SUSTAINABILITY IN CONSTRUCTION SECTOR THROUGH LEAN METHODS

Abstract

The construction sector plays a pivotal role in the construction sector economy, contributing to infrastructure developments and urbanization. However, it also exerts a substantial environmental impact and resource consumption. To address these challenges and achieve sustainable development, lean methods have emerged as a promising approach. This abstract provides an overview of the study focused on sustainability in the construction sector through the application of Lean Methods. This study sheds light on the promising prospects of lean methods in promoting sustainability within the construction sector, emphasizing not only economic efficiency but also environmental and social responsibility. By adopting lean practices, the construction industry can make significant strides towards a more sustainable and resilient future.

Keywords: Lean Construction; Total Quality Management; Lean Methods; Sustainable Construction

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I. INTRODUCTION

The Indian construction industry plays a major role in the country's growth and development. As per Central Statistical Office, 2019, India's contribution to GDP is 8% [1]. Rapid urbanization is one of the major challenges faced by the Indian Construction Industry and the various steps are taken by the government in building houses and other services. By 2030 India's 40% of the population will be shifted to Urban areas [2]. The success of the construction projects mainly depends on the Decision making. Poor quality in decision-making leads to deliver poor quality of works leads to poor quality of work resulted in 70% of the time overrun projects, and a large amount of material wastage [3]. Material waste is identified as one of the major factors which badly affects the environment and reworking leads to an increase in construction cost and time. Certain new methods had to be adopted in the construction sector to improve the productivity and sustainability [4]. One of such method which was borrowed from Toyota manufacturing was Lean Method emerged in 1990 helps in increase in productivity, less wastage of time, and maximum output [5]. Traditional Methods of construction phases have a low value on the project's overall performance and productivity. The traditional methods in the construction sector provide only less low value on the project's overall performance and increase individual tasks and lesser productivity [6]. Lean construction helps to reduce uncertainty in construction projects, boost dependability and productivity, decrease waste, enhance workflow, and helps to improve overall project delivery efficiency. These resulted in more profits and lower costs [7]. Traditional Methods of decision-making can be overcome with the help of Building Information Modelling.

Poor quality in decision-making leads to deliver poor quality of works leads to poor quality of work resulted in 70% of the time overrun projects, and a large amount of material wastage [8]. Material waste is identified as one of the major factors which badly affects the environment and reworking leads to an increase in construction cost and time. Certain new methods had to be adopted in the construction sector to improve the productivity and sustainability. One of such method which was borrowed from Toyota manufacturing was Lean Method emerged in 1990 helps in increase in productivity, less wastage of time, and maximum output [9]. Traditional Methods of construction phases have a low value on the project's overall performance and productivity. The traditional methods in the construction sector provide only less low value on the project's overall performance and increase individual tasks and lesser productivity [10]. Lean construction helps to reduce uncertainty in construction projects, boost dependability and productivity, decrease waste, enhance workflow, and helps to improve overall project delivery efficiency [11]. These resulted in more profits and lower costs.

Traditional Methods of decision-making can be overcome with the help of Building Information Modelling. Waste is one of the other major issues faced by the construction sector. The building and infrastructure categories are all included in the construction industry, which is the world's largest user of resources, energy, and materials. Further the generation of large amounts of Green House gas emissions [12]. 5% of the GDP had been reduced because of environmental impact resulting in an overall increase in construction costs and time [13]. Although the lean ideology does not aim to expressly address environmental issues, it helps to increase project efficiency and plays a major role in waste reduction, both of which have an impact on environmental performance. Based on the survey

of literature LC is a method for reducing construction waste and fulfilling the needs of customers. The study analyzes the studies from several perspectives on lean wastes, principles, and tools to reveal the strong relationship between construction and environmental sustainability.

Six fundamental ideas that underpin lean construction are as follows:

- Value definition: What does value look like from the perspective of the customer?
- Define the value stream as follows: Which procedures are necessary to provide that value? Getting rid of garbage focuses on eight key waste categories
- Process flow for work: establishing a consistent, reliable process
- Pull scheduling and planning: Discuss and coordinate work with others.
- Find methods to improve existing and upcoming projects through continuous improvement.

II. LEAN PRINCIPLES AND THEIR IMPACT ON ENVIRONMENT

It is a systematic method which helps in waste reduction and provides a major contribution to improvement in production Before the emergence of Lean a lot of philosophies had been used in the construction sector but all these didn't gives much result. Lean construction, a term coined by the international organization of lean construction (IGLC) at their first conference in 1993, came into being [14]. Project completion and increased profits can be attained with the help of philosophies. Lean is built on a set of guiding principles intended to get rid of waste and help businesses to do better way at what they do. Five Lean Principles were outlined by as a means of reducing waste in business. According to Womack and Jones, one strategy for enhancing organizational performance in terms of value creation is Lean Thinking. The primary objective is to "optimize the total value," not "minimize the cost [15]. Fig 1 shows a detailed view of the Lean Principles. To overcome all these process the concept of sustainability has emerged. A philosophy known as lean building is based on lean manufacturing ideas [16].

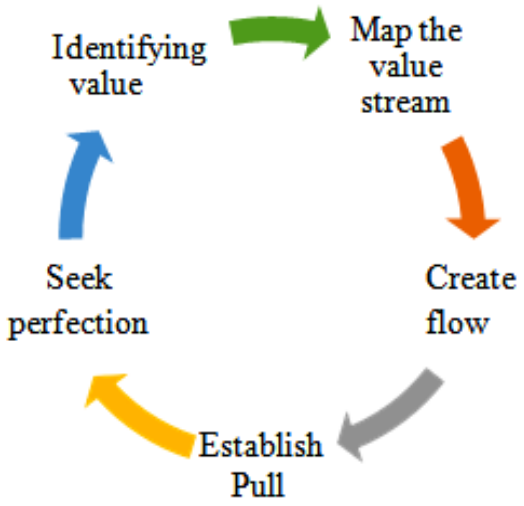

Figure 1: Lean Principles [5]

LPS controls all seven channels by establishing connections, starting discussions, and getting pledges to take action at the appropriate level and moment. The ability to judge success is one of the key advantage of LPS since it substitutes idealistic planning with practical planning [17]. Lean Tool increased visualization helps to visualize things like workflow, performance goals, and particular required actions. First-run studies frequently use images, pictures, and graphics to illustrate job instructions or show a process [18]. It is important to carefully review the initial attempt at a chosen assignment in order to generate ideas and suggestions for exploring different approaches to completing it. The study's development is advised to follow a PDCA cycle "Plan means to choose a work process to research, gather people, examine the process in the process, come up with ideas for eliminating steps, and assess the process for quality, productivity, and safety [19]. Its five levels of housekeeping can aid in reducing resource waste. In concurrent engineering the participation of all the parties in the early design is essential for the success of the Lean process development. The customer may support concurrent engineering efforts that lower projects cost, therefore the client – engineering relationship should not be disregarded. Concurrent engineering efforts might also be affected by collaboration with suppliers and subcontr actors.

The Lean Principles: Lean Enterprise Institute (LEI) introduced the concept of Lean Principles by James. P. Womack and Daniel.

T. Jones (1997). The five Lean Principles: Defining Value, Value Stream Mapping, Creating Flow, Establishing Pull, Continuous Improvement.

1. **Defining Value:** In Lean Projects identifying customer needs helps to deliver the customer needed projects. This helps to meet price and other requirements. This fundamental idea should have communicated to all project participants so that they can constantly work on what client needed [20].

2. **Value Stream Mapping:** The next step is to map the value stream after defining the value for your end-user. In order to accomplish this, each step should be described and associated process that goes into creating end product from a raw material. Design, procurement, HR, administration, delivery, and customer support are more areas where you can pinpoint the processes used to make your product [21].

3. **Creating flow:** After removal of waste from value stream we need to make sure the next processes should flow smoothly to avoid delays, obstacles, interruptions that can slow down the production and risking timeline and budget. To achieve this Value Stream should be done in a specific order. To increase the efficiency collaborating cross functional team's increases productivity [22].

4. **Establishing Pull:** Pull refers to how faster customer can get the result. Pull helps to reduce the time from years to months and months to weeks. This helps to reduce resources, money, costs. The flow established in the previous steps depends on how it exactly works [23].

5. **Continuous Improvement:** This step comes in second place only to the first if the first is

the most crucial of the five Lean Principles. It involves working for perfection in all aspects of your corporate culture [24]. You should utilize this step to specifically loop to the initial step. Yes, you must keep doing these actions. Lean project management depends heavily on this continuous improvement, also termed as kaizen in Japanese.

III. IMPORTANCE OF LEAN CONSTRUCTION

Lean construction is centred entirely on the idea of reducing waste. This comprises squandered resources, time, and labour with the aim of more effectively creating outputs of greater quality. To increase the work flow process some fundamental concepts, have to be followed. The concept of Lean can be used for companies for their new start-ups. The main aim of the Lean principles is to eliminate the waste and make the process construction process faster [25]. Wastes in construction industry will not give any value to the projects which will definitely result in increase in production cost, extended completion time and increased use of resources [26]. With the improvement in quality in construction sector, use of Lean Principles leads to make company more competitive, reduce wastes and helps to meet the changes of clients whatever they need to change without affecting the entire work. With the proper management techniques of Lean, the cost, storage space of materials can be reduced to a certain extend resulted in decreasing construction cost. Implementation of Lean is a bigger task, lack of Government support is one of the major challenges faced in the implementation of Lean. To implement Lean, the project will be divided as various sections and each section has a responsible person [27]. In certain cases, unwillingness of division of works to other responsible managers are one of the major challenges in implementing Lean [28]. Lean helps in better team management, better relation with stakeholders, increase in changing priorities in the modern world can be sorted to a greater extend gives more value to customer's perception [29]. Lean methods provide an adequate solution to this problem. Lean principle can also be applied in the business sector also to obtain a better performance and results. To consider a building as Lean building performance evaluation is required [30]. In production sector also same principles have been used. The main aim is to deliver things with less wastage and maximum efficiency. The results from all the sectors are same which resulted in less wastage, more efficiency, just-in-time delivery etc [31]. Lean construction follows a continuous flow and processes. Flow helps to divide the works equally to workers and resulted in pull planning and just-in- time delivery

IV. LEAN TOOLS

1. **Bottle Neck Analysis:** "Bottle neck analysis" is the systematic approach which helps to identify how many times project got stuck. By identifying and resolving operational and process concerns, bottleneck analysis is also used to address issues that are currently occurring as well as those that may arise in the future. Bottle neck analysis helps to improve time, money value etc [32].

2. **Just –In –Time (JIT):** With an on-demand approach called "Just in Time" helps the producers to produce manufacturing only after the client has demanded it [33]. This helps to reduce the problems of storage-related damage issues and overstock problems.
3. **Value Stream Mapping:** Value Stream Mapping is a Lean Manufacturing method that provides the visualization of all the parts required to offer a product or service. Value

Stream Mapping help in the continuous improvement process and is used in varieties of industries [34].

4. **Overall Equipment Effectiveness:** It helps to check whether the planned work and actual work happened on the same date. If the planned work is 6 hours per day and for certain miscellaneous activities, you spent 2 hours. Then the actual work is calculated by worked hours divided to planned working hours.

5. **Plan Do-Check Act:** The Deming Cycle is another name for the Plan-Do-Check-Act scientific approach to managing change. Dr. W. Edwards Deming created it in the 1950s. The PDCA cycle consists of four steps: Plan - Identify a procedure or opportunity that needs improvement, Do - Build a quick test, Check - Examine the test's outcomes, Act – Continue based on those findings [35].

6. **Error Proofing:** A common process analysis tool that is founded on the concept of prevention is error proofing, commonly referred to as Poka-yoke [36]. Poka-yoke focuses on ensuring that the proper circumstances are there before any procedure is put in place, according to Business Map, a project management software provider. Defects and human mistakes are less likely to occur as a result of this action [37].

7. **Last Planner System:** Last Planner System is developed by Lean Construction Institute and is one of the important management methods to improve worker accountability and productivity. It is one of the most effective tool used in Lean Construction. Through detailed group planning and scheduling Last Planner System was introduced by the Lean Construction Institute for increased worker productivity and accountability [38]. LPS gives more value to customers. LPS helps to create last planners to each and every work. LPS helps in continuous contact with contractor, subcontractor and workers so that lesser chances of rework, strong communications among responsible persons helps to create better productivity. Work reporting and weekly meetings of LPS helps to create a transparency in construction. The Last Planner System along with Transformation Flow Value (TFV) theory helps in proper management, planning and coordination in construction and provides greater value to customers. Improper management of materials leads to excessive increase in construction cost which leads to large amount of wastage of money and resources. Hence material management is one of the important factors in construction sector. With the help of a skilled project manager the problem can be solved to a greater extend. Lean Construction helps to reduce the waste and maintain a material management to create a sustainable construction [39]. The main two pillars of Lean are continuous improvement and respect to people. In Lean Organisations collaboration among employees, good communication can be achieved through respect among all the employees. Lean Organisations are famous in terms of less mental stress among workers because each and every member’s skills, productivity are managed equally which leads to less stress among workers in most of the company’s project failures, wastages, delays occur because of the lack of meeting among workers which should be carried out on weekly or daily basis [40]. Through weekly planning, reporting, monitoring, taking feedbacks, correcting the wrong which happened by effective collaboration LPS plays a major role. Lack of acceptance of lean among old aged contractors, engineers play a major role in less productivity [41]. Lacks of acceptance of lean due to certain cultural traditions are one of the major problems faced by the construction industry. Proper study

is required to identify the factors which is not accepting Lean methods and to find out remedies for the better improvement and development.

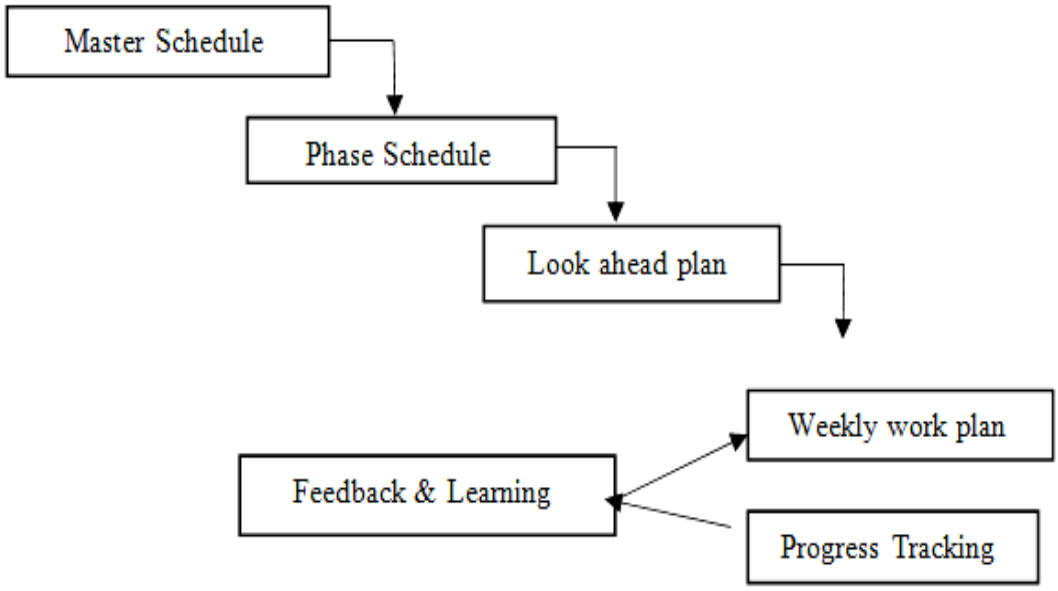

Figure 2: Last Planner System

Project management helps to manage all the works of construction from the initial stage to the final stage. In the modern world what clients needed is to visualize the things that they are proposing. Everyone chooses for better efficiency, productivity, less cost and to deliver the building as early as possible [42]. Most of the clients did not have a proper idea about the building they need to get constructed. In that case, they will definitely take the support of a design engineer or project planner. The role of the engineer is to make a plan according to the client's point of view [43].

The management of the project can be done with the help of a project manager. The client may or may not accept this work. If any corrections are needed, then the engineer has to recreate the plan again and work until the customer gets satisfied. During earlier times, software analysis or modelling is not done. In that case when a work is done if the customer needs to make any changes, or if the work is not done according to his point of view nothing can be done [44]. They had to accept that because work is already completed and if they need to make correction, they need to rework on what they had already constructed which results in increase in time, loss of money, work delay etc. All these problems can be solved with the help of software analysis and software modelling.

With the Proper resource allocation in Primavera software, client will be able to identify the expected start date, expected finish date. In most of the cases project will finish within the expected finish date. If any change in decision occurs while doing construction it may affect the whole construction process with increase in cost, time, resources etc. This case will not happen in software method, if any change occurs it can directly be entered to software and can analyse the changes in the Critical Path and

make corrections without affecting the total Float [45]. After making changes, rescheduling can be done in software's. Each activity linkage can be changed according to clients or engineers point of view at any time without affecting the entire project. Approximate Cost estimation can be done clearly before the starting of a project and can also be shared with the client. So that identify the allocation and expected cost of the project. Projects can easily visible in a single screen as table view and Gant charts in terms of Primavera. Hence software modelling has a greater acceptancy in the present modern construction industry [46].

Chart view helps to identify the relationship between work and the responsible person. Corrections can be done with the help of modify option without affecting the whole projects at any time. One main advantages of software system are that multiple projects can be worked at the same time with different folders can save all the projects in the software for future use also [47]. In Primavera budget summary, dates, findings, codes, resources calculations all these are available in a single page which makes it more user friendly to customers and also to planners. These all things cannot be implemented as a single file or in paper in traditional methods. The Lean Construction can benefit from industry 4.0 in the construction sector which includes essential technology for Cyber- Physical Construction Systems (CPCS) [48]. The integration of BIM and Cyber Physical Systems helps in improving information exchange and providing real time data.

However, there is a chance to use modern digital technologies to assist in carrying out this notion in building sites in an appropriate manner. Digital solutions that translate policies into the system in a language that is accessible to all project stakeholders may lead to improvements in performance. In order to monitor performance in real-time, sensors are also necessary [49]. 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 in order to take advantage of its capability for a variety of uses, including safety, life cycle cost optimization quality control, ands hared communication channels among stakeholders. BIM is known as one of the foundational proven technologies in the construction industry [50].

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, precise schedule scheduling, and overall project cost reduction. BIM has been used to create and manage parametric models of buildings in order to reduce document errors and rework and, as a result, shorten the design process' time. This allows for the creation of digital models, construction design, operation management of the construction process, and project management [51].

V. BENEFITS OF LEAN CONSTRUCTION

In 1992, Koskela developed the hypothesis of how lean production may function in the building sector to reap the same advantages as the automobile sector. Koskela went over

the components of the lean production theory as well as its intellectual underpinnings as a production philosophy [52]. The difficulties that practitioners would face in implementing the strategy were articulated as a production philosophy. Following are the three Koskela recognized tiers of lean production: A general management philosophy, a mode of production that was efficient and waste-free, and a set of tools for ongoing quality improvement. In addition, Koskela (2000) stated that the production of building should not be viewed as conversion activities but rather as a process flow. The elimination of non value-adding tasks like waiting, transferring, and material inspection is one advantage of adopting a process flow approach.

The reorganization of the workforce to facilitate new operating processes and the cultural changes necessary for the success of the lean production philosophy are two crucial aspects that are identified in the general management philosophy of lean production [53]. Because lean implementation in different sectors might provide varied outcomes, it is crucial for a business planning to adopt a lean production philosophy to think about what would be the best organizational structure for the new style of working. The business must also develop new tools and processes to support its new operational and managerial structures or adapt old ones to fit its particular environment. It should be highlighted that the techniques and tools are created to assist the first two parts.

Lean construction advantages fall into three categories: social, economic, and environmental. One method for raising the sustainability of the building industry is lean construction [54]. There were several instances of how lean building methods were used given in 2002 by Forbes et al. This includes a Brazilian business that worked with the University of Sao Paulo on a research effort to enhance the fusion of the manufacturing and design processes, and utilised Last Planning a 90-day building project and using the Last Best Offer is a home development in Quito, Ecuador, employing the planner control system. several of the following benefits are each presented: Motivation and dialogue within the design team affected how design aspects were integrated with direct process considerations, lean construction implementation, and Technologies for Sustainable Construction, 332 controls greatly increased production effectiveness in terms of build ability, manufacturing cost management, and non-material waste minimization wasteful but unproductive [55].

Added advantages include a decreased rework and a reduction in project length from 90 to 83 days. Lean implementation and increased quality control were made possible by The Last Planner. approaches, including Performance Factor (PF) and Percent Plan Complete (PPC) improved. On the building site, it was demonstrated that forward-thinking planning permits one to maintain a connection between current actions and the master pull schedule. It helps in evaluating the effects of implementing lean decision-supporting design procedures in construction consultant businesses utilizing a computer simulation tool in the early stages of construction projects. It was determined that using lean construction concepts throughout the design process greatly enhanced process efficiency, as measured by reduced longer process times and more resource use [56].

VI. ORGANIZATIONAL CHALLENGES IN THE LEAN CONSTRUCTION IMPLEMENTATION

1. **Process-Related Barriers:** Process-related challenges include inadequate lean knowledge and comprehension, a lack of implementation ideas and understanding, gaps

in standards and techniques, and lengthy implementation times. Mossman (2009) pointed out the lack of time for innovation, whereas Alarco'n et al. (2002) and Abdullah et al. (2009) discovered that extended implementation times were the problem in several firms. The length of the lean principles' adoption process has discouraged many firms. Lean adoption should be seen as a journey for continual improvement rather than as a short process. It calls for long-term planning, training, the adoption of a culture of continuous improvement, and system development to enable the implementation of lean (Mossman, 2009; Rother, 2010). The lack of existing standards for lean implementation is one of the biggest challenges to its adoption. Standard methods for a corporation to implement lean are lacking; this has made it difficult for organizations planning to do so. 2004 (Bernson). The difficulties of a standard were outlined by Bernson (2004). choosingthe proper amount of detail, avoiding local customization, and using a top-down implementation style are all examples of approaches to lean.

2. **Barriers Relating to People:** In many firms, problems with human attitudes and reluctance to change make lean construction difficult to adopt. Misconceptions regarding lean practice, a lack of committed leadership, inadequate leadership, a lack of cooperation, a lack of teamwork, and a lack of comprehension of client briefs are Some psychological variables toward moving Companies require employee engagement to change business culture for sustainability Culture [57]. The success of environmentally friendly Employee participation in culturally responsible practices Organizations must adapt because they are seen as complicated systems of people. It is critical that all personnel of a business 336 Sustainable Construction Technologies adjust their attitudes and values toward the environment [58]. Employees must be aware of the need for change and be able to formulate suitable answers in order to accomplish this. Employees commit to their organizations when they have a clear understanding of the future direction of the company's aims. One of the key factors in encouraging a creative workplace is organizational culture. The human aspect in an organization's culture cannot be ignored since it determines successful corporate performance and change management. In order to alter an organization's culture, changes must be made to people's values, norms, and attitudes so that they appropriately contribute to the culture of the organization as a whole. Another thing to realize is that every organization needs a unique set of cultural values [59]. There is a greater requirement for flexibility when an organization is coping with uncertain situations that call for a diversity of perspectives.

3. **Other Barriers:** Other obstacles to the adoption of lean include government regulations and the fragmented character of the building sector [60],[61]. Government policy concerns in various nations, such as inconsistent policies and unstable prices the application of lean construction is hampered by the flow of commodities. It is acknowledged that the fragmented character of the building business prevents the sector from changing [62]. An obstacle to the successful adoption of any process improvement within the construction sector is seen to be the complicated and fragmented structure of the UK construction industry. According to [63] the conventional construction process is defined by its fragmented nature and loosely coupled individuals who only participate in parts of its phases. Numerous studies have noted the impact of the construction industry's fragmentation.

VII. DISCUSSION & CONCLUSION

Lean construction is the application of efficient management process which helps in waste reduction and increase in efficient. This is one of the new management techniques which helps in reducing time, money and environment. Lean Construction methods helps in limited misuse of materials and time and produce most extreme conceivable measure of significant worth. This method helps to provide a general frame work of work among contractor, client and A systematic review was conducted on papers of Lean tools and Principles and their acceptance in Indian Construction Industry. The most commonly used Digital Methods are BIM, A3, Esteem Chain Mapping, 5s, Visual Site.

During 1950s Toyota Motor Company used the method of Lean Production. Toyota framework has both the idea Just in Time (JIT) and Automation. In order 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. In 1992 Koskela has proved how Lean Manufacturing Concepts make changes in the manufacturing sector and conceptualized in three complementary ways specifically as transformation, flow, Lean Project Management is different from other management tools which has a clear set of objectives for the delivery process, helps in enhancing client execution at the project level and helps to control the project throughout the life span.

According to the lean philosophy, in order to get work to flow reliably and regularly on a construction site, the entire inventory network in charge of built offices must be meticulously organised so that value is increased and waste is minimised. Any sane person, would concede that tools found in Lean Manufacturing and Lean Production, as refined by Toyota and others, have been altered to be used as a component of the fulfilment of Lean development criteria given their extensive scope. In the same way, tools and techniques from many fields—such as sociology and business—are applied where they are relevant. Executions of lean development also leverage the tools and techniques used in development administration, such as CPM and work breakdown structure. The Last Planner System, Target Value Design, and the Lean Manufacturing Method are the three outstanding tools and methodologies that were particularly taken into consideration for lean development.

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