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Efficient Project Delivery Using Lean Principles - An Indian Case Study

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Abstract:	Construction industry in India is growing at a rapid pace. Along with this growth, the industry is also facing numerous challenges that are making delivery of projects inefficient. Experts believe that capacity constraints in the industry need to be addressed immediately. Government has recommended 'introduction of efficient technologies and modern management techniques to raise the productivity of the industry'. In this context lean principles can act as a lever to make project delivery more efficient and provide the much needed impetus to the Indian construction sector. Around the globe lean principles are showing positive results on projects. Project teams are reporting improvements in construction time, cost and quality along with softer benefits of enhanced collaboration, coordination and trust in project teams. Can lean provide similar benefits in the Indian construction sector? This research was conducted to answer this question. Using an action research approach a key lean construction tool called Last Planner System (LPS) was adopted on a large Indian construction project. This paper reports the findings of LPS implementation on the case study project. The work described in this paper investigates the improvements achieved in project delivery by adopting LPS in Indian construction sector. Comparison in pre- and post-implementation data provides increase in the certainty of work flow and improves schedule compliance. This is measured through a simple LPS metric called Percent Promises Complete (PPC). Explicit improvements in schedule performance are seen during the eight week LPS implementation along with implicit improvements in coordination, collaboration and trust in the project team. The authors envision that lean construction can make project delivery more efficient in the India.

ORIGINAL CONTRIBUTION

EFFICIENT PROJECT DELIVERY USING LEAN PRINCIPLES—AN INDIAN CASE STUDY

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ABSTRACT

Construction industry in India is growing at a rapid pace. Along with this growth, the industry is also facing numerous challenges that are making delivery of projects inefficient. Experts believe that capacity constraints in the industry need to be addressed immediately. Government has recommended '*introduction of efficient technologies and modern management techniques to raise the productivity of the industry*'. In this context lean principles can act as a lever to make project delivery more efficient and provide the much needed impetus to the Indian construction sector. Around the globe lean principles are showing positive results on projects. Project teams are reporting improvements in construction time, cost and quality along with softer benefits of enhanced collaboration, coordination and trust in project teams. Can lean provide similar benefits in the Indian construction sector? This research was conducted to answer this question. Using an action research approach a key lean construction tool called Last Planner System (LPS) was adopted on a large Indian construction project. This paper reports the findings of LPS implementation on the case study project. The work described in this paper investigates the improvements achieved in project delivery by adopting LPS in Indian construction sector. Comparison in pre- and post-implementation data provides increase in the certainty of work flow and improves schedule compliance. This is measured through a simple LPS metric called Percent Promises Complete (PPC). Explicit improvements in schedule performance are seen during the eight week LPS implementation along with implicit improvements in coordination, collaboration and trust in the project team. The authors envision that lean construction can make project delivery more efficient in the India.

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ABSTRACT

Construction industry in India is growing at a rapid pace. Along with this growth, the industry is also facing numerous challenges that are making delivery of projects inefficient. Experts believe that capacity constraints in the industry need to be addressed immediately. Government has recommended '*introduction of efficient technologies and modern management techniques to raise the productivity of the industry*'. In this context lean principles can act as a lever to make project delivery more efficient and provide the much needed impetus to the Indian construction sector. Around the globe lean principles are showing positive results on projects. Project teams are reporting improvements in construction time, cost and quality along with softer benefits of enhanced collaboration, coordination and trust in project teams. Can lean provide similar benefits in the Indian construction sector? This research was conducted to answer this question. Using an action research approach a key lean construction tool called Last Planner System (LPS) was adopted on a large Indian construction project. This paper reports the findings of LPS implementation on the case study project. The work described in this paper investigates the improvements achieved in project delivery by adopting LPS in Indian construction sector. Comparison in pre- and post-implementation data provides increase in the certainty of work flow and improves schedule compliance. This is measured through a simple LPS metric called Percent Promises Complete (PPC). Explicit improvements in schedule performance are seen during the eight week LPS implementation along with implicit improvements in coordination, collaboration and trust in the project team. The authors envision that lean construction can make project delivery more efficient in the India.

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Efficient Project Delivery using Lean Principles—An Indian Case Study

1 Status of Project Delivery in India

The Indian construction sector is forecasted as being among the fastest growing in terms of construction output due to economic growth and urbanization in the country [1]. However, the sector is still plagued by several existing and impending project delivery issues [2]. With a construction demand poised to exceed US $ 500 billion from infrastructure and real estate projects during 2012-17, the sector needs to tackle issues such as lack of project delivery standards and inadequate use of technology across the construction supply chain [3]. Time and cost outruns [4][5][6]; irregularities in procurement [7]; and below par performance on development projects amongst its peers [8] are among the most pressing challenges currently weighing down the construction industry in India.

The multitude of challenges faced by Indian construction have been creating a restrictive environment to the effective delivery of projects and in turn responsible for the sectors constrained growth. Lack of coordination and mistrust are commonly cited reasons for the current state of the Indian construction sector. This by itself creates the need for testing of a different project delivery approach and adoption of an efficient project operating system.

Around the globe stakeholders in the construction industry are shifting towards lean principles and practices for efficient project delivery and for addressing issues cited above. Should such a shift take place in India also? Can lean principles be adopted by the Indian construction sector to tackle some of these challenges? Is lean a panacea for the troubles that Indian construction faces? This paper attempts to answer this question by undertaking a case study approach and highlighting possible transformational forces that address mistrust and lack of coordination in the industry.

Lean, seen by many as a goal (being lean), as a continuous change process (becoming lean), as a set of tools or methods (doing lean/toolbox lean) and as a philosophy [9], has more to it than its shallower interpretations of waste elimination and waste minimizing tools. Having its roots in the Toyota Production System (TPS) [10], implementing lean in core business processes is said to change the way organizations or an entire sector operates. Having continuous improvement (kaizen) and respect for people at its foundation, Lean involves adopting a 'challenge all' and 'embrace change' attitude [11]. The construction industry on understanding the potential benefits of this way of thinking, embraced these principles by distinguishing it as 'lean construction' [12].

Lean construction was chosen in this research to explore possible ways of making project delivery more efficient in India. Specifically, Last Planner System (LPS), a popular lean construction tool [13], was selected for further exploration and implementation. This paper reports on the case study research conducted to capture the benefits of LPS and implementation difficulties in the Indian context.

2 OVERVIEW OF LEAN CONSTRUCTION

Lean construction, a concept that is not entirely new, emerged from the successful application of lean philosophy in manufacturing with a fundamental intention of identification and elimination of waste while simultaneously accomplishing client needs by Toyota's engineer Taiichi Ohno [14]. Lean construction is defined as *'a production management-based approach to project delivery–a new way to design and build capital facilities'* [15] with '*A pursuit of concurrent and continuous improvements*'. Koskela [16] was the first to challenge the construction industry upon finding this novel concept's adoptability and similarity to construction and project delivery processes. The first ever documentation of the expression 'Lean Construction' was at the 1993 conference by the International Group of Lean Construction (IGLC). Thereafter researchers and practitioners worldwide have diffused lean thinking into their respective construction sectors such as North America (US [17]), Europe (UK [18], Germany [19] , Finland [20][21]), South America (Brazil [22], Chile [23], Ecuador [24]), Middle East [25], South and East Asia (Singapore [26], China [27]) and Australia [28].

Although the implementation of lean is possible at the project level or at the organization level, many implementers of lean focus on the construction site level. While the lean philosophy is viewed as 'commonsensical', implementation can be quite challenging. In countries like India additional challenges are anticipated. Low availability of core professionals, limited use of standards and project management techniques, cultural and social issues, low awareness and other mindset barriers need to be overcome when implementing in these countries. Reports of low adoption of lean principles by Indian construction companies is available in literature [29].

Like any approach, lean construction is applied to projects using a variety of tools and techniques that focuses on improving the delivery of projects throughout its lifecycle and generating value for all stakeholders. There are several widely used lean tools in construction such as [30] [31]:

- Lean Integrated Project Delivery System (LIPDS)—this system enables a collaborative platform for designers, constructors and other project team members reducing rework, improved relationships and better communication [32][33];
- Just-in-time—works on the theory of pull rather than push planning and aims to reduce inventory levels and improved cash flows [34];
- Root cause analysis—Fishbone Diagrams, 5 Whys, Pareto charts, Control Charts among many other to solve underlying problems;
- Waste Walk—which are focused trips to areas of site where there is active work to make note of the happenings as well as waste, unlike the intentional observation for waste that occurs in go-see activities;
- 5S system—helps in organizing the work area by sorting, setting out, shining, standardizing and sustaining thus eliminating waste from the work area;

- A3 reports—A one page report for problem solving which works on the basis of Deming's PDCA cycle;
- Value stream mapping—pinpoints waste in the active processes and generates an action plan for further optimization of resource use in subsequent stages [35]; and
- Last Planner system (LPS)—a significant planning tool of the lean project delivery systems (LPDS), is a methodology that helps to produce reliable work flow in construction projects. Percentage of completed work (PPC) is the principal measurement metric element of this system [13].

Among the commonly used lean tools, the LPS links lean thinking best to project delivery process in construction. Since it works in a manner that eradicates the deficiencies of the traditional Critical Path Method [36], successful implementation has been reported widely. Solis et al. [37] reported findings from 26 cases that implemented LPS; and also many benefits are seen reported such as improvement in project delivery, creation of a more predictable production program, reduction in project duration, better cost management, reduced stress on project management staff, and improvement in the overall production process [38].

3 Last Planner System

Glenn Ballard and Greg Howell [13] [39] are credited with the development of LPS. They define LPS as "*a philosophy, rules, procedures, and a set of tools that shifts the focus of control from the workers to the flow of work that links them together and thus proactively managing the production process"* [13]. LPS is described by several researchers as an approach that gives definition to workflow while accounting for construction uncertainties thereby improving predictability and reliability in project delivery [40]; the research on which it is based began well before "lean" became part of the management vocabulary, with initial experiments being conducted as early as 1980s [13]. In LPS, as the name suggests, the power to shape the project progress rests on the "*last planner*" or project staff who are at the workface, so that they can involve themselves and commit to the tasks that can be accomplished for the planned week [13]. The LPS has been tested internationally by academicians and industry experts to demonstrate consistency in project delivery processes in construction projects within the US [41], the UK [42], South America [43], the Middle East [44], Korea [45], among many others. Also large-scale complex projects have reported improved productivity and lower workflow unevenness with the application of LPS to their construction phases [33][46].

The concept of the LPS has five main sequential stages [39][47] as shown in figure 1. At the topmost level, the *Master plan* is used to create a broad plan which categorizes the work packages of the entire project. It brings out duration of the key activities in sequence.

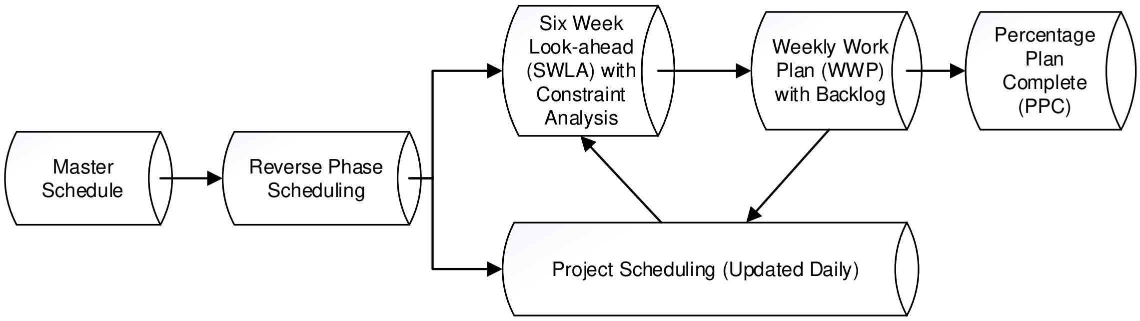


Figure 1: LPS implementation steps

Second stage of *phase planning* breaks down the master plan into major phases detailing work plan and creating trade wise goals that can be monitored as milestones by project members. It essentially connects the master plan to the look ahead planning stage. Thirdly, the *look ahead planning* brings attention to short term periods of six weeks or lesser showing the activities that are going to be executed in site in near future breaking them down into level of execution in the weekly work plans. The management team's efforts are focused to making ready resources for the anticipated tasks, phasing out constraints for smoother work flow thus replacing firefighting mode with a proactive approach to task completion. Ballard [47] indicated that look-ahead schedules are tools to control work flow. They acts as a link between master schedule and weekly work plans. Activities are not allowed to enter the look-ahead unless confirmation exists for execution when scheduled and allowed to remain in it only if the last planner is confident that all inputs for the look ahead tasks scheduled can be made ready. The duration of look-ahead plans varies from 3 to 12 depending on the complexity of project but 6 week time frame is usually used in practice.

Constraint identification should also be started along with this look-ahead plan to make the tasks ready for execution ensuring that the necessary materials, machinery and information are available on time (screening and pulling mechanism). The number of people involved in preparing these look-ahead plans should be as high as possible as a single person cannot identify all constraints in a construction project. New constraints might enter during these six-weeks which should be identified and removed.

The look ahead planning trickles down to the fourth element of *weekly work plan* where last planners at site, who are usually the foremen or supervisors, promise to deliver work found achievable in the coming week. Weekly work plan is a highly detailed plan consisting of details of activities that are going to be executed on site during that week. Tasks are entered into the weekly work plan only after resolving all the identified constraints. In case all the constraints are not removed, the work must be re-scheduled for a later date. The key terms in the weekly wok plan are 'Should', 'Can' and 'Will'. 'Should' indicates works to be done according to the look-ahead schedule. 'Can' indicates the work which can be achieved due to removal of various constrains. Upon considering all constraints the works committed by last planners are then indicated by ‘Will’ [30][48].

The concluding step in LPS is the *Feedback Statistics* which uses the measurement index of percent plan (or promises) completed (PPC) calculated as ‘DID’ activities upon ‘WILL’ activities. Also a list of reasons for non-completion of activities substantiates the planning phase by registering them in the WWP form. These information help to identify and pinpoint planning inadequacies that are otherwise missed out thus facilitating informed decision making and continuous improvement.

LPS implementation is reported to be challenging. According to past studies, if an organization is planning LPS adoption in their organization or project, a good place to start is by gathering data from its projects about the percentage of tasks delivered for a given week that were planned in that week. So going by the adage “if you can’t measure it you can’t manage it” collecting data and calculating PPC over a period of few weeks may convince the management to look towards LPS implementation. The key challenge in this method is to check for reliability of last planners. Simple, however, powerful tools such as process charts depicting workflow strategies should be tutored to trade supervisors and their crew, and ensuring by closely monitoring that the steps laid down by the process charts are synchronized. Ballard and Greg however call it a philosophical issue, the non-occurrence of training of tradesmen on a frequent basis to enable use of such tools within their workflow [49].

4 CASE STUDY

The purpose of this research was to demonstrate the applicability and benefits of LPS in the Indian context and to demonstrate that indirectly LPS promotes better coordination and trust among project team members. The notion that Indian construction projects and project teams are culturally different to the ones where lean principles have been successfully adopted had to be confronted. In this research an actual implementation of LPS as an action research initiative was conducted to answer some of these unanswered questions about practicality of LPS in the Indian context and benefits to the involved organizations [50]. It was decided to select an industrial construction project for this study, a large automobile factory in western India. Action research process adoption is justified, as it gives flexibility and at the same time allows learning from the change created on implementing an action within managerial practices, thus adding research value and understanding [51][52]. The overall flow of the research activity is shown in

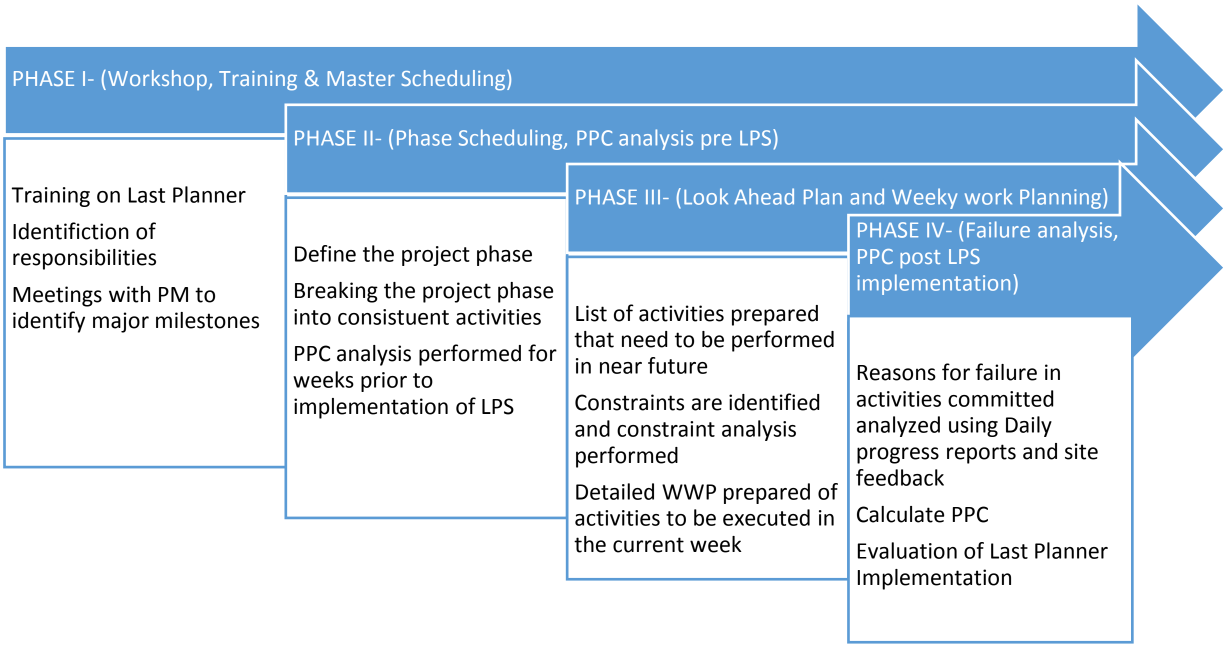


Figure 2. The implementation of LPS on the case study was started when the researcher stationed himself on the site as part of project planning and monitoring team. The contractor had two large-footprint industrial buildings to complete. The master schedule prepared for the project after identification of various milestones based on contract agreement at the starting of the project itself became a key resource for LPS implementation. Before implementing the LPS, the researcher calculated and analysed PPC for a period of 15 weeks.

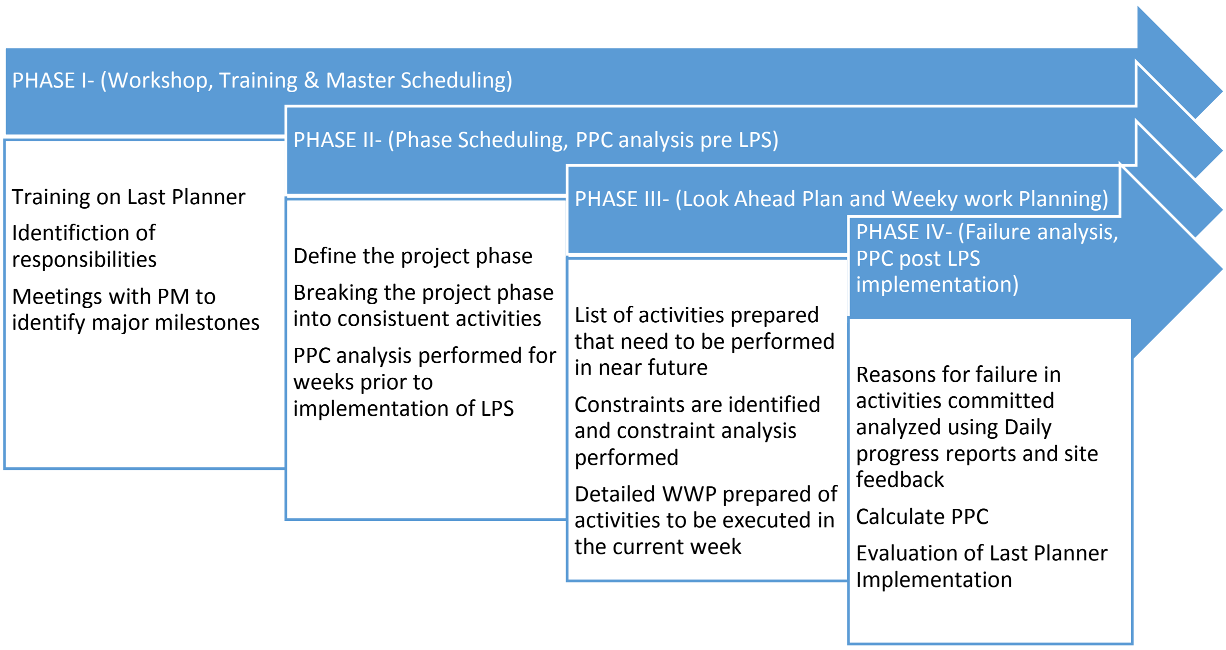


Figure 2**:** LPS implementation plan for the case study

The PPC of many projects reveals the failure of plans. Percent plan (or promises) complete is the performance index that is used to calculate and monitor the effect of the implementation of LPS. After completion of each work plan, the reliability of planning should be identified by measuring PPC after checking whether the activities are completed or not (no credit is given for partial completion of an activity) along with the reasons for plan failures. Data from the project site was gathered and percentage of tasks delivered in a week to that planned for that given week were identified.

In this case study, prior to beginning LPS implementation, look-ahead plans were prepared based on the current status and activities to be executed during the next six weeks were broken down into sub-parts. Look ahead plan was updated at the end of every week. Whenever an activity entered the last window of look-ahead plan, it was broken down into sub-activities.

Constraint analysis was carried out for the activities those were entered into last window of look-ahead plan and solutions for the constraints were found out during the 5 weeks. The site engineers provided the planning team with the activities that they were planning to execute in next week based on the look-ahead plan. The planning team ensured the commitments using constraint analysis, prepared weekly plan and finally a check was made by site in-charge before the work was committed.

Ballard and Howell [39] indicated of giving priority to PPC alone, WWP also need to be analysed to find the reasons behind inability to complete a week's promised task. It is necessary to identify preventive measures for these reasons in-order to avoid them in future and for a continuous improvement. A team should be assigned to identify the areas of reoccurring failures that require analysis of cause using a suitable problem solving technique such as five why or root-cause analysis.

At the end of each week, the reasons for failure in activities committed was analysed using daily progress reports and by taking feedback from the site engineers. PPC was measured to monitor the performance of the two buildings and overall project as shown in Table 1.

Table 1: PPC Calculations for the case study

	Average PPC	*Minimum PPC*	*Maximum PPC*
Building-1	*52.9%*	*12.5%*	*82.1%*
Building-2	*52.7%*	*18.2%*	*66.6%*
Overall site	*52.8%*	*15.8%*	*72.1%*

5 RESULTS OF IMPLEMENTATION

After the 15 week data collection (pre-LPS), LPS was implemented for a period of 8 weeks in close collaboration of the project team. The researcher remained embedded in the project team and conducted many formal and informal interactions to explain, learn and discuss issues surrounding LPS implementation. Extensive data collection took place during these 8 weeks. Using this data weekly PPC values were calculated and shared with the team members. Summary of the PPC calculations is shown in Table 2.

Table 2: Percentage of Tasks Completed Every Week

Week	1	2	3	4	5	6	7	8	Cumulative
Tasks planned	24	24	38	28	33	19	22	21	209
Tasks completed	13	17	22	20	24	16	19	20	151
PPC	54.16	70.83	57.89	71.43	72.73	84.21	86.36	95.24	72.25

The results of PPC before and during the implementation of LPS are shown in Figure 3.

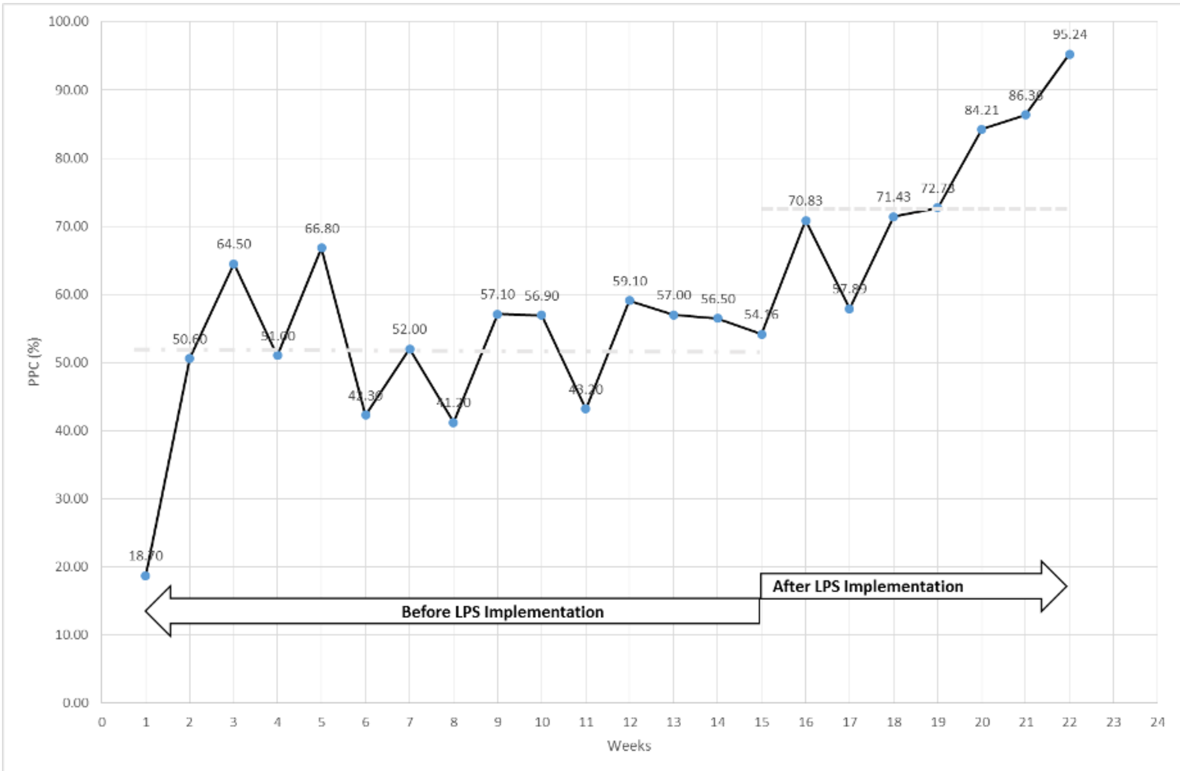
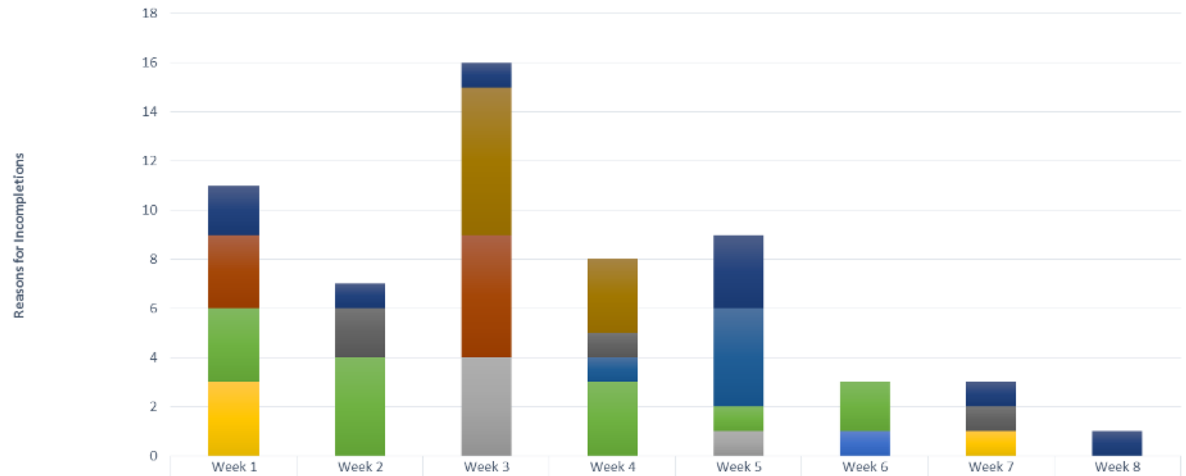


Figure 3: Variation of PPC before and during Implementation

Reasons for failure of weekly plans were also identified at end of every week. The reasons for failure and their frequencies are shown in figure 4. Reasons for failure were initially categorized into ten types and ‘hold by client’ was added as an eleventh option due to its high frequency of occurrence. Predecessor availability on time is the major reason identified for failure occurred thirteen times during the implementation period followed by hold by client and others with a frequency of nine each.



	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Others	2	1	1	0	3	0	1	1
Hold/clearance by client	0	0	6	3	0	0	0	0
Labour	0	2	0	1	0	0	1	0
Weather	3	0	5	0	0	0	0	0
Space	0	0	0	1	4	0	0	0
Predecessors	3	4	0	3	1	2	0	0
Machinery	0	0	0	0	0	1	0	0
Materials	3	0	0	0	0	0	1	0
Design	0	0	4	0	1	0	0	0
Submittals	0	0	0	0	0	0	0	0
Contract	0	0	0	0	0	0	0	0

Figure 4: Reasons for failure and corresponding frequency of occurrences

Plan failure reasons were categorized into execution or planning failure based on the causes. 58 activities failed to be completed during this period, out of which 38 were plan failures and 20 were execution failures. It was identified that plan failures contribute 65 % of total failures which shows that better planning increases the work flow. Similarly 62 % causes of the failures were found to be due to internal reasons such as machinery, materials, submittals etc., which can be avoided, and 38 % of the failures are due to external reasons such as weather, design changes, hold by client etc.

Of all the reasons for incompletion of work planned for the week, the most frequent constraint observed during the eight weeks of LPS implementation was incompletion of predecessor activity, which occurred for 13 activities over the eight weeks. However towards the last two weeks of observation, constraints that occurred were observed to be limited to only labour shortage, a problem owing to the unorganized nature of labour forces and material unavailability. Predecessor activity incompletions were eliminated to a large extent due to the last planners being able to keep to their commitments and to contribute in a collaborative planning process.

6 Conclusion

The LPS implementation brings along effective relationship which form the backbone of a stabilized project based-production system that the tool advocates. The implementation of the new tool on a construction site progresses through a learning curve which ultimately results in creating value. This study identified and tested the effectiveness of LPS, a lean construction tool in improving the PPC.

Maintaining different durations for identification of constraints in planning and execution should also be considered as the constraints in execution will be difficult to identify much before actual execution. Providing training to employees is a key to successful use of lean construction tools. An organization involved in testing and successfully implementing lean concepts in construction project management would stand to benefit not only in terms of duration but also cost wise. From the research, it is found that predecessor availability on time is the major reason identified for failure occurred during the implementation period followed by hold by client and others. Reasons for failure were initially categorized into ten types and hold by client was added as an eleventh option due to its high frequency of occurrence. Plan failure reasons were categorized into execution or planning failure based on the causes. 58 activities failed to be completed during this period, out of which 38 were plan failures and 20 were execution failures. It was identified that plan failures contribute to 65% of total failures which shows that better planning increases the work flow. 62% causes for the failures were found to be due to internal reasons such as machinery, materials, submittals etc., which are avoidable and 38 % of the failures are due to external reasons such as weather, design changes, hold by client etc.

REFERENCES

[1] Accenture and CIDC, "High Performance in Infrastructure and Construction: India Perspective 2012," 2012. [Online]. Available: http://www.accenture.com/in-en/Pages/insight-infrastructure-construction-industry-india.aspx. [Accessed: 13-Nov-2014].

[2] A. Sawhney and R. Agnihotri, "Grand Challenges for the Indian construction industry," *Built Environ. Proj. Asset Manag.*, vol. 4, no. 4, pp. 317 – 334, 2014.

[3] Planning Commission of India, "Investment in Infrastructure during the Eleventh Five Year Plan," 2011.

[4] R. Singh, "Delays and Cost Overruns in Infrastructure Projects : Extent , Causes and Remedies," *Econ. Polit. Wkly.*, vol. xlv, pp. 43–54, 2010.

[5] K. N. Satyanarayana and K. C. Iyer, "Evaluation of Delays in Indian Construction Contracts," *J. Inst. Eng.*, vol. 77, pp. 14–22, 1996.

[6] K. C. Iyer and K. N. Jha, "Critical Factors Affecting Schedule Performance: Evidence from Indian Construction Projects," *Journal of Construction Engineering and Management*, vol. 132. pp. 871–881, 2006.

[7] S. Tabish and K. N. Jha, "Analyses and evaluation of irregularities in public procurement in India," *Construction Management and Economics*, vol. 29. pp. 261–274, 2011.

[8] K. Ahsan and I. Gunawan, "Analysis of cost and schedule performance of international development projects," *Int. J. Proj. Manag.*, vol. 28, no. 1, pp. 68–78, 2010.

[9] J. Pettersen, "Defining lean production: some conceptual and practical issues," *The TQM Journal*, vol. 21. pp. 127–142, 2009.

[10] J. P. Womack, D. T. Jones, and D. Roos, *The Machine That Changed the World: The Story of Lean Production*, Reprint. HarperCollins, 1991, p. 323.

[11] G. A. Howell, "What Is Lean Construction?," in *Proc. of 7th IGLC*, 1999.

[12] A. Sawhney, "Modelling Value in Construction Processes using Value Stream Mapping," *Masterbuilder*, Feb-2014.

[13] H. G. Ballard, "The Last Planner System of Production Control," The University of Birmingham, 2000.

[14] T. Ōno, *Toyota production system: beyond large-scale production*. Productivity Press, 1988.

[15] G. Howell, "What is lean construction," in *Concurrent Engineering*, 1999, vol. 7, no. July, pp. 1–10.

[16] L. Koskela, "Application of the new philosophy to construction," Center for Integrated Facility Engineering, Stanford University, 1992.

[17] O. Salem, J. Solomon, A. Genaidy, and I. Minkarah, "Lean Construction: From Theory to Implementation," *J. Manag. Eng.*, vol. 22, no. 4, pp. 168–175, Oct. 2006.

[18] A. Mossman, "Why isn ' t the UK construction industry going lean with gusto?," *Lean Constr. J.*, vol. 2009, pp. 24 – 36, 2009.

[19] E. Johansen and L. Walter, "Lean Construction: Prospects for the German construction industry," *Lean Constr. J.*, vol. 3, pp. 19–32, 2007.

[20] A. Koskenvesa, L. Koskela, T. Tolonen, and S. Sahlsted, "Waste and labor productivity in production planning case Finnish construction industry," in *18th Annual Conference of the International Group for Lean Construction*, 2010.

[21] L. Koskela and J. Leikasb, "Implementation of lean production in construction component manufacturing," in *Automation and Robotics in Construction XII*, 1995, pp. 211–220.

[22] G. Barbosa, C. Biotto, and B. Mota, "Implementing lean construction effectively in a year in a construction project," in *21st Annual Conference of the International Group for Lean Construction*, 2013, pp. 1017–1026.

[23] L. F. Alarcón, S. Diethelm, and O. Rojo, "Collaborative implementation of lean planning systems in Chilean construction companies," in *Tenth Annual Conference of the International Group for Lean Construction (IGLC-10), August, Brazil*, 2002, pp. 1–11.

[24] M. Fiallo C and G. Howell, "Using Production System Design and Takt Time to Improve Project Performance," in *Proceedings for the 20th Annual Conference of the International Group for Lean Construction*, 2012.

[25] R. Al-Aomar, "Analysis of lean construction practices at Abu Dhabi construction industry," *Lean Constr. J.*, vol. 2012, pp. 105–121, 2012.

[26] W. Peng and L. S. Pheng, “Lean and green : emerging issues in the construction industry – a case study,” in *20-21 Sep 2011, EPPM, Singapore*, 2011, pp. 20–21.

[27] G. Shang, “The toyota way model: an implementation framework for large chinese construction firms,” National University of Singapore, 2013.

[28] M. Horman, R. Kenley, and V. Jennings, “A lean approach to construction: an historical case study,” in *In: & Tucker, S.N., 5th Annual Conference of the International Group for Lean Construction*, 1997, pp. 63–76.

[29] I. McKinsey & Company, “Building India- Accelerating Infrastructure Projects,” 2009.

[30] O. Salem, J. Solomon, A. Genaidy, and M. Luegring, “Site Implementation and Assessment of Lean Construction Techniques,” *Lean Constr. J.*, vol. 2, no. 2, pp. 1–21, 2005.

[31] Engineers Australia WA Division, “Recommended Practices for the Application of LEAN Construction Methods to Building New Australian LNG Capacity,” *Engineers Australia*, 2012. [Online]. Available: https://www.engineersaustralia.org.au/sites/default/files/shado/Divisions/Western Australia Division/Technical Presentations/lean_construction_august_2012.pdf. [Accessed: 02-Sep-2014].

[32] J. Darrington, “Using a design-build contract for Lean Integrated Project Delivery,” *Lean Constr. J.*, pp. 85–91, 2011.

[33] G. Ballard and I. Tommelein, “Lean management methods for complex projects,” *Engineering Project Organization Journal*, vol. 2. pp. 85–96, 2012.

[34] S. Bertelsen and J. Nielsen, “Just-In-Time Logistics in the Supply of Building Material,” in *1st nternational Conference on Construction Industry Development: Building the future Together*, 1997, pp. 9–11.

[35] M. Rother, J. Shook, J. Womack, and D. Jones, *Learning to See: Value Stream Mapping to Add Value and Eliminate MUDA*. Lean Enterprise Institute, 1999.

[36] G. Ballard, “Lean construction and EPC performance improvement,” in *Proceedings of the 1st Annual Meeting of the International Group for Lean Construction*, 1993, pp. 79–92.

[37] J. L. Fernandez- Solis, Z. K. Rybkowski, S. Lavy, V. Porwal, N. Lagoo, K. Son, and A. Shafaat, “Survey of Motivations, Benefits and Implementation Challenges of Last Planner® System Users,” *Journal of Construction Engineering and Management*. p. 451, 2012.

[38] A. Mossman, “Last Planner - 5+1 crucial & collaborative conversations for predictable design & construction delivery,” 2013. [Online]. Available: http://www.leanconstruction.org/media/docs/Mossman-Last-Planner. [Accessed: 10-Oct-2014].

[39] G. Ballard and G. Howell, “An update on last planner,” in *11th Annual Conference of the International Group for Lean Construction*, 2003, pp. 1–10.

[40] S. Gao and S. P. Low, “The Last Planner System in China’s construction industry - A SWOT analysis on implementation,” *Int. J. Proj. Manag.*, vol. 32, pp. 1260–1272, 2014.

[41] J. Garza and M. Leong, "Last Planner Technique: A Case Study," in *Construction Congress VI*, 2000, pp. 680–689.

[42] E. Johansen and G. Porter, "An Experience of Introducing Last Planner Into a UK Construction Project," in *The 11th Annual Conference of the International Group for Lean Construction*, 2003.

[43] M. Fiallo and V. H. Revelo, "Applying the Last Planner Control System to a Construction Project - A Case Study in Quito, Ecuador," in *In:, Formoso, C.T. & Ballard, G., 10th Annual Conference of the International Group for Lean Construction*, 2002, pp. 1–12.

[44] A. Alsehaimi, "Last planner system: Experiences from pilot implementation in the Middle East," in *in: 17th Annual Conference of the International Group for Lean Construction*, 2009.

[45] Y. W. Kim and J. W. Jang, "Case Study: An Application of Last Planner to Heavy Civil Construction in Korea," in *Proceedings of the 13th Annual Conference of the International Group for Lean Construction*, 2005, pp. 405–411.

[46] M. Liu, G. Ballard, and W. Ibbs, "Work Flow Variation and Labor Productivity: Case Study," *Journal of Management in Engineering*, vol. 27. pp. 236–242, 2011.

[47] G. Ballard, "Lookahead planning: the missing link in production control," *Proc. 5 th Annl. Conf. Intl. Gr. Lean Constr*, pp. 1–14, 1997.

[48] G. Ballard and G. Howell, "Implementing lean construction: improving downstream performance," in *Presented at the 2nd Annual Conference on Lean Construction at Catolica Universidad de Chile*, 1994.

[49] G. Howell and G. Ballard, "Lean production theory: Moving beyond 'Can-Do,'" in *2nd Annual Conference on Lean Construction*, 1994, no. September 1994, pp. 17–24.

[50] P. Järvinen, "Action research is similar to design science," *Qual. Quant.*, vol. 41, no. 1, pp. 37–54, 2007.

[51] B. Dick, "Action research: action and research," 2002. [Online]. Available: http://www.scu.edu.au/schools/gcm/ar/arp/aandr.html\nhttp://www.aral.com.au/. [Accessed: 10-Nov-2014].

[52] E. Gummesson, "Qualitative methods in management research," *Long Range Planning*, vol. 25. SAGE Publications, p. 131, 1992.

[53] F. Hamzeh, G. Ballard, and I. D. Tommelein, "Rethinking Lookahead Planning to Optimize Construction Workflow," *Lean Constr. J.*, pp. 15–34, 2012.

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