Documentation	Tools like project management software, document management systems, and collaboration platforms enhance communication and information sharing among team members.	Abdelhamid & Salem 2005, Martens & Carvalho 2017, Molavi & Barral 2016, Lopez et al. 2021, Gatell & Avella 2024, Bag et al. 2024, Frank et al. 2024
Supply Chain Management Software	Digital Tools can optimize the supply chain by providing real-time visibility into material availability, tracking deliveries, and managing inventory efficiency.	Tam et al. 2007, Rahim et al. 2012, Ying et al. 2020, Woodhead et al. 2018, Womack & Jones 1996,
Predictive Analytics	This technology can analyze historical project data to identify patterns and predict potential issues. By using predictive analysis, teams can make data-driven decisions to optimize resource allocation and avoid potential delays.	Molavi & Barral 2016, Shirowzhan et al. 2020, Singh et al. 2014, Womack & Jones 1996, Moser & Santos 2003, Mostafa et al. 2017, Moser & Santos 2003

sector, which includes essential technology for Cyber-Physical Construction Systems (CPCS), (Shirowzhan et al. 2020). The integration of BIM and CPCS helps to improve information exchange and provide real-time data (Ying et al. 2020, Sepasgozar et al. 2018). Digital solutions that translate policies into the system in a language that is accessible to all project stakeholders may lead to improvements in performance. To monitor performance in real-time, sensors are also necessary. BIM and IoT are robust technologies with a wide range of untapped uses that may enhance the use of lean. Scholars want to connect other innovations and tools to BIM to take advantage of its capability for a variety of uses, including safety, life cycle cost optimization, quality control, and shared communication channels among stakeholders. The industry's deliverables, connections, and roles are affected by the innovative technology, procedures, and policies that make up BIM. BIM enables the improvement of project quality, and rework and, as a result, shortens the design process time.

INTEGRATED PROJECT DELIVERY IN SUSTAINABLE CONSTRUCTION

The construction industry uses Integrated Project Delivery (IPD), an open-ended project delivery strategy, to enhance efficiency, reduce waste, and improve cooperation. IPD brings together key point stakeholders, including the owner, architect, contractor, and sometimes other consultants, in a highly collaborative and integrated manner. IPD represents a departure from the traditional Construction Project Delivery System to the most modern integrated method (Abdelhamid & Salem 2005). Fig. 5 shows a brief description of Integrated Project Delivery and its advantages. Some benefits of using IPD in construction are enhanced collaboration, early involvement, risk management, improved communication, optimized design, streamlined decision-making, cost control, improved risk management, faster project delivery, higher quality, team building, sustainability, transparency, owner satisfaction, and innovation. While IPD offers numerous benefits, it is essential to note that successful implementation depends on the commitment and collaboration of all project stakeholders. It may not be suitable for every project or organization, but when applied effectively, it can lead to more efficient, cost-effective, and successful completion of projects.

DISCUSSION

Lean construction is the application of an efficient management process that helps in waste reduction and increases efficiency. This is one of the new management techniques that help in reducing time, money, and environment.

Lean Construction methods help in limited misuse of materials and time and produce the most extreme conceivable

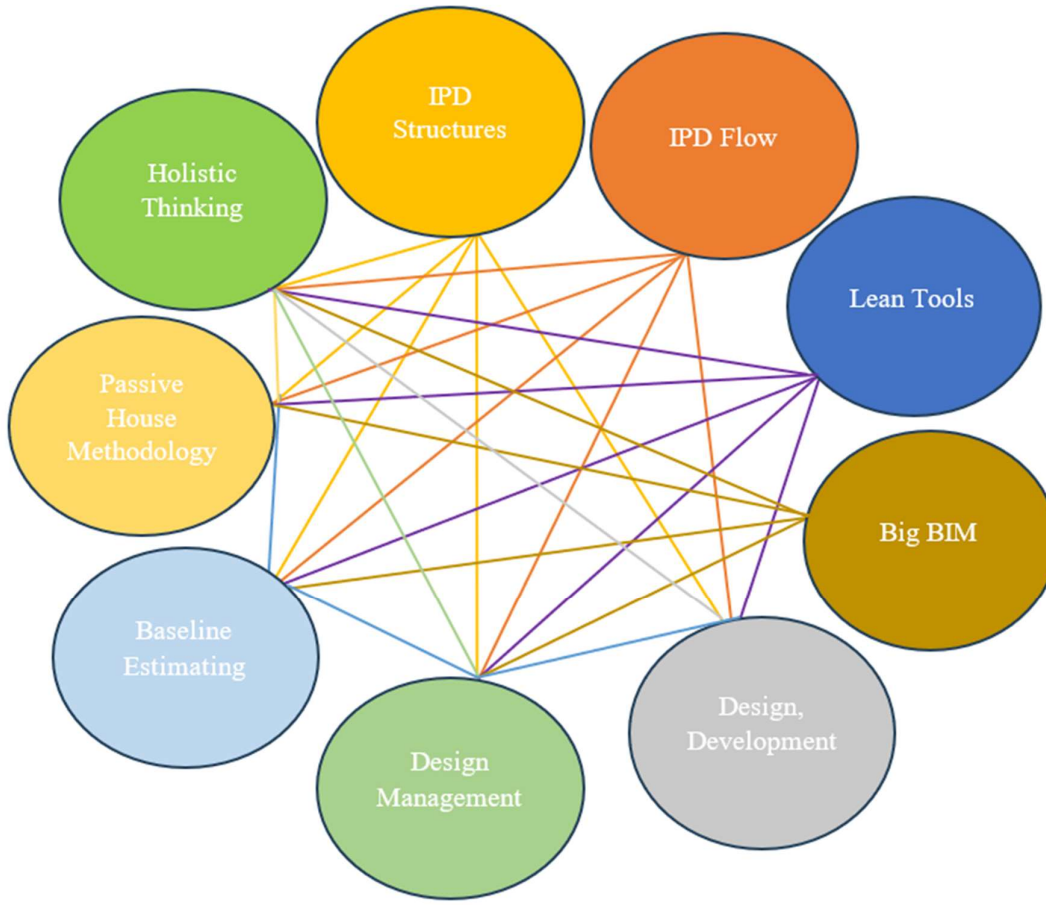

Fig. 5: Integrated Project Delivery (Ngowtanasuwan 2013).

measure of significance. This method helps to provide a general framework of work among contractors, clients, and customers. A systematic review was conducted on papers on Lean tools and Principles and their acceptance in the Indian Construction Industry. The outcome also demonstrates that the JIT, one of the 15 LCPs found in the study literature, is the most widely used. Notably, the JIT includes several lean construction planning concepts that facilitate efficient project planning, making it both a lean construction tool and a conduit for lean construction implementation. It has been referred to as a widespread, ecologically friendly, and lean construction and site management approach that has been incorporated into conventional construction procedures. The most commonly used Digital Methods are BIM, A3, Esteem Chain Mapping, 5s, and Visual Site. Fig. 1 gives a detailed description of the beginnings of Lean Production.

During the 1950s, Toyota Motor Company used the method of Lean Production. Toyota's framework has both the idea JIT and Automation. To meet exceptional customer requirements, Lean creation refers to the planning and production of items that are differentiated from mass and art types of generations by the destinations and strategy. Koskela (1992) proved how Lean Manufacturing Concepts make changes in the manufacturing sector and conceptualized them in three complementary ways, specifically as transformation, flow, and value. Lean Project Management is different from other management tools, which have a clear set of objectives for the delivery process, help in enhancing client execution at the project level, and help to control the project throughout the life span.

The LPS is the one that has been used the second most. Notably, the LPS includes several lean construction planning concepts that facilitate efficient project planning; as a result, it may function as both a lean construction tool and a conduit for lean construction implementation. LPS is a crucial component of a new production management system for production based on one-off projects, such as design and building, and it enables project managers to greatly increase efficiency and client/end-user satisfaction. Additionally, LPS is a potent strategy that managers use

when formulating work schedules, planning strategies, and operations since it encourages the development of new explicit knowledge inside a project. Consequently, it is viewed as a genuine improvement in planning and control. Tables 2 & 3 give a brief description of different levels of Lean methodologies and Lean Tools. LPS is the most well-known and widely used lean construction technique because it makes use of a variety of planning techniques, including continuous improvement, daily huddle meetings, etc. This makes it particularly well-suited for the construction industry. Table 4 identifies 16 different benefits of Lean Principles in this review. In conclusion, the benefits of lean principles are multifaceted and extend across various dimensions of an organization, from operational efficiency and cost reduction to quality enhancement and employee engagement. Embracing lean principles can position an organization for sustainable growth and competitiveness in an ever-changing business landscape.

Table 5 gives a brief description of 7 different digital tools in lean and their advantages in implementation in the construction sector. Digital tools play a significant role in enhancing the implementation of lean construction principles. These tools leverage technology to streamline processes, improve communication, and increase efficiency. This research paper gives a brief description of some of the common digital tools used in lean construction and their associated benefits. In conclusion, digital tools play a crucial role in modernizing and optimizing the construction industry in line with lean principles. These tools offer numerous benefits, including improved collaboration, efficiency, communication, and decision-making, ultimately leading to reduced waste, enhanced productivity, and more successful lean construction projects.

This review has highlighted the importance of Lean Principles and its importance in organizations to improve their operations, deliver value to customers, and foster a culture of continuous improvement. Fig. 2 gives a brief description of lean principles. It helps in reducing waste by focusing on identifying and eliminating waste in the process. This includes the elimination of overproduction, excess inventory, unnecessary transportation, and other forms of waste. Fig. 4 gives a detailed picture of the total number of articles referred to in this literature and countries. India leads among the smaller number of studies regarding Lean Principles and its implementation. Fig. 5 gives a detailed description of Integrated Project Delivery in construction, which helps to make projects more successful and efficient construction projects. It helps in enhanced collaboration, early involvement of stakeholders, helps in improving decision-making, cost saving, quality improvement, and enhanced productivity.

CONCLUSIONS

Through an organized review of the literature, this paper has discovered, classified, and analyzed the many lean methods used in the construction sector and their advantages in the sustainability agenda. The extensive body of literature leads to the following conclusions:

1. The application of lean practices to increase the construction industry's sustainability and productivity is demonstrated in this study.
2. According to the lean philosophy, to increase productivity, from design to the executive stage, the inventory network requires meticulous organization so that value is increased and waste is minimized.
3. Lean Construction Practices offer numerous advantages over traditional construction methods. These advantages contribute to increasing the efficiency of project performance and productivity, cost-effectiveness, waste minimization, and successful completion of the project.
4. The LPS, TVD, and the Lean Manufacturing Method are the three outstanding tools and methodologies that were particularly taken into consideration for sustainable construction.
5. Further, this paper discusses the Implementation of Digital Tools into Lean Construction Practices to enhance the efficiency, transparency, and overall success of construction projects.

Credit Authorship Contribution Statement

Ardra Suseelan: Conceptualization, Methodology, Reviewing, Writing, Investigation and Visualization**. Senthil Vadivel T:** Conceptualization, Methodology, Reviewing, Investigation, Visualization, Editing and Supervision**.**

Declaration Of Competing Interest

The study's authors so acknowledge that no third-party money was received from any organization to conduct the research stated in this publication. The writers further declare that none of them has any financial or non-financial interests that might jeopardize the accuracy of the work presented in this publication. No conflicts of interest are disclosed.

REFERENCES

Abdelhamid, T.S. and Salem, O.M., 2005. *Lean Construction: A New Paradigm for Managing Construction*. The International Workshop on Innovations in Materials and Design of Civil Infrastructure.

Abdelhamid, T.S. and Salem, O.M., 2005. Lean construction: a new paradigm for managing construction. *The International Workshop on Innovations in Materials and Design of Civil Infrastructure*, Cairo, Egypt.

Agrawal, A.K., 2024. Moving toward lean construction through automation of planning and control in last planner system: A systematic literature review. *Developments in the Built Environment*, 18, p.100419.

Ahiakwo, O., Oloke, D., Suresh, S. and Khatib, J., 2013. A case study of last planner system implementation in Nigeria. *Lean Construction*, 112, pp.699-707.

Alhuraish, I., Robledo, C. and Kobi, A., 2016. Assessment of lean manufacturing and Six Sigma operation with decision-making based on the analytic hierarchy process. *IFAC-PapersOnLine*, 49(12), pp.59-64.

Alhuraish, I., Robledo, C. and Kobi, A., 2016. Assessment of lean manufacturing and Six Sigma operation with decision-making based on the analytic hierarchy process. *IFAC-PapersOnLine*, 49(12), pp.59-64.

Andelin, M., Karhu, J. and Junnila, S., 2015. Creating shared value in a construction project: A case study. *Procedia Economics and Finance*, 21, pp.446-453.

Andelin, M., Karhu, J. and Junnila, S., 2015. Creating shared value in a construction project – A case study. *Procedia Economics and Finance*, 21, pp.446-453.

Ansah, R.H. and Sorooshian, S., 2017. Effect of lean tools to control external environment risks of construction projects. *Sustainable Cities and Society*, 32, pp.348-356.

Ansah, R.H. and Sorooshian, S., 2017. Effect of lean tools to control external environment risks of construction projects. *Sustainable cities and society*, 32, pp.348-356.

Anvari, B., Angeloudis, P. and Ochieng, W.Y., 2016. A multi-objective GA-based optimization for holistic manufacturing, transportation, and assembly of precast construction. *Automation in Construction*, 71(2), pp.226-241.

Anvari, B., Angeloudis, P. and Ochieng, W.Y., 2016. A multi-objective GA-based optimization for holistic manufacturing, transportation, and assembly of precast construction. *Automation in Construction*, 71(2), pp.226-241.

Aziz, R.F. and Hafez, S.M., 2013. Applying lean thinking in construction and performance improvement. *Alexandria Engineering Journal*, 52, pp.679-695.

Babalola, O., Ibem, E.O. and Ezema, I.C., 2019. Implementation of lean practices in the construction industry: A systematic review. *Building and Environment*, 148, pp.34-43.

Bag, S. et al., 2024. Building digital technology and innovative lean management capabilities for enhancing operational performance: An empirical study. *Production Planning & Control*, pp.1-20.

Ballard, G. and Howell, G., 1998. Shielding Production: Essential Step in Production Control. *Journal of Construction Engineering and Management*, 1(11), pp.11-17.

Banawi, A. and Bilec, M.M., 2014. A framework to improve construction processes: Integrating lean, green and Six Sigma. *International Journal of Construction Management*, 14(1), pp.45-55.

Bansal, S., Biswas, S. and Singh, S., 2017. Fuzzy decision approach for selection of most suitable construction method of green buildings. *International Journal of Sustainable Built Environment*, 6(1), pp.122-132.

Bansal, S., Biswas, S. and Singh, S., 2019. Review of green building movement and appraisal of rating systems in the Indian context. *International Journal of Technology Management & Sustainable Development*, 18(1), pp.55-74.

Batwara, A., Sharma, V., Makkar, M. and Giallanza, A., 2023. Towards smart, sustainable development through value stream mapping: A systematic literature review. *Heliyon*, 9(5), p.15852.

Brioso, X., 2015. Teaching Lean Construction: Pontifical Catholic University of Peru Training Course in Lean Project & Construction Management. *Procedia Engineering*, 123, pp.85-93.

Bynum, P., Issa, R.R.A. and Olbina, S., 2013. Building information modeling in support of sustainable design and construction. *Journal of Construction Engineering and Management*, 139, pp.24-34.

Carvalho, M.M. and Rabechini, R., 2017. Can project sustainability management impact project success? An empirical study applying a contingent approach. *International Journal of Project Management*, 35(6), pp.1120-1132.

Carvalho, M.M. and Rabechini, R.R., 2017. Can project sustainability management impact project success? An empirical study applying a contingent approach. *International Journal of Project Management*, 35(6), pp.1120-1132.

Dave, B., Buda, A., Nurminen, A. and Främling, K., 2018. A framework for integrating BIM and IoT through open standards. *Automation in Construction*, 95, pp.35-45.

Desai, A.E. and Shelat, M.J., 2014. Value stream mapping as a lean construction tool – A case study. *International Journal of Engineering Research & Technology (IJERT)*, 3(12), pp.354-358.

Dineshkumar, K., Ramanathan, P. and Ramasamy, S., 2015. Comparative study on prefabrication construction with cast in-situ construction of residential buildings. *IJISET – International Journal of Innovative Science Engineering Technology*, 2(4), pp.1-6.

Ding, K., 2019. Defining a digital twin-based cyber-physical production system for autonomous manufacturing in smart shop floors. *International Journal of Production Research*, 57, pp.6315-633.

Dombrowski, U. and Mielke, T., 2013. Lean leadership – Fundamental principles and their application. *Procedia CIRP*, 7, pp.569-574.

Dulaimi, M. and Tanamas, C., 2001. The principles and applications of lean construction in Singapore. *Lean Construction Journal,* 54, pp.712-721

Dunlop, P. and Smith, S.D., 2004. Planning, estimation, and productivity in the lean concrete pour. *Engineering, Construction, and Architectural Management*, 11(1), pp.55-64.

Eldeep, A.M., Farag, M.A. and El-hafez, L.A., 2022. Using BIM as a lean management tool in construction processes – A case study. *Ain Shams Engineering Journal*, 13(2), p.68.

Forbes, L. and Ahmed, S.M., 2003. *Construction Integration and Innovation through Lean Methods and E-Business Applications*. American Society of Civil Engineers, pp. 1-10.

Frank, A.G., Thürer, M., Filho, M.G. and Marodin, G.A., 2024. Beyond Industry 4.0 – Integrating lean, digital technologies and people. *International Journal Of Operations & Production Management,* 19, 1121-1130.

Gatell, I.S. and Avella, L., 2024. Impact of Industry 4.0 and circular economy on lean culture and leadership: Assessing digital green lean as a new concept. *European Research On Management And Business Economics*, 30(1), p.100232.

Gil, N., Tommelein, I., Kirkendall, R. and Ballard, G., 2000. Contribution of specialty contractor knowledge to early design. *Lean Construction,* 17-19, pp.641-652.

Gran, A.D. and Picchi, F., 2004. Construction Sites: Using Lean Principles to Seek Broader Implementations. In: *12th Annual Conference of the International Group for Lean Construction*. Helsingor.

Green, S.E., 2005. Systematic review and meta-analysis. *Singapore Medical Journal*, 46(6), pp. 270-274.

Gupta, S. and Jain, S.K., 2014. The 5S and kaizen concept for overall improvement of the organization: a case study. *International Journal of Lean Enterprise Research*, 1(1), pp. 23-40.

Hossain, M.M. and Purdy, G., 2023. Integration of Industry 4.0 into Lean production systems: A systematic literature review. *Manufacturing Letters*, 35, pp. 1347-1357.

Issa, U.H., 2013. Implementation of lean construction techniques for minimizing the effect of the risk on project construction time. *Alexandria Engineering Journal*, 52(4), pp.697-704.

Issa, U.H., 2013. Implementation of lean construction techniques for minimizing the effect of the risk on project construction time. *Alexandria Engineering Journal*, 52(4), pp. 697-704.

Jamil, A.H.A. and Fathi, M.S., 2016. The integration of lean construction and sustainable construction: A stakeholder perspective in analyzing

sustainable lean construction strategies in Malaysia. *Procedia Computer Science*, 100, pp.634-643.

Jiang, R., Wu, C., Mao, C. and Shrestha, A., 2016. Ecosystem Visualization and Analysis of the Chinese Prefabricated Housing Industry. *Procedia Engineering*, 145, pp.436-443.

Jørgensen, B. and Emmitt, S., 2008. Lost in transition: the transfer of lean manufacturing to construction. *Engineering Construction and Architectural Management*, 15(4), pp.383-398.

Kamara, J., 2003. Enablers for Concurrent Engineering in Construction. In: Proceedings of the *11th Annual Conference of the International Group for Lean Construction*. University of Salford, Salford, UK.

Kanan, R., Elhassan, O. and Bensalem, R., 2018. An IoT-based autonomous system for workers' safety in construction sites with real-time alarming, monitoring, and positioning strategies. *Automation in Construction*, 88, pp.73-86.

Kazaz, A., 2015. Fresh ready-mixed concrete waste in construction projects: A planning Approach. *Procedia Engineering*, 123, pp.268-275.

Kelly, J. and Male, S., 1992. Value Management in Design and Construction. Springer, p. 196.

Khodeir, L.M. and Othman, R., 2018. Examining the interaction between lean and sustainability principles in the management process of the AEC industry. *Ain Shams Engineering Journal*, 9(4), pp.1627-1634.

Koskela, L., 1992. *Application of the new production philosophy to construction*. Stanford University.

Kumar, K.S., 2022. Implementation of 5S practices in small-scale manufacturing industries. *Materials Today Proceedings*, 62(4), pp.1913-1916.

Lakmal, D., 2014. Managing the challenge of generational diversity in the workplace. *SSRN*, 110, pp.1-11.

Lee, J.H., Ostwald, M.J. and Gu, N., 2020. *Design Thinking and Building Information Modelling*. Springer, pp.147-163.

Li, P. and Froese, T.M., 2016. Life-cycle assessment of high-performance, low-cost homes. *Procedia Engineering*, 145, pp.1322-1329.

Li, X., Shen, G.Q., Wu, P. and Teng, Y., 2019. Integrating building information modeling and prefabrication housing production. *Automation in Construction*, 100, pp.46-60.

Lodgaard, E., Ingvaldsen, J.A., Gamme, I. and Aschehoug, S., 2016. Barriers to Lean Implementation: Perceptions of Top Managers, Middle Managers and Workers. *Procedia CIRP*, 57, pp.595-600.

Lopez, S., Gardoki, O.A. and Lizundia, E., 2021. Comparative life cycle assessment of high-performance lithium-sulfur battery cathodes. *Journal of Cleaner Production*, 282.

Marhani, M.A., Jaapar, A. and Bari, N.A.A., 2012. Lean construction: Towards enhancing sustainable construction in Malaysia. *Procedia - Social and Behavioral Sciences*, 68, pp.87-98.

Martens, M.L. and Carvalho, M.M., 2017. Key factors of sustainability in project management context: A survey exploring the project managers' perspective. *International Journal of Project Management*, 35(6), pp.1084-1102.

Ministry of Finance, 2022. Real GDP growth in 2021-22 stands at 8.7 percent, 1.5 percent higher than the real GDP of 2019-20. PIB Delhi.

Mohammad, M.F., Sham, A.B., Musa, M.F. and Yusof, M.R., 2016. The potential application of IBS modular system in the construction of housing scheme in Malaysia. *Procedia - Social and Behavioral Sciences*, 222, pp.75-82.

Molavi, J. and Barral, D.L., 2016. A Construction Procurement Method to Achieve Sustainability in Modular Construction. *Procedia Engineering*, 145, pp.1362-1369.

Moser, L. and Santos, A.d., 2003. Exploring the role of visual controls on mobile cell manufacturing: a case study on drywall technology. In: *Proceedings of the Eleventh Annual Conference of the International Group for Lean Construction*, Blacksburg, pp.418-426.

Mossman, A., 2009. Why isn't the UK construction industry going lean with gusto? *International Journal of Construction Management*, 5(1), pp.24-36.

Mostafa, S., Chileshe, N. and Jr, R.R., 2017. Can project sustainability management impact project success? An empirical study applying a contingent approach. *International Journal of Project Management*, 35(6), pp.1120-1132.

Musa, M.F., Mohammad, M.F., Yusof, M.R. and Ahmad, R., 2016. Industrialised Building System Modular System (IBSMS) Organisational Readiness Framework. *Procedia - Social and Behavioral Sciences*, 222, pp.83-92.

Ngowtanasuwan, G., 2013. Mathematical model for optimization of construction contracting in housing development project. *Procedia - Social and Behavioral Sciences*, 105, pp.94-105.

Ngowtanasuwan, G., 2013. Mathematical model for optimization of construction contracting in housing development project. *Procedia - Social and Behavioral Sciences*, 105, pp.94-105.

Paez, O., Salem, O.M., Solomon, J. and Genaidy, A.M., 2005. Moving from lean manufacturing to lean construction: Toward a common sociotechnological framework. *Human Factors and Ergonomics in Manufacturing*, 15(2), pp.233-245.

Paez, O., Salem, O.M., Solomon, J. and M, A.G., 2005. Moving from lean manufacturing to lean construction: Toward a common sociotechnological framework. *Human Factors and Ergonomics in Manufacturing*, 15(2), pp.233-245.

Pamfilie, R., Petcu, A.J. and Draghici, M., 2012. The Importance of Leadership in Driving a Strategic Lean Six Sigma Management. *Procedia - Social and Behavioral Sciences*, 58, pp.187-196.

Phaniraj, K., 2015. Lean construction: A case study at Precast Plant. *International Journal of Engineering Research & Technology (IJERT)*, 4(5), pp.823-827.

Pheng, L.S. and Hui, M.S., 1999. The application of JIT philosophy to construction: a case study in site layout. *Construction Management and Economics*, 17(5), pp.657-688.

Picchi, F. and Granja, A.D., 2004. Construction Sites: Using Lean Principles to Seek Broader Implementations. In: *12th Annual Conference of the International Group for Lean Construction*, Helsingor, Denmark.

Rahim, A.A., Zen, I., Hamid, Z.A. and Ismail, Z., 2012. Adaptable Housing of Precast Panel System in Malaysia. *Procedia - Social and Behavioral Sciences*, 50, pp.369-382.

Rahman, N.A.A., Sharif, S.M. and Esa, M.M., 2013. Lean manufacturing case study with Kanban System. *Procedia Economics and Finance*, 7, pp.174-180.

Ryan, M., Murphy, C. and Casey, J., 2019. Case Study in the Application of the Last Planner® System. In: *Proceedings of 27th Annual Conference of the International Group for Lean Construction (IGLC)*, pp.215-226.

Salem, O.M., Solomon, J., Genaidy, A.M. and Minkarah, I., 2006. Lean Construction: From Theory to Implementation. *Journal of Management in Engineering*, 22(4), pp.168-175.

Samaila, A. and Hamid, R.A., 2012. Lean construction techniques implementation in Nigeria's construction industry. *International Journal of Scientific & Engineering Research*, 3(12), pp.1-11.

Sapuay, S.E., 2016. Construction waste: Potentials and constraints. *Procedia Environmental Sciences*, 35, pp.714-722.

Sarhan, J., Xia, B., Karim, A. and Fawzia, S., 2018. Barriers to implementing lean construction practices in the Kingdom of Saudi Arabia (KSA) construction industry. *Construction Innovation*, 18(2), pp.246-272.

Sepasgozar, S., Forsythe, P. and Shirowzhan, S., 2018. Evaluation of Terrestrial and Mobile Scanner Technologies for Part-Built Information Modeling. *Journal of Construction Engineering and Management*, 144, p.1051.

Sepasgozar, S.M., 2020. Digital technology utilisation decisions for facilitating the implementation of Industry 4.0 technologies. *Construction Innovation,* 3, p.12.

Shirowzhan, S., Tan, W. and Sepasgozar, S., 2020. Digital twin and

CyberGIS for Improving Connectivity and Measuring the Impact of Infrastructure Construction Planning in Smart Cities. *International Journal of Geo-Information*, 9(4).

Singh, J., Vikas, R. and Sharma, R., 2014. Implementation of 5S practices: A review. *Uncertain Supply Chain Management*, 2(3), pp.155-162.

Singh, S. and Kumar, K., 2016. Review of literature of lean construction and lean tools using systematic literature review technique (2008–2018). *Ain Shams Engineering Journal*, 11(2), pp.465-471.

Singh, S. and Kumar, K., 2016. the integration of lean construction and sustainable construction: A stakeholder perspective in analyzing sustainable lean construction strategies in Malaysia. *Procedia Computer Science*, 121, pp.634-643.

Tam, V.W., Tam, C.M., Zeng, S.X. and Ng, W.C., 2007. Towards adoption of prefabrication in construction. *Building and Environment*, 42(10), pp.3642-3654.

Tommelein, I.D. and Koskela, L., 2002. Lean construction tools and techniques. *Des Constrme*, 18, p.504.

Vargas, A. R., Arredondo-Soto, K. C., Gutiérrez, T. C. and Ravelo, G., 2018. Applying the plan-do-check-act (PDCA) cycle to reduce the defects in the manufacturing industry: A case study. *Applied Sciences*.

Womack, J. P. and Jones, D. T., 1996. Lean thinking: Banish waste and create wealth in your corporation. *Journal of the Operational Research Society*, 48(11), pp.24-39.

Woodhead, R., Stephenson, P. and Morrey, D., 2018. Digital construction: From point solutions to IoT ecosystem. *Automation in Construction*, 93, pp.35-46.

Xu, G., Li, M., Chen, C.H. and Wei, Y., 2018. Cloud asset-enabled integrated IoT platform for lean prefabricated construction. *Automation in Construction*, 93, pp.123-134.

Ying, L., Yongping, R., Jiamin, W. and Hsiu, L. C., 2020. BIM-based cyber-physical systems for intelligent disaster prevention. *Journal of Industrial Information Integration*, 20, p. 114.

Zhang, H., Yan, Q. and Wen, Z., 2020. Information modeling for cyber-physical production system based on digital twin and automation. *The International Journal of Advanced Manufacturing Technology*, 107, pp.1927-1945.

Zhang, L. and Chen, X., 2016. Role of lean tools in supporting knowledge creation and performance in lean construction. *Procedia Engineering*, 145, pp.1267-1274.

ORCID DETAILS OF THE AUTHORS

Senthil Vadivel. T.: https://orcid.org/0000-0001-5979-718X