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Lean readiness factors for construction organizations

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Application of the principles of the "Toyota Production Systems" and the advancements such as lean management systems for the construction projects are very beneficial. Implementation of lean systems in any organization is a journey of transformation that requires an intrinsic recognition of the need and commitment towards improvement, driven with passion by the top management, changes to existing organizational cultures and practices before it can be implemented. Studies have been documented that more than 90% of the organizations fail in their journey of lean implementation and a majority of the organizations have failed to sustain the implementation and reap the benefits thereon. Research has been conducted in SMEs and manufacturing, healthcare & emergency, humanitarian & higher education domains to identify a set of conditions/practices which indicate the state of readiness of organizations to embrace the lean journey. Currently, no studies exist which have investigated the aspect of lean readiness of construction organizations. The present study has identified the lean readiness factors for construction organizations covering all the phases of construction projects, through literature review and experts' opinions. The factors identified form the basis for the design of the framework which shall benefit construction organizations immensely for sustainable lean transformation.

Keywords: Lean Construction, Lean readiness, Readiness factors, Lean transformation, Culture

1 Introduction

Efficiency and productivity losses continue to plague the successful delivery of construction projects. Time and cost overruns are the most common symptoms, coupled with abandoning projects, litigation among parties to the contract[1]and contractual disputes[2,3]exposing the vulnerability of construction organizations and making it commercially unsustainable and unattractive business. Studies conducted in the United Kingdom indicated that rework accounts for nearly 30% of all construction work, labour efficiency is typically between 40% to 60%, 3% to 6% of total costs are attributed to accidents, and material wastage accounts for at least 10%[4,5]. The alarming and staggering drop in productivities and wastages are depicted in Fig. 1. The construction industry spends almost equivalent time in Non-Value Adding (NVA) activities (57%) as compared to the time spent by manufacturing towards value-adding activities (62%). A recent study[6] indicated the global economy suffers a cost impact of an alarming $1.6 Trillion every year because of this significant drop in productivity levels.

The success gained by Toyota through its customised production systems attracted many of the manufacturing organizations to follow and adopt the practices in their journey of continuous improvement. In the 1990s, the application gathered momentum and research studies further started investigating the application of these novel production management principles and practices to construction projects. Koskela *et al*.[8] proposed the application of production theories to construction projects by proposing the Transformation, Flow, and Value (TFV) concept in construction projects. This theory related production management to – (a) a set of operations that transform the various inputs to outputs of desired quality (b) elimination of non-value adding activities or processes from the production cycle and (c) a set of practices that understand the requirements of the owner/end-user and deliver the requirements that meet the expectations and provide value. The application of these to construction projects gradually got coined as lean construction. Over the last two decades, many of the construction organizations have harnessed the ability of this philosophy to cut down the time overruns & various types of wastages on projects, improve in the throughput, enable conditions

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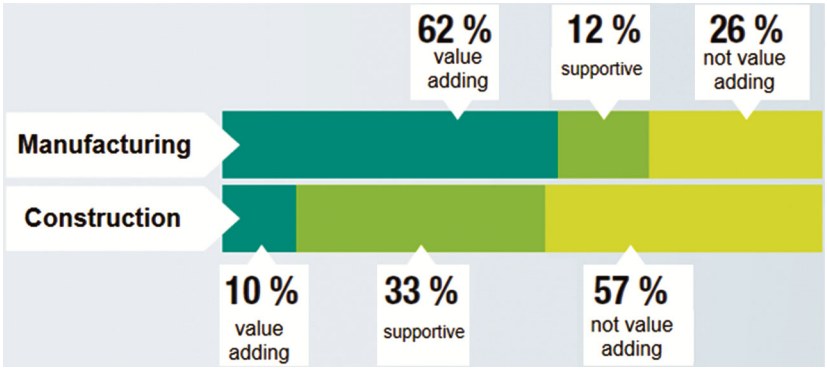

Fig. 1 — Percentage (%) of NVA activities in construction and manufacturing industries (Eastman *et al.*[7])

of collaborations, cut down the uncertainties by proactively eliminating the constraints, resources to be used optimally and most importantly deliver value to the customer. Carefully planned and properly executed application of lean principles have been found to cause significant improvements in the quality, safety and efficiency of construction projects[5].

Research studies over the last decade have made attempts to capture the progress of various organizations in their lean transformation and the lessons learnt during lean implementation. Many of the studies have reported that, although a lot of organizations undertake the initiative to implement the lean practices in the organization, more than 90% of the organizations have failed to institutionalize the lean practices[9], and have failed miserably to make a sustainable implementation[10]and have not been successful to yield any significant benefits from the implementation[11].

As compared to manufacturing organizations or any other service sector industries, construction organizations or projects are characterized by a diverse set of unique challenges. Construction projects are known for practices that lack transparency, a huge variation in the mindset, skill-set, educational levels, and cultural background of the people deployed on the projects, issues with learning, lack of access to formalized training and development schemes, unwilling snail-paced acceptance of advanced tools and technology, fluctuations and seasonal variations in the availability of skilled labour for work, language and communication barriers etc.

Lean production philosophy advocates transparency, creating collaborative working environments, reducing barriers for communication, a strong commitment from the top management and willingness to change, driven by a passion[12]. These ideologies are not common in most construction organizations and therefore, implementation of lean principles mean a change in the organizational practices and culture, upskilling of the resources and their capabilities, competencies, balancing of the core methodologies with the planned changes, and integration of efforts across the organization[13].

Organizations, therefore, need to gauge and make an assessment of the present state of their practices, culture, employee skill and awareness levels before the lean implementation itself to ensure the successful, sustainable lean practices implementation. The outcome of this assessment indicates the level of readiness of organizations to smoothly sail through to the journey of lean transformation. Many research studies have been conducted in the last decade mostly focused on manufacturing organizations to determine the "readiness levels" of the organizations which shall enable organizations to create necessary conducive conditions and environment well in advance formalization of lean management processes and to ensure the successful implementation of lean systems.

2 Materials and Methods

2.1 Research background

As indicated in the previous section, there has been very limited research in assessing the readiness of construction organizations for lean implementation. With this fundamental need and gap, the authors intend to develop a comprehensive framework for assessing the lean readiness of construction organizations. As a first step, readiness factors need to be identified covering the full lifecycle of the construction projects. The scope of this paper, however, is limited to establishing the lean readiness factors only.

The present study intends to:-

- To review the literature on lean readiness and identify themes, focus areas and key metrics of organizational lean readiness
- Specifically explore studies on lean construction management to identify best practices across the construction project lifecycle and set up lean readiness factors for each of the major process areas such as Engineering, Planning, Project control, Contract management, Waste reduction and inventory control etc.

2.2 Research methodology

Research studies have documented that the success and validity of any study significantly improve with the adoption of mixed methods or methodological triangulation. Accordingly, the present study has used a combination of the methods of a thorough analysis of literature supplemented by the opinion of the lean experts. This helps in identifying the literature gaps and also bring rich, diverse inputs benefiting the study significantly.

As a starting point, during the first stage, various literature on the area of lean readiness are systematically identified and reviewed. From the review of this literature, various focus areas, the individual KPIs and the gaps are identified. The literature review process shall continue to the second stage by carefully identifying, selecting literature related to the implementation of lean practices in various key activities of the construction project lifecycle such as Engineering, project planning, project monitoring and control, procurement, contract and/or subcontract management are looked into. As the project planning phase contributes significantly to the success of construction projects, studies related to the metrics of the Last Planner System were specifically looked into and analysed.

Selecting the right literature suiting the objectives of the study in itself is a scientific process. Literature review acts as the foundation for the entire research work. The direction of a study can be significantly influenced by the methodology adopted for the identification of literature and the type of articles reviewed during the phase. To ensure that only relevant studies are taken up for review and to eliminate any intended/unintended bias during the selection of the literature studies have proposed the Systematic Literature Review (SLR) methodology. To systematically identify relevant literature suiting the purposes and objectives of this study, the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) method of Systematic Literature Review (SLR) was adopted. The database and source chosen for the search of literature also are very important parameters at this stage. For this study, authors chose Scopus - the world's largest database of scholarly published literature. The search was carried out in the last week of April 2021 and all publications available in the Scopus database till that period were considered. The search criteria initially listed 117 documents. The search and screening criteria are explained in Table 1 and Fig. 2.

The initial list of 117 documents obtained required further screening for the selection of only those literature important for the present study. The authors also could identify 4 documents about lean practices specifically in construction projects through other sources. However, while going through the document lists, 2 duplicates were excluded. This initial list of 121 documents was further sieved through additional screening filters available in the Scopus database. The authors put English as the filter for the language, limited the subject area to Engineering and Business Management only, and only final stage publication to avoid any potential issues about a change in the publication /document characteristics at a later stage. The application of these filters brought down the list to 93 documents for synthesis.

However, all the 95 documents may not pertain to or be fully relevant for the objectives of the current research work. Hence, the title of the identified articles was reviewed. If the title of the articles were found to be consistent with the objective, the authors proceeded with the review of the abstract of the article. However, if the title of the article is not found

Table 1 — Methodology for the identification and selection of literature

Filter /search type	Parameters	Results
Keywords in Scopus database	Lean Readiness Readiness for lean Readiness for lean implementation Lean Readiness assessment	117
Relevant secondary literature	Through a review of lean practices	6
Duplicate articles	Remove duplicate articles	-2
Exclusion criteria	Limiting language to English Limiting to final publication stage Engineering Business Management	-26
Consolidation	Review article title Review article abstract Non-availability of full text	-60
Final sample size		35

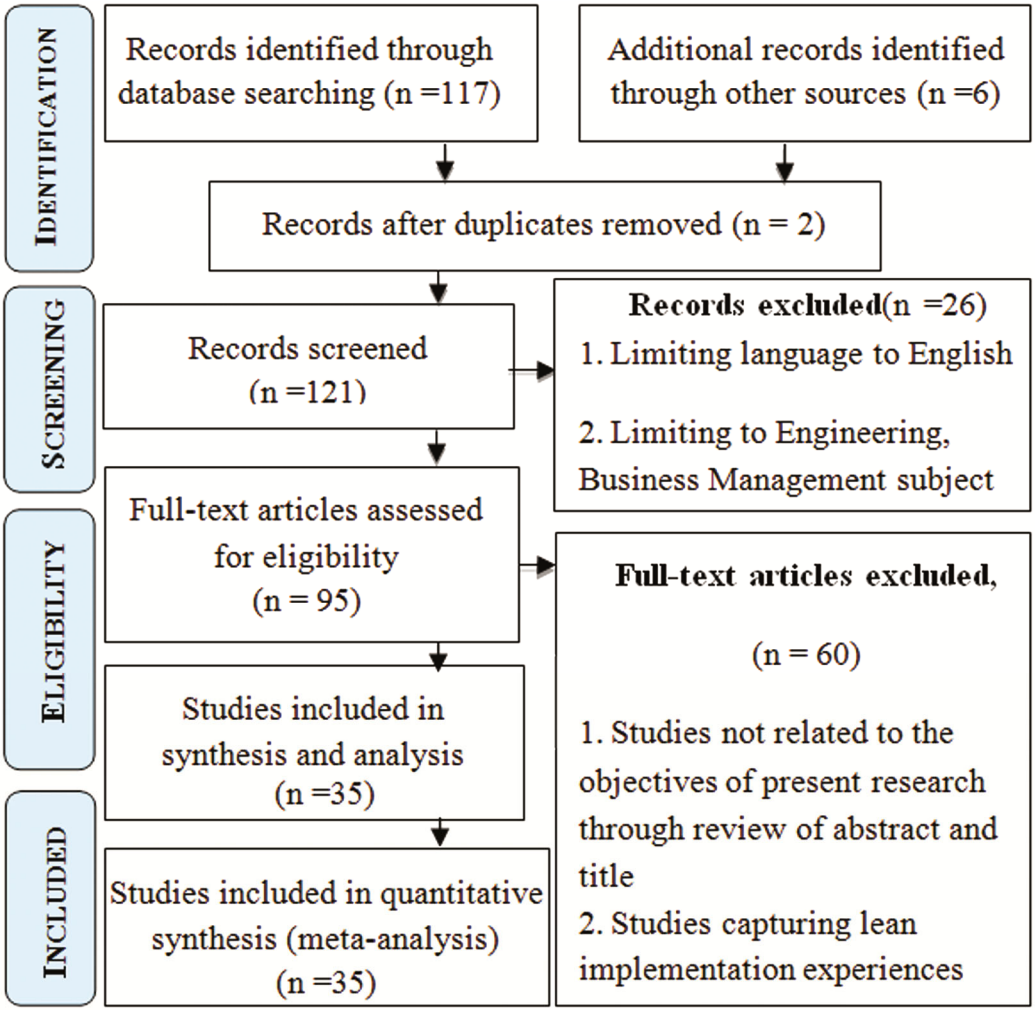

Fig. 2 — PRISMA flow for Systematic Literature Review (SLR).

relevant, the same was rejected without further examination.

The abstract of the articles whose title was found relevant was reviewed and the objectives of the particular paper, research methodology, design of the study, the results and conclusions reported by the paper, etc., were closely examined. Upon review of the abstract, if the article's objectives and scope of work were found relevant to the present study, those were selected for full-text review. Through this process, the authors excluded 60 research articles that were found to be irrelevant to the present study. Finally, 35 articles were selected for analysis. The process of literature search, screening, inclusion, and exclusion of the documents are provided in Fig. 2.

A thorough review of the finally selected 35 research articles was done. During this phase, the objective was to identify the area of investigation/sector of the study, purpose and objectives of the research, the method of investigation, statistical analysis carried out and most importantly the areas/themes and the individual KPIs were identified. Upon completion of this phase, authors identified experts having a strong foundation with immense and rich academic knowledge in the area of lean construction and also professionals employed in construction organizations with exposure/experience in implementation of lean construction methodologies and have contributed to research studies. Leading experts having international standing in the field of lean construction education and practice, from among different nations were chosen and contacted for their inputs towards this study. There was a resounding consensus among all of the experts on the need, purpose and objectives of the present study and experts readily agreed to share their

experiences and inputs to improve upon the factors identified. Table 2 summarizes the profile of the experts who participated and contributed to this study with their valuable inputs.

The initial list of factors identified through the process of the systematic literature review was organized and grouped and compiled in a spreadsheet with the major clusters/themes. An Email enclosing the detailed list of factors and the focus areas was sent out to experts requesting their valuable inputs. The E-mail was structured in three parts. The first part introduced the researchers to experts with their personal and professional information such as name, academic qualifications, industry/research experience, country, and the institution where the research was being conducted. The second part provided information on the research background, purpose, objectives of the research work, and broad research methodology. The third part related the research background with the experts' area of knowledge and research experience, seeking their valuable inputs. The factors identified through literature review were enclosed in an excel spreadsheet for the experts to review and add/amend/delete the factors as deemed fit by them.

Further, the emails and the factors recommended are coded based on the experts who participated with a numerical code. The email received from expert 1 is coded as E1 and the factors recommended by them are listed with the same coding.

2.3 Literature review

The list of finally selected 35 articles were subjected to a detailed and extensive review. The focus of the review process was to understand the nuances, lean readiness factors reflecting the state of the organization, the methodology adopted by the researchers in evaluating the lean readiness of organizations.

A study by[14]emphasized that implementing lean successfully requires a balanced focus on factors associated with people, process, and technology and designed a framework for measuring the relationships among these factors for lean transformation.

The process of systematic literature review (SLR) started by identifying the studies into various segments of industries and it was evident from the review that research studies have been conducted in other sectors and industries – in manufacturing[15, 16, 17], in healthcare institutions[18], for humanitarian organizations[19, 20] and higher education[21]to assess the organizations' readiness for sustainable lean implementation and transformation. Most of the studies focused naturally on assessing the lean readiness of manufacturing organizations. This was natural and expected as lean philosophy had originated from the Toyota Production System.

2.3.1 Studies in manufacturing organizations

The earliest study of lean readiness assessment was found to be conducted by[22]. Their study investigated the lean readiness of SME organizations in Kuwait. The study had adopted a questionnaire with 47 variables grouped into six themes of top management & leadership, human resources, supplier's relations, customer's relations, planning and control and processes. The study conducted a survey of 50 respondents from Kuwaiti SME organizations to

Table 2 — Information of the experts contributed to this study

Construction industry experience	Research/ academic experience	Country	Job designation	Number of International Research publications
32	6	India	Professor	~ 20
7	12	Canada	Associate Professor	~120
11	2	India	Assistant Professor	~10
6	4	UK	Senior Lecturer	~35
1	12	India	Assistant Professor	~ 60
2	5	India	Assistant Professor	~10
15	-	Singapore	CEO	~5
12	2	India	Assistant Professor	~10
12	2	India	Assistant Professor	~5
8	6	India	Assistant Professor	~10
30	-	India	Vice President	1
	~30	Chile	Professor	~190
	~15	Finland	Associate Professor	~90
	~30	USA	Director & Professor	~203
	`30	UK	Professor	~310
12	3	India	Senior Planning Manager	3
12	1	India	Assistant Professor	5

check for lean readiness and found out that the Kuwaiti organizations had a low level of lean readiness.

Baskaran and Lakshmanan[15] conducted a study on manufacturing organizations to evaluate lean readiness by considering the influences of critical success factors and barriers. The questionnaire survey approach was adopted with increasing scale for critical success factors and decreasing scale for barriers. The responses were then analyzed through fuzzy logic in MATLAB. The study found that the case organization was more likely to introduce lean in the premises.

Abdullah A. Alkhoraif and Patrick McLaughlin[23, 24]conducted a study to investigate the role of organizational culture in moving organizations towards the state of lean readiness. Their study found that change management, ability to sustain continuous improvement were ranked the lowest attributes in the case study organization.

Garza-Reyes *et al.*[25] conducted a study on evaluating the lean readiness of the Turkish Automotive Suppliers industry. The study identified 47 variables grouped into six groups - top management & leadership, human resources, supplier's relations, customer's relations, planning and control and processes and evaluated the lean readiness level through a questionnaire survey. The study concluded that the size of the suppliers did not have an impact on the lean readiness level of organizations.

Kumar and Murugan[16] conducted a study on three manufacturing organizations in India. The study identified 23 variables grouped into five categories of leadership skills, organizational culture, process management, communication, and employee involvement. The study evaluated the lean readiness of organizations based on a survey of 31 managers from three organizations. The study found out that only one of the organizations was lean ready while the other two organizations were still not ready.

2.3.2 Studies in other sectors

Narayanamurthy *et al.*[18], Vaishnavi and Suresh[26,27] conducted studies on assessing the lean readiness of healthcare organizations through the fuzzy logic approach. The studies identified leadership, frontline management, lean sensei and team, patients and other customer groups, supplier groups, healthcare institution attributes as the elements for readiness.

A study by Al-Najem *et al.*[17] in their study on emergency departments, stressed the aspect that assessing lean readiness in service industries is not easy as compared to that of manufacturing organizations as the nature of services provided are intangible and it is very difficult to measure these intangible services.

From the studies reviewed, it was clear that there was no study comprehensively investigating the lean readiness of construction organizations covering all the phases and processes of construction projects. The next sections of the paper present the results of the literature review and further expert opinion on the lean readiness factors identified for construction organizations.

3 Results and Discussion

As outlined in the research methodology, the initial review of lean readiness literature along with specific literature on construction projects enabled the identification of an initial list of factors that need to be extended and tailored to construction projects. The initial list of factors identified 30 attributes/factors based on the studies in other sectors and 32 attributes about construction projects. This was floated to various experts as outlined in Table 2. All of the experts had a general agreement on the need of this study and how this can fill the gap and help construction organizations to progress towards lean culture and ensure implementation of lean. Table 3 presents the response and expert opinion shared contributing to the improvement of initially identified factors.

The first author based on his experience in the construction industry has added a few additional factors which are coded as E 17. Based on the expert opinion received as above, changes were incorporated in the initial list of factors proposed. Table 4 and Table 5 summarize the results of the readiness factors. Table 4 presents the generic lean readiness factor groups and individual factors applicable to organizations which can be scaled to any type and Table 5 presents the lean readiness factor groups and factors for construction organizations across the major processes of the construction project development lifecycle.

The lean readiness factors have been broadly categorized into six themes/focus areas viz., Top management commitment & leadership, Organizational Culture, Employee Engagement, Customer focus, Communication, Technology & Process management which are briefly discussed.

Table 3 — Expert feedback and opinion received on the initial factors proposed

Expert No.	Expert feedback/comments on the initial list of factors proposed
1	Add factors/change existing factors to include top-down as well as bottom-up communication, including all stakeholders in planning, use of portable devices, split some of the factors for better readability and understanding.
2	The topic is interesting and needs research. Factors related to lean culture may be added
3	Include emphasis on short-term detailed planning as a factor. Merge points on Risk management as they imply the same
4	Factors are reviewed and they seem relevant
5	Cost/budget-related factors may be added
7	Agreed in principle. Additional detailed comments on the factors provided
8	Agreed in principle. Additional detailed comments on the factors provided
9	Include availability of technology for seamless implementation of organizational processes as a factor
11	To include involvement of last-mile employees in the planning process
12	Proposed factors found very comprehensive. To include the following factors 1. Non-hierarchical culture, reduced barriers for creativity &innovation 2. The network of commitments is actively managed in the organization 3. Value is measured & monitored continuously during project lifecycle 4. All lifecycle stages are considered in the design 5. Collaborative planning with participation of last planners 6. Focus on as planned execution than variance detection 7. Interests of all the stakeholders are aligned
13	The points are good in general. Add transparency and continuous automated measurements of processes as a factor
14	Benchmarking against competitors to be changed to learning from whomever you can including competitors
15	Factors are reviewed and this is a comprehensive set of factors
6, 10 & 16	Agreed with the factors proposed without any comments

3.1 Top management commitment & leadership

For any change initiative / continuous improvement initiative to be successful, it is very essential that the top management remains committed & supports throughout implementation[28]. Top management must be ready, willing to be involved[30, 31], spend time to resolve issues[43] and must lead the teams with humility[18]. Lean implementation requires leadership to facilitate the teams, provide all the necessary means, resources and infrastructure for implementation[16, 21].

Table 4 — Lean Readiness Factor groups with KPIs/factors

Lean Readiness Factor group	Lean Readiness Factors
Top management commitment & leadership	• Top management's support & commitment to provide the required infrastructure for implementing new improvement initiatives[28] • Organization's commitment to financial and economic objectives as well as long term survival and growth[29] • Senior Management dedicates their time to ensure the adoption of improvement initiatives[30, 31] • Leading with humility, respect for peers and subordinates
Organizational culture	• Systemic thinking, the link between corporate goals and strategic initiatives[32,33] • Existence of cooperation between firm and its stakeholders[34] • Flexibility to adapt to changing market and customer demands[16] • The organization supports and promotes a blame-free culture across all levels of the organization[21] • Culture emphasizing and promoting the team-working philosophy in projects/ across organization[30, 35] • Non-hierarchical culture, reduced barriers to creativity and innovation from all organizational levels [E 12] • Culture of seeking perfection [E 2] • Culture of embracing scientific thinking • Active management of the network of commitments [E 12]
Employee involvement and engagement	• Complete involvement of employees in all the key activities[31] • Multifunctional training is given to employees and they have the required skill-set to implement problem-solving tools[36] • Employeesare empoweredto take full ownership for improving theirprocesses and take corrective actions[37] • Employees are recognized and rewarded for their efforts • Culture supports the employees to take self-initiatives and support continuous improvement initiative activities • junior employees &the lowest level of employees are involved in the project review meetings[34, 38] • Employees are assigned clear roles and responsibilities [E 1] • Periodic feedback on employee performance

(*Contd.*)

Table 4 — Lean Readiness Factor groups with KPIs/factors (*Contd.*)

Lean Readiness Factor group	Lean Readiness Factors
Customer focus	• Selection of the right projects suiting the organizational competencies[39] • Existence of process for understanding customer requirements and what is value to the customer[35] • Customer involvement and engagement in planning and development of the project[37] • Processes and systems in place to gather customer feedback for improvement[E 17] • Value is measured and monitored continuously during the project lifecycle [E 12]
Communication	• Regular communication across the organization by the senior management regarding the vision of key initiatives[40] • The organization'svision, mission, strategy, goals, and objectives are regularly shared with all the employees[41] • Horizontal and vertical information exchanges of communication across the hierarchy[42] • Short-term wins and failures are effectively communicated to all the employees
Technology / process management	• Learn from whomever you can, including competitors but benchmark against your own previous best performance [E 14] • Measuring and analyzing the cost/benefit of key initiatives, categorizing the critical processes[E 1] • Use of performance measurement system (PMS) to understand the state of the process and pathways for improvement • Share the lessons learned from the implementation across the company • Availability of appropriate technology for seamless implementation of the organizational processes [E 9] • Control systems are set up to reduce process variations and to sustain improvement from the new initiatives

* [E] Stands for Expert as defined in Table 2

3.2 Organizational culture

Organizational culture is one of the essential areas that help in linking the strategic objectives with the lean implementation and establishes a link between important stakeholders connected with the implementation[16]. The organization should have a culture that encourages team working[18], blame-free working environment[16]. Establishing a culture that encourages a supportive working environment is one of the essential prerequisites for lean implementation[44].

Table 5 — Lean Readiness Factors for construction projects across process areas

Lean Readiness Factor category	Lean Readiness Factors
Engineering and design	• Involvement of specialist designers during the early stages of the project[52] • Exhaustive process for stakeholder requirements identification[52] • Systematic involvement and participation of clients in the design phase is sought[52] • A responsible person identifies, registers and collaboratively releases the design process constraints[52] • All lifecycle stages are considered in design [E 12]
Project planning	• Formalization of the planning and control process[52] • The correct definition of work packages[53] • Standardization of short-term & medium term planning meetings[52, 53] • Use of an easy to understand, transparent master plan[52, 53] • Emphasis on short term detailed planning [E 3] • Inclusion of only work packages without constraints in short-term plans[52, 53] • Collaborative planning with participation of last planners [E 12] • Involvement of project stakeholders in decision making in short-term planning meetings[52, 53] • Provision & commitment of adequate financial resources [E 5]
Project monitoring and control	• Use of visual devices to disseminate information[52, 53, 54] • Use of metrics to evaluate performance and corrective actions based on the causes of non-completion of plans[52, 53, 54] • Critical analysis of data & systematic removal of constraints[52, 53, 54] • Systematic update of the master plan as and when necessary[52, 53, 54] • Use of indicators to assess schedule accomplishment [52, 53, 54] • Continuous, transparent automated measurement of the process [E 13] • Use of simple portable devices for project updates [E 1] • Focus on ensuring the project is executed as planned instead of variance detection after the fact [E 12]

(*Contd.*)

Table 5 — Lean Readiness Factors for construction projects across process areas (*Contd.*)

Lean Readiness Factor category	Lean Readiness Factors
Inventory and wastage management	• "Pull" based approach for procurement planning[49, 50, 55, 56] • Rationalized planning & location of material stockyard facilities [E 17] • Existence of systems process for housekeeping, material classification [E 17] • Procurement of materials to the size, lengths and dimensions as required at the site [E 17] • Existence of practices for reconciliation of materials [E 17] • Use of IT tools to optimize the usage of resources consumption and cost reduction [E 17] • Cost of quality and rework is analyzed and controlled [E 17]
Contract management	• Interests of all stakeholders are aligned [E 12] • Structuring of agreements with key risks shared[57] • Transparency of operations through open-book accounting[58] • Substantial and regular communication to deal with emerging issues[16] • Existence of an incentive mechanism linked to project KPIs[59]

* [E] Stands for Expert as defined in Table 2.

3.3 Employee engagement

The successful lean implementation extends beyond the tools and techniques. It is more of a process in itself that requires employees to be fully aware of the methodologies involved, complete involvement of the employees[31], empowerment of employees to take full ownership[37], employees to be provided with periodic, regular, multifunctional training[36]. In addition, employees also need to be recognized for their efforts and rewarded[45].

3.4 Customer focus

Developing products and providing services that provide/enhance value to the customer is at the core of lean philosophy. The ability to define the customer is a key requirement for applying lean in any organization[46]. Organizations need to have processes that keep the customer at the centre of key processes, engage with them during improvement/change initiatives and seek feedback at all stages[20].

3.5 Communication

Communication is one of the critical factors that aid in successful lean implementation. The top management should frequently communicate the strategies and progress of key initiatives[40], there should be mechanisms that encourage two-way communication[42], communication across different departments/verticals, periodic meetings with the employees and processes to share the knowledge across the organization.

3.6 Technology and process management

Organizations should constantly explore avenues for improvement and this may require cost/benefit analysis of the key processes, eliminating non-value adding activities and mapping the value-stream stream of key processes. Organizations shall institutionalize a conducive environment that encourages them to learn from failures, learn from competitors, improve upon the previous performance and supports the initiatives through technology that is appropriate and ensures the seamless implementation of initiatives.

However, the above does not cater to the construction project-specific processes and this requires that lean readiness factors across all the important project lifecycle stages are identified. There have been very few studies[47] that have looked at lean readiness in construction projects. Other studies have been in isolated individual domains[48, 49, 50]. Keeping in mind the Integrated Lean Project Delivery (ILPD) / Lean Project Delivery System (LPDS) stages shown in Fig. 3 adopted from[51], the themes/categories of lean readiness factors holistically integrating the various phases/processes of the construction projects are identified.

The extension of the readiness factors for construction projects at each phase of the project are summarized in Table 5 and are discussed in the following sections of the paper.

3.7 Engineering and design

One of the first processes during the construction project lifecycle is the Engineering & design process. To identify the lean readiness factors pertinent to this stage, the work by Herrera *et al.*[48] was referred to that investigated the lean design management aspects in construction projects. Some of the essential attributes of lean readiness at the design management stage are involvement of specialist designers during the early

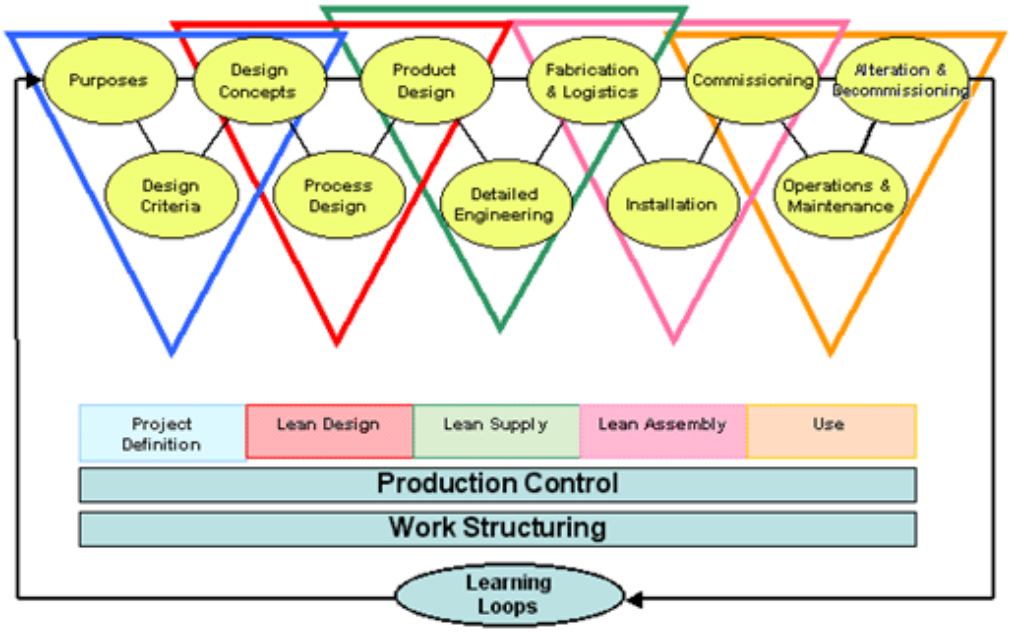

Fig. 3 — Lean project delivery system[51].

stages of the project, setting up of processes that assess the requirements of all the stakeholders, involvement of clients/customers, considering all the stages of the project during the design stage etc.

3.8 Project planning

Project Planning is one of the most critical processes in the construction project lifecycle that sets up the direction for the project. Last Planner System® (LPS) is one of the most successful philosophies for improving the efficiencies of the planning processes[60] and the works by Soares *et al.*[52], Sterzi *et al.*[53] and Viana *et al.*[54] have defined various attributes for successful planning based on lean principles. These attributes include having a formalized planning process, defining the work packages correctly, involvement of the last level of planners in the process, transparent master plan and prioritizing activities that are constraint-free for execution.

3.9 Project monitoring and control

Once the plans are created, the success of the project is ensured by a robust monitoring process that ensures the plans are executed on the ground successfully. The lean readiness factors identified that this stage of the project is – periodic analysis of data and systematic removal of constraints[52, 53, 54], systematic update of the project master plans, use of portable and visual devices to assess the status of execution and disseminate the communication and proactive correction of the plans.

3.10 Inventory and waste management

Minimizing wastes of all forms is one of the essential lean principles. The lean readiness factors identified during this stage focused on processes that optimize the procurement, minimize the inventory and reduce wastage. The factors identified included – pull-based procurement mechanisms, systematically and rationally designed stores and stacking facilities, a regular reconciliation process that analyzes the planned consumption of materials vs. the actual consumption and wastages, and the use of IT enabled tools to optimize the resource consumption.

3.11 Contract management

Lean advocates transparency, collaborative working with all stakeholders. The lean readiness factors identified largely align with the relational contracting systems that ensure that interests of all the stakeholders of the projects are aligned, sharing of the project risks, transparency, frequent and regular communication with stakeholders on contractual issues to address them proactively and a reward system linked to the performances on the project.

3.12 Further research on Lean Readiness Framework

The authors' further research work is to develop a detailed evaluation model/framework based on the lean readiness factors identified in this study. The

authors intend to explore the approaches of the Analytic Hierarchy Process (AHP) or Fuzzy methods to determine the weights for all the identified themes and factors. Once weights are determined, the model can be developed. With the prepared model, the authors would like to conduct the lean readiness evaluation of the construction organizations in India through the selection of some case projects/organizations.

4 Conclusion

Construction organizations continue to be facing the issues of efficiency losses year on year. The industry also is alarmingly lagging in terms of productivity levels and wastages as compared to manufacturing and other sectors. Lean construction as an extension of production management philosophy is found to be benefitting many of the organizations and projects wherever it has been successfully implemented. Despite its advantages and the benefits, it can create in the development, and management of construction projects, the industry is yet to take up lean construction as a core methodology/practice. Studies also have indicated implementation of lean construction methodologies requires preparation, planning, change and tuning of the existing processes of the organization to that of the practices encouraged by lean construction. Hence, "readiness for lean implementation" is an important stage of evaluation without which implementation would be futile. There is no assessment framework available presently to evaluate the lean readiness of construction organizations. The present study has identified this gap and is the first study to develop a set of comprehensive lean readiness factors for construction organizations. These factors shall act as the foundation for designing the framework for lean readiness assessment which shall help organizations go through a lean readiness evaluation and identify areas of improvement. This assessment shall help organizations improve on the weak areas. This shall prevent failures and ensure the successful implementation of lean construction practices across the organization and contribute to the progression, advancement of the construction industry.

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