International Journal of Applied Research 2017; 3(8): 348-356

ISSN Print: 2394-7500
ISSN Online: 2394-5869
Impact Factor: 5.2
IJAR 2017; 3(8): 348-356
www.allresearchjournal.com
Received: 23-06-2017
Accepted: 24-07-2017

Anirban Deshmukh
Post Graduate,
Department of Civil Engineering (Infrastructure), Birla Institute of Technology & Science, Pilani, Rajasthan, India

Correspondence
Anirban Deshmukh
Post Graduate,
Department of Civil Engineering (Infrastructure), Birla Institute of Technology & Science, Pilani, Rajasthan, India

A review on lean construction approach and its application in construction sector

Anirban Deshmukh

Abstract
The production efficiency in the construction sector has been declined over the past few decades. When in the late 1950s, Toyota Motor Company introduced Lean Manufacturing approach, it resulted in performance improvement in productivity as well as reducing the waste production without spending extra money or time. Over the decades by improving and modifying that approach "lean construction" (LC) had been developed. LC is a new form of production management for the construction sector which features some vital objectives like "delivery process", "maximizing performance at the project level", "concurrent design", "project control" (throughout the lifecycle of the project from design to delivery). This paper demonstrates how "lean" thinking can be incorporated into construction sector and advantages/disadvantages of it over traditional approaches. The Last Planner System technique which is a vital application network of lean construction approach is demonstrated briefly – how it can be implemented and the expected results from it. Also, a performance improvement based model has been included showing and describing the relationships of all of the involved components. In general, LC projects are easier to manage, economically feasible, saves a lot of the project time, reduces losses, reduces waste production and delivers a better quality outcome.

Keywords: Lean construction, last planner system, performance improvement, construction industry

Introduction
Lean production approach had been first coined and implemented by Toyota Motor Company in the 1950s. At that time, Toyota production system had 2 major principles: (1) "Just-In-Time flow" (JIT) and (2) "Autonomation" (smart automation). The term ''lean'' by definition is about attaining an all in balance in terms of materials, resources, and people working on a project (Lim 2008) [19]. This paves the path for reducing project costs, eliminating or reducing waste production and finishing the job in time. Lean production management has caused a revolution in manufacturing design, supply, and assembly (Lean Construction Institute, 2012) [20]. What started with manufacturing production, the implementation of lean techniques has now been extended to construction sector also as to meet customer wishes while spending less of everything (Howell, 1999) [1]. Sustainable construction is viewed as a way the construction industry will be able to achieve sustainability in terms of development, while also taking environmental, socio-economics and social or political issues into consideration (Shafii *et al*., 2006) [2]. For example, green building construction is able to lessen the overall cost of a project while still sustaining the quality of the environment. To achieve a complete sustainable environment, the construction industry needs to abandon their traditional approach towards construction and implement lean construction (LC) techniques to get an energy efficient, time-saving and less waste generating results (Abdullah *et al*., 2009) [3]. Many well-known researchers such as Lim (2008) [19], Abdullah *et al*. (2009) [3], Koskela (1992) [4] have confirmed that LC offers several benefits when properly applied in the construction projects. Its main advantage being cutting down the overall construction cost by using appropriate materials and generating less waste at the sites (Suresh *et al*., 2011) [5] and it is done by proper project planning at the very beginning. Also, having a proper project planning will reduce the length of the construction time. Koskela (1992) [4] advised 3 principles of production philosophy which needs to be applied at the early phase of project. It include tools (i.e. 'Kanban' and quality circles), a manufacturing scheme and a management viewpoint [i.e. "Just-In-Time" (JIT) and "Total Quality Control" (TQC)].

In border terms, all of the key features of LC are "Lean manufacturing", JIT, TQC, "Total Productive Maintenance" (TPM), "Concurrent engineering" (CE), "Value-based strategy", "Employee involvement", "Time-based competition", "Benchmarking", "Visual management" "Reengineering" and "Continuous improvement". Alinaitwe (2009) [6] has shortened and streamlined the key conceptions of LC by including JIT, 'Total Quality Management' (TQM), CE, 'Business Process Re-engineering' (BPR), 'Last Planner System' (LPS); 'Value Based Management' (VBM) and 'Teamwork'. Six Sigma is a disciplined, data-driven approach and methodology for eliminating defects (driving toward six standard deviations between the mean and the nearest specification limit) in any process – from manufacturing to transactional and from product to service. It is normally denoted as "6s" and similarly "5s", "4s" etc. will represent Five Sigma, Four Sigma etc. respectively. The relation of Six Sigma with Health and Safety and Environmental Management System is forming the key concepts of LC and giving the output of maximizing benefit values and minimizing waste. The given fig. 2 can be used to compare the primitive approach of Lean production in 1950s (fig. 1) and notice the improvements. In 2005 [7], Salem *et al*. gauged the usefulness of six LC main conceptions at the University of Cincinnati's "the garage project". His data gathering were consists of survey on sites, interviews, questionnaires and various document analysis. The important conceptions involved were LPS, daily hurdles meetings, 5s (housekeeping) process, increased visualization, first run studies and a failsafe for quality & safety. On basis of the discoveries, the implementation of 5s process and failsafe for quality & safety failed to meet the expectations due to increase in budget. Behavioral changes and training for effective use of main concepts was needed and rest of the crucial notion designated for the project were either already in use or were suggested with slight adjustments. Likewise, Adamu and Abdul Hamid (2012) [8]'s study examined LPS using four main features and applied them in the construction of housing units in Yobe State Government of Nigeria. Due to some limitations, "5s" was not tried. The data collecting procedures was comprised of direct involvement in the production management, survey, interviews and questionnaires. On basis of the discoveries, with effective training and full implementation of LPS and partial implementation of the other vital features had reduced waste production on site. Furthermore, there was a need of co-operation from the top management in order to increase the interest of LC amid the shareholders. As mentioned earlier, LC have certain principles and going by the definition given by lean enterprise institute (2009) it will have five key points as can be seen in fig. 3. On the other hand, Koskela (1992) [4] coined 11 principles for LC; while Womack and Jones (1996) [21], Lim (2008) [19] and Bashir *et al*. (2011) [5] - all of them mentioned only 5 principles for LC (Table 1).

Table 1: LC Principles as suggested by researchers

Authors	LC Principles
Koskela (1992) [4]	Reduce non-value-adding activities
	Increase output value
	Reduce variability
	Reduce cycle time
	Minimize the number of steps, parts and linkages
	Increase output flexibility
	Increase process transparency
	Focus control on the complete process
	Build continuous improvement into the process
	Balance flow improvement with conversion improvement
	Benchmarking
Womack and Jones (1996) [21], Lim (2008) [19] and Bashir *et al*. (2011) [5]	Specify value
	Identify the value stream
	Flow
	Pull
	Pursue perfection
Lean Enterprise Institute (2009)	Identify value
	Map the value stream
	Create flow
	Establish pull
	Seek perfection

Table 2: LC Principles in Construction sector as suggested by Researchers

Authors	LC Principles in Construction sector
Cain (2004)	Delighted end users
	End users benefitting from the lowest optimum cost
	Elimination of inefficiency and waste
	The involvement of suppliers to achieve integration and buildability
	A single point of contact for the most effective coordination and clarity of responsibility
	Establishment of current performance and improvement achievements by measurement
Salem and Zimmer (2005) [7]	Customer focus Culture/people
	Workplaces standardization Waste elimination Continuous improvement/built-in quality

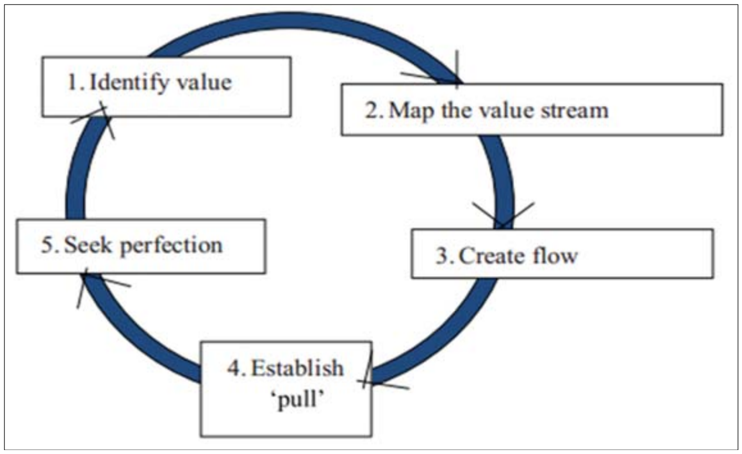

Fig 1: LC Principles (Source: lean enterprise institute (2009))

For construction sector, principles were defined separately; while suggested 6 principles to be achieved, Salem and Zimmer (2005) [7] went for five. So, in order to implement LC techniques successfully, construction sector needs to maintain all the major principles as suggested by researchers and incorporate concepts of LC at the correct phases of construction.

Application networks of LC

Lean Project Delivery System (LPDS): LPDS consists some functions, decision-making rules, procedures for how to execute the functions, and few carrying out aids and tools, as well as software when suitable. Ballard (2000) [22] developed this conceptual framework to guide the operation of LC on project-based production system. LPDS is a model with 5 main phases and each phase is consist of 3 modules (Fig. 2). In the figure, the interdependency of the phases can be noticed where two neighboring phases shares one module. Production control and work structuring both extends through all of the main phases and "Learning Loops" is there to highlight the requirements of documenting learned lessons from 1 meeting to another.

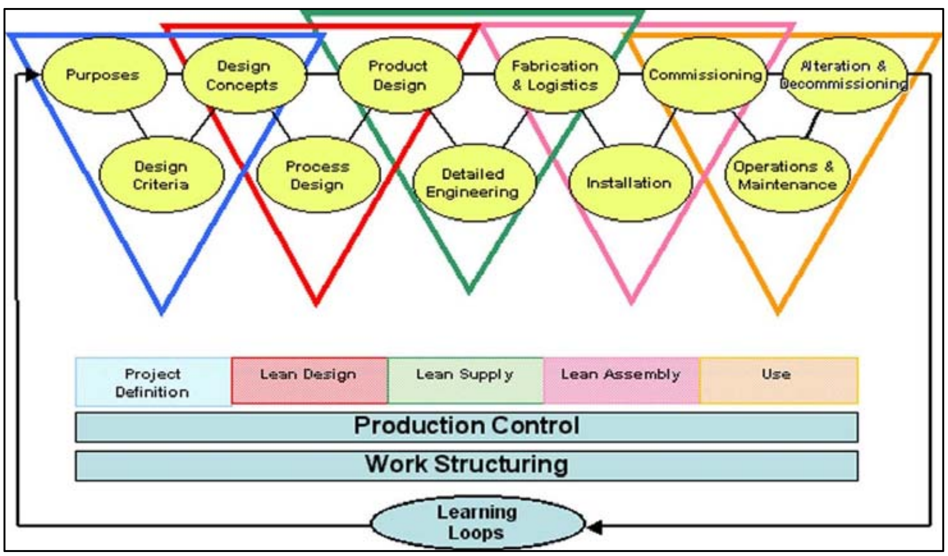

Fig 2: Highlighting the main features of LPDS

The LPDS model features a total of 15 modules of which 11 is organized in proper way and they are connected to 4 interconnecting triangles starting from "project definition" and finishing with "lean assembly". Also, 2 "production control" modules and a "work structuring" module both considered to spread through all of the project phases. The "post-occupancy evaluation" module connects the end of 1 project period to the start of the next:

a) "Project Definition": (a) "Needs and Values Determination"; (b) "Design Criteria"; and (c) "Conceptual Design";
b) "Lean Design": (a) 'Conceptual Design'; (b) 'Process Design'; and (c) 'Product Design';
c) "Lean Supply": (a) 'Product Design'; (b) 'Detailed Engineering'; and (c) 'Fabrication/Logistics';
d) "Lean Assembly": (a) 'Fabrication/Logistics'; (b) 'Site Installation'; and (c) 'Testing/Turnover';

And e) "Production Control": (a) 'Work Flow Control'; and (b) 'Production Unit Control'.

When it comes to counting vital LPDS features, they can be written as follows: (1) Structure and project management are there to create values; (2) Cross-functional team involves in planning and design and members are from all production process zones; (3) "Project control" would be performed throughout the venture; (4) Optimization efforts are fixated on workflow reliability and does not emphasis on improving yield; (5) Pull techniques governs the flow of resources and info; (6) Capacity and inventory buffers absorbs inconsistency in the production process; (7) Feedback loops are fused at each level and are aimed towards fast system adjustment; and (8) Work structuring upsurges value and diminishes waste during the project delivery level. By improving performance at the planning stage, project performance increases.

Last Planner System (LPS): Improvement in planning and control processing is an effective approach in increasing productivity of a construction industry. In LC, planning and control are two balancing and dynamic processes and throughout the progression of the project, they are maintained. Planning stage outlines all the criteria's, generates strategies vital to fulfill project objectives. Control process ensures that every event will occur as per the sequence mentioned in planning. Re-planning needs to be done when the earlier established sequences are no longer appropriate. Feedback facilitates helps to learn when the events do not occur as per planning [Ballard (2000) [22]; G. Howell, G. Ballard (1998) [23]. Last Planner System is a very effective instrument for the construction management and it continuously monitors the planning effectiveness, assisting in foresight development, making smooth workflow variations, and reduces/removes uncertainties associated with construction processes. It mainly comprises of "workflow control" and "production unit control". "Workflow control" is accomplished primarily via the forecasting process, while "production unit control" is done through weekly planning of work.
According to Mossman [2005] [25], last planner system is for jointly handling relationship networks and exchanges requirement for coordination of programs, planning of production and delivery of the project, by promoting exchanges between trade foreman and site management at apt points of detail before the issue becomes serious. Last Planner System's objective is to divert the attention of control from workers to workflow which connects them together. The two core goals of
LPS are – 1) to create superior projects by directing the workers through continuous process of learning and teaching them how to take correct action and 2) to channel the work to flow across all production units in the best sequence possible with better efficiency. The LPS integrated modules are: master-plan, planning of phases, forecast planning, weekly planning of works, "Percentage of Promises Completed" or "Percent of Planned Completed" (''PPC'') on time (is used to measure the success of LPS) and "reasons for incompleteness". When all the modules are systematically applied – they can bring several benefits to construction management practices. PPC only measures planning efficiency, but indirectly the PPC values are connected to both production and productivity. It is presumed that when a project team have proper planning from the start, and able to shrink the variations were able to increase the overall productivity by matching resources narrowly towards demand for them, thus be able to reduce waste in the process. After executing weekly work plans, a previous work report is made for analysis purpose, then PPC is obtained using

$$\frac{the\ quantity\ of\ works\ effectively\ completed}{the\ total\ quantity\ of\ works\ that\ had\ been\ planned}$$

After that, a re-programming of the services is made which indicates "the services that had already been executed" and those which "had been planned but were not executed". This allows to calculate a new date on which the construction work will be finished (Auada, 1998) [25]. As from the Fig. 3, it can be observed that, after implementing LPS in construction sector there is a positive result both in terms of increase in productivity and on budget (L. Alarcon, 2001) [26]. As stated by Fernandez *et al*. (2013) [27] benefits credited to LPS operation were as follows: (1) "smooth work flow", (2) "predictable work plans", (3) "reduced cost", (4) "reduced time of project delivery", (5) "improved productivity", and (6) "greater collaboration with field personnel and subcontractors". Fernandez *et al*. (2013) [27] also described the certain obstacles encountered by partakers when they apply LPS and those challenges are as follows: (1) "lack of leadership", (2) "organizational inertia", (3) "and resistance to change", (4) "and lack of training", (5) "contractual issues", and (6) "lack of experience and knowledge".

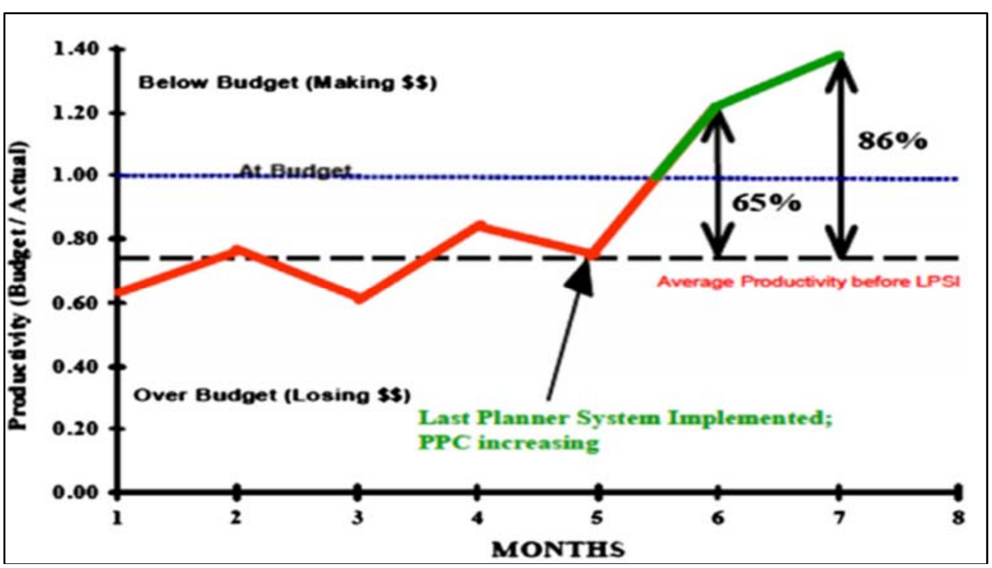

Fig 3: Productivity improvement for the companies by using LPS

LPS has 4 major elements [Mossman, 2005] [25]: (1) "Programming Workshop": Creating a sequence for the production process (and compacting it if necessary); (2) "Make-Ready": Tasks are always completed so that whenever there is a need, immediate fulfillment is possible; (3) "Production Planning": Planning the upcoming tasks of production process for the next day or week; and (4) "Continual Improvement": by learning from past and through experience or training.
The several differences of traditional approach of Critical Path Method (CPM) and lean thinking of LPS approach can be identified in table 4. It is clear that on all of those mentioned occasions, LPS have a huge advantage over CPM.

Table 3: CPM vs. LPS

Critical path method	Last Planner System
CPM logic embedded in software	Applied common sense
High maintenance	Low maintenance
Managing critical path	Managing variability
Focus on managing work dates	Focus on managing workflow
Planning based on contracts	Planning based on interdependencies

Last Planner System is built on a traditional planning approach and is executed by field personnel's. The situation of "SHOULD-CAN-WILL-DID" is applied in LPS and Fig. 4 and 5 represents how the idea is a part Last Planner System.

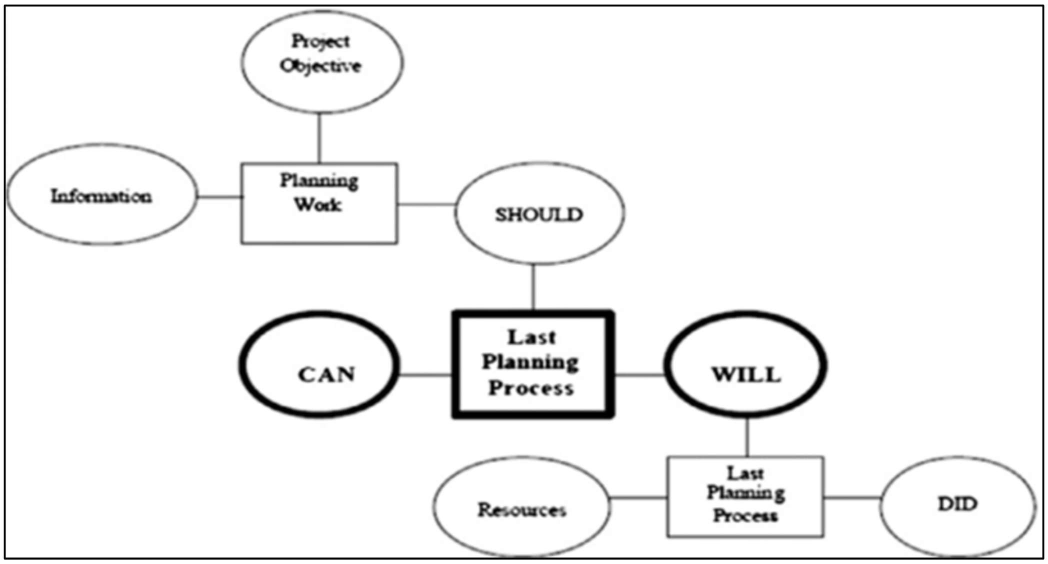

Fig 4: SHOULD-CAN-WILL-DID of LPS approach [G. Howell, (1998) [23]]

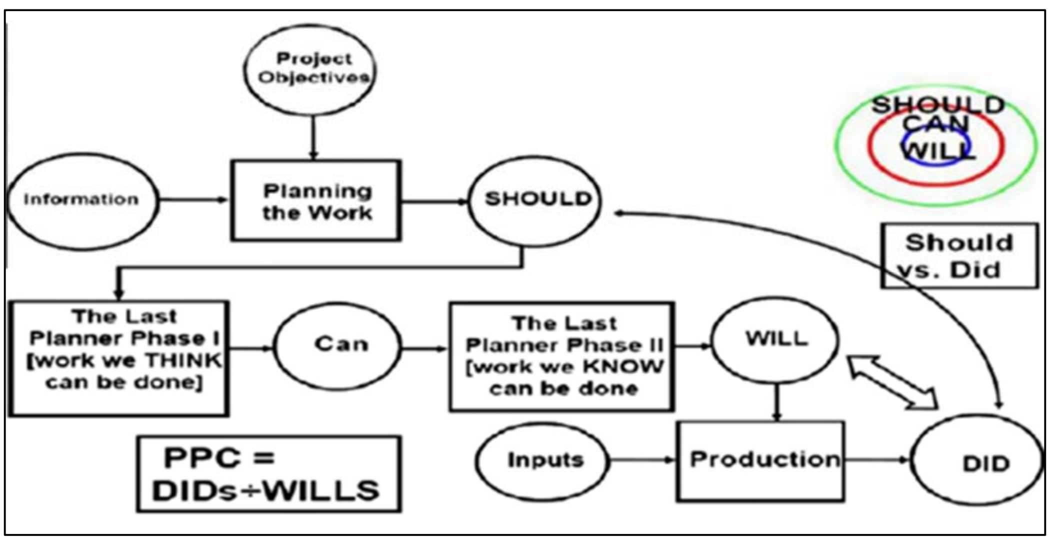

Fig 5: Should-Can-Will-Did Of Lps Approach [Lean Construction Institute. (2012)]

A project phase or assignment which is finished at required time regulates what WILL be done, after bearing in mind both what SHOULD from high-level plans and what CAN be done based on the situation at hand. Only an assignment is well-defined, resource-sound, one which have a right sequence, and within the limit of the crew – is more likely to get finished on time. A planner's job is to make sure an assignment is meeting all those criteria's by adding tasks that fulfill it and reject those who do not. By the definition of G. Howell, G. Ballard (1998) [23]: "To be effective, production management systems must tell what should be done, what can be done, and what will be done and then compare what was done to improve planning". The term SHOULD here denotes: "Hopefully"; CAN stands for: "Probably" and WILL denotes: "Absolutely". Fig. 6 demonstrates the probable relationships among SHOULD-CAN-WILL. "A" in fig. 6 represents the situation with the highest possibility of task completion and diagram "B" shows the probability of failure. Diagram "A" is well-defined, resource-sound, have a right sequence and within the limit of the crew – so it is more likely to get finished on time; while on other hand Diagram "B" is disorganized and needs to control the variability's, hence the probability of completing the task at required time decreases.

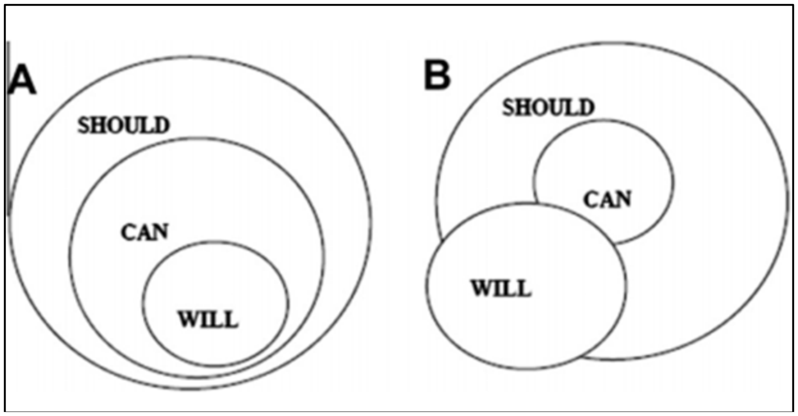

Fig 6: Probable relationships among SHOULD-CAN-WILL

Last Planner System has 4 stages G. Howell, 2000 [29]: (1) "Master Schedule": set mileposts and identifying the strategy for long leading objectives; (2) "Phase Schedule": Pull-planning (identifies handoffs and operation conflicts); (3) "Look-ahead Plan": To ensure that work is always completed so that whenever there is a need, immediate fulfillment is possible; re-planning in case of necessity; and (4) "Weekly Work Plan" (WWP) : Creation of the work sequence in a certain manner, commitment to perform it as mentioned, learning from past mistakes and through experience or training, observing the reasons for failure properly. Fig. 7 gives a detailed illustration of processes involved in LPS.

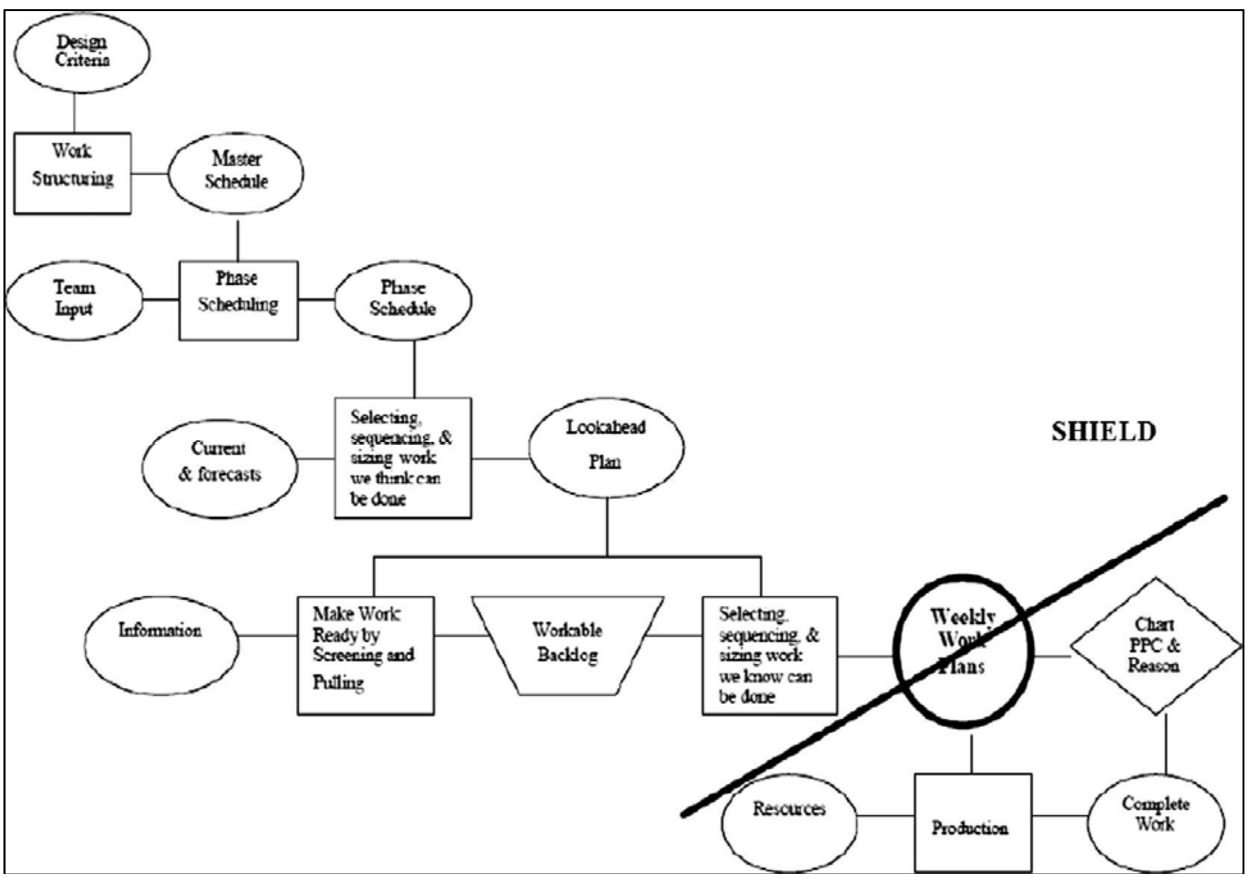

Fig 7: Process of LPS

Fig. 8 explains the sequences of LPS in which it should be implemented and Fig. 9 explains how Last Planner System is able to achieve "lean" model.

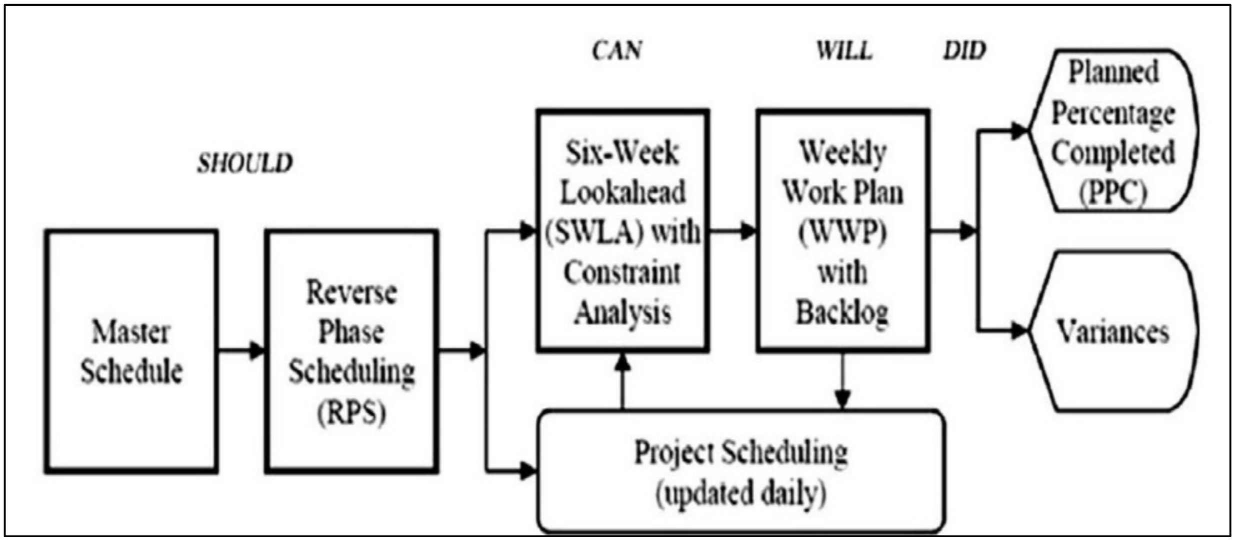

Fig 8: Sequence of LPS

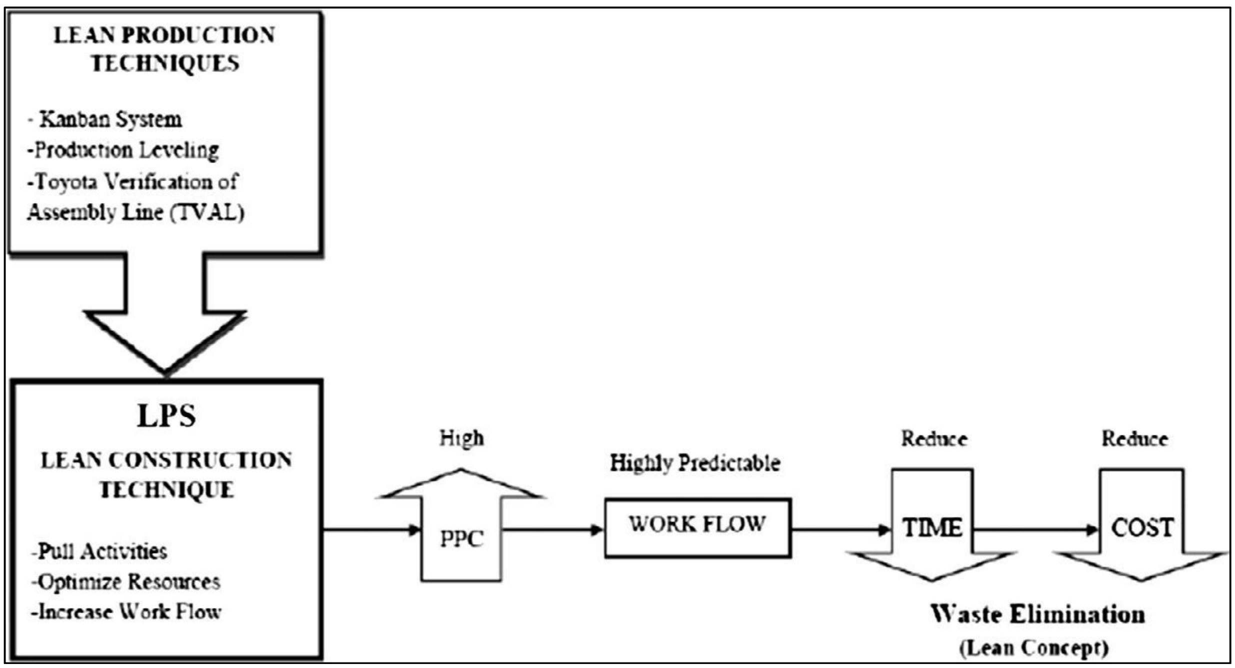

Fig 9: How LPS accomplishes lean concept

Wambeke *et al*. 2012 [29] by providing quantitative data, validated how using the Last Planner System method mechanical contractor were able reduce and/or eliminate variations in a construction project. Also a risk assessment matrix was formed as to prioritize which causes of variation should be targeted first. Kim and Ballard 2010 [22] investigated the theories implicit in 2 predominant project control systems: (1) "Earned Value Method" (EVM) and (2) "Last Planner System" (LPS). They introduced 2 essential and contending management conceptualizations: (1) "Managing By Means" (MBM) and (2) "Managing By Results" (MBR). When observed, it was found that the LPS method is based on the MBM view only.

Performance Improvement Model: Fig. 10 shows the main elements that decides the success of improvement process. The model is a causal loop illustration and demonstrates the kind of connections between the main elements.

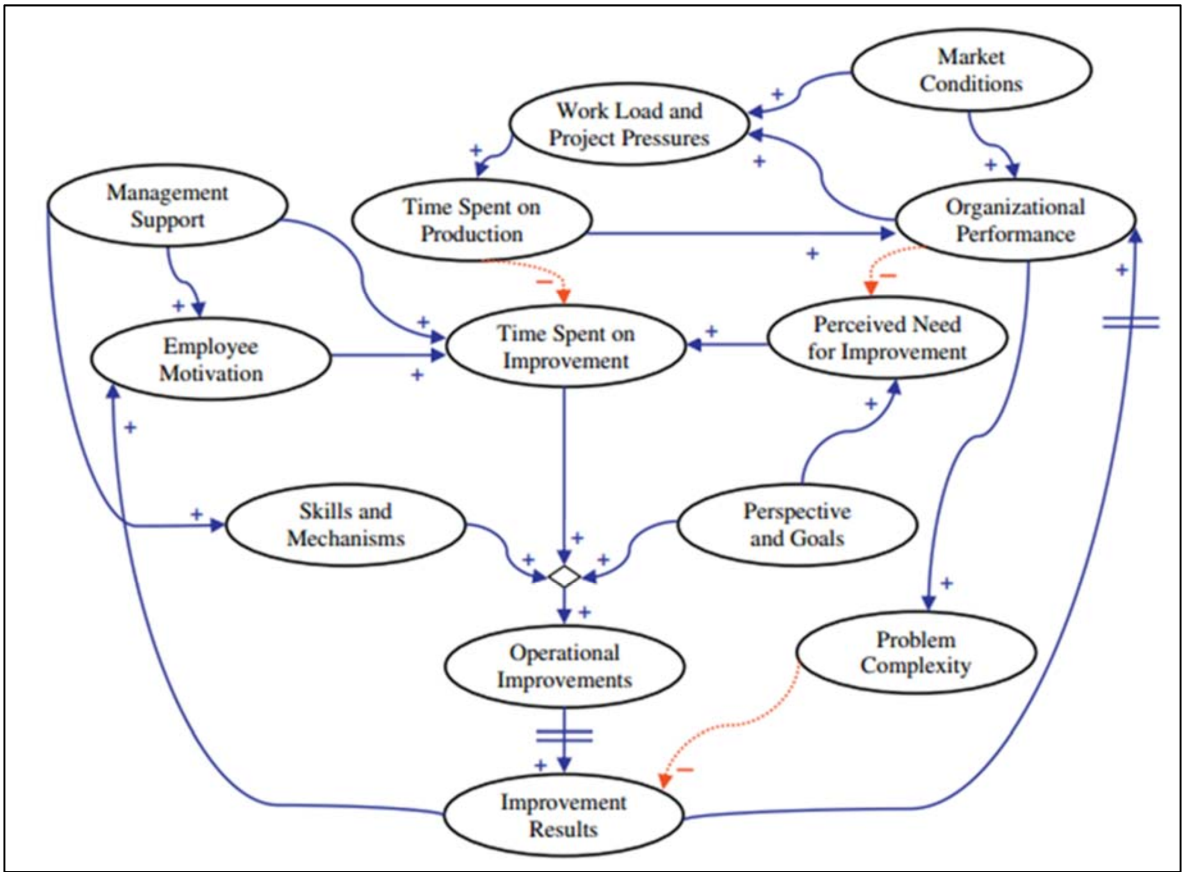

Fig 10: Model describing performance improvement process

Table 4: Descriptions of notation involved in performance improvement process model

Notations	Significance
Arrow between factors →	Factor X affects factor Y
Positive sign →	If factor X increases → factor Y increases
Negative sign →	If factor X increases → factor Y decreases
Double line →	Time lag
More than 1 arrow converges to a diamond →	ALL of conditions need to be present for the resulting factor to occur.

Table 4 describes the logic of all the relationships and diagram notations. So to "Operational Improvements" to occur, ALL of the conditions that converges to the diamond must be present.

Summery Conclusion & Discussion: The review study focused on knowing the evolution of "lean" thinking's and implementations of it over the years on various fields and sectors. The Main features of Lean Construction & main features of LC in views to construction stages were highlighted. A brief discussion based on literature reviews related to "lean" techniques and how things have been implemented over the years for understanding principles involved in LC. An introduction to the application networks of LC is discussed which helps in describing Lean Project Delivery System as briefly as possible. Study reduction and elimination of wastes as classified under LPS as a method of LC operation is also briefly discussed which in return is found useful in evaluation of applying LPS. An Introduction to a performance improvement model after analyzing the features of a successful performance improvement program is been given to show every terms related to it. This model classifies 3 crucial components: (a) "Time spent on Improvement", (b) "Improvement skills and mechanisms", and (c) "Improvement perspective and goals". The authors identified the various ways to structure an improvement program such as 1) outcome focused (ex. – "Critical Success Factors") and 2) process focused (ex. - Lean Construction). This paper describes the advantages of LPS over traditional approach of Critical Path Method and how by focusing on a structure and time-to-time planning, "lean" way performance improvement of a project can be achieved.

References

1. Howell GA. What is Lean Construction?. Proceeding Seventh Annual Conference Of International Group Of Lean Construction, IGLC-7, University Of California, Berkeley, CA, USA, 1999.
2. Shafii F, Arman Ali Z, Othman MZ. Achieving sustainable construction in the developing countries of Southeast. Asia Proceedings of the 6th Asia-Pacific Structural Engineering and Construction Conference, Kuala Lumpur, Malaysia, 2006.
3. Abdullah S, Abdul Razak A, Abu Bakar AH, Mohammad IS. Towards Producing Best Practice in the Malaysian Construction Industry: The Barriers in Implementing the Lean Construction Approach, 2009.
4. Koskela L. Application of the new production philosophy to construction. Tech. Report No. 72. CIFE, Stanford University, CA, 1992.

5. Suresh S, Bashir MA, Olomolaiye PO. A protocol for lean construction in developing countries. SPON Press. New York, 2011.
6. Alinaitwe HM. Prioritising Lean Construction Barriers in Uganda's Construction Industry. Journal of Construction in Developing Countries. 2009, 15-30.
7. Salem O, Solomon J, Genaidy A, Luegring M. Site implementation and assessment of lean construction techniques. Lean Construction Journal. 2005, 1-21.
8. Adamu S, Abdul Hamid R. Lean construction techniques implementation in Nigeria construction industry. Canadian Journal on Environmental, Construction and Civil Engineering, 2012.
9. Small HM, Yasin MM. Assessing the implementation and effectiveness of process management initiatives at technologically consistent firms Business Process Management, 6-20. RIBA. RIBA Plan of Work, 2011, 2012.
10. Salem O, Solomon J, Genaidy A, Minkarah I. Lean construction: From theory to implementation. J. Manage. Eng. 2006; 22(4):168-175.
11. Seppanen O, Ballard G, Pesonen S. The combination of last planner system and location based management system, 2010.
12. Pepper MPJ, Spedding TA. The evolution of Lean Six Sigma. International Journal of Quality & Reliability Management. 2010; 27(2):138-155.
13. Puvanasvaran AP, Kerk RST, Muhamad MR. Principles and Business Improvement Initiatives of Lean Relates to Environmental Management System, 2011.
14. George JM, Jones GR. Understanding and managing organizational behavior. Pearson International Edition, 2008.
15. Excellence C. Effective teamwork: a best practice guide for the construction industry Constructing Excellence. 2004, 1-20.
16. Summers DC. Quality Management, Creating and Sustaining Organizational Effectiveness Upper Saddle River, New Jersey: PEARSON Prentice Hall, 2005.
17. Mohd Yunus NM. Implementation of OHSAS 18001:1999: The experienced of construction companies in Malaysia. Universiti Teknologi MARA Shah Alam, Malaysia, 2006.
18. Abdelhamid TS. Six-Sigma in Lean Construction Systems Opportunities and Challenges, 2003.
19. Lim VLJ. Lean construction: knowledge and barriers in implementing into Malaysia construction industry, 2008.
20. Bashir AM, Suresh S, Proverbs D, Gameson R. A critical, theoretical, review of the impacts of lean construction tools in reducing accidents on construction sites In: Egbu, C. and Lou, E.C.W. (Eds.) Procs 27th Annual ARCOM Conference, Bristol, UK, Association of Researchers in Construction Management. 2011, 249-258.
21. Womack James P, Jones, Daniel T. Lean Thinking. Simon and Schuster. New York. 1996, 350.
22. Ballard G. Lean Project Delivery System, Lean Construction Institute, Ketchum, 2000.
23. Howell G, Ballard G. Implementing lean construction: understanding and action, in: Proceedings Sixth Annual Conference of the International Group for Lean Construction, Guaruja, Sao Paulo, Brazil, 1998.
24. Mossman A. Last Planner Overview: Collaborative Production Planning, Collaborative Programme Coordination, Lean Construction Institute, UK, 2005.
25. Auada J, Scola A, Conte A. Last planner as a site operations tool, in: The 6th Annual Conference of the International Group for Lean Construction, (IGLC-6) Guaruj, Brazil, 1998.
26. Alarcon L. Lean construction in Chile: a national strategy and local results, in: 3rd Annual Lean Construction Congress, < www.leanconstruction.org>, 2001.
27. Fernandez J, Porwal V, Lavy S, Shafaat A, Rybkowski Z, Son K, *et al*. Survey of motivations, benefits, and implementation challenges of last planner system users, Journal of Construction Engineering and Management. 2013; 139(4):354-360.
28. Howell G. A Guide to the Last Planner for Construction Foremen and Supervisors, Restricted White Paper Lean Construction Institute, California, 2000.
29. Wambeke B, Liu M, Hsiang S. Using last planner and a risk assessment matrix to reduce variation in mechanical related construction tasks, Journal of Construction Engineering and Management. 2012; 138(4):491-498.
30. Kim Y, Ballard G. Management thinking in the earned value method system and the last planner system, Journal of Management in Engineering. 2010; 26(4):223-228.