Enhancement of Productivity and Minimization of Waste using Lean Construction Techniques

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Abstract:- The Lean construction is aimed at improving construction performance by eliminating wastes that do not add value to the customer. In this technique waste is minimized and productivity is enhanced. In this case study researchers tried to study the effects of lean construction on waste minimization and on overall project completion. With the help from project manager data was collected with reference to performance and application of lean techniques, the study focuses on one project near Pune city in Maharashtra, in this project problems were identified and solutions are provided for further improvements. The study also focuses on identifying various barriers towards implementation of lean techniques in constructions. The study is based upon primary data collected after implementation of lean construction techniques in one of the projects in Pune. The Last planner concept was also used for observing the productivity improvements over time.

Keywords: *Lean Contruction, Management, Cost, Productivity, Waste minimization*

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1. Introduction

Lean Construction is a combination of operational research and practical development in design and construction with an adaption of lean manufacturing principles and practices to the end-to-end design and construction process. Unlike manufacturing, construction is a project based-production process. Lean construction is concerned with the alignment and holistic pursuit of concurrent and continuous improvements in all dimensions of the built and natural environment: design, construction, activation, maintenance, salvaging, and recycling (Abdelhamid 2007, Abdelhamid et al. 2008). This approach tries to manage and improve construction processes with minimum cost and maximum value by considering customer needs (Koskela et al. 2002).

The case study is based on the residential project. In which 8 buildings and the general site work that is carried daily was noted and then the calculations were done to show the daily productivity. As well as an average productivity is was shown in the graphical form. The aim of the study is to show how the productivity is increased by using various techniques and the time can be saved by using various technologies.

2. Review of Literature

Although there are still debates about whether the productivity of the construction industry is increasing or declining, the performance of the construction industry is widely perceived as unsatisfactory when compared with many other industries. ―Lean construction‖ is a production management strategy for achieving significant, continuous improvement in the performance of the total business process of a contractor through elimination of all wastes of time and other resources that do not add value to the product or service delivered to the customer (Womack & Jones, 2003).

Lean concepts have resulted in dramatic performance improvements in manufacturing, and the principles behind lean have also been successfully applied to construction. Some of the lean principles that are related to the construction industry are improvements such as the construction planning process, construction supply chain, and downstream performance (Howell, 2007). Attempts have also been made to apply lean principles to all project management processes, including the project delivery system, production control, work structuring, design, supply chain, project controls, and overall construction project management. The value of lean construction has been demonstrated in many case studies. For example, Koskela et al. (1996) closely examined a fast-track office building project and showed how the building process could be made leaner and speedier, and Tsao et al. (2000) illustrated how lean thinking and work structuring helped to improve the design and installation of metal door frames for a prison construction project.

Summary of literature reviewed,

Table No-01: Review of literature

Key concepts	Essential Factors	Authors Authors
Just-In-Time (JIT)	Three methods linked with JIT: optimise inventories according to backward requests (Japanese: Kanban), construction levelling and decreasing the number of setup activities.	Salem et al. (2006)
	Related to the waste concept. Continuous improvement of procedures, equipment and processes in order to eliminate waste.	Koskela (1992) Small et al. (2011)
Total Quality Management (TQM)	As an integrated management thinking and actions encouraged an organisation-wide focus on quality. Effective organizations needed an accurate understanding of customers' expectation.	Jorgensen, B., & Emmitt, S. (2008) Summers (2005)
Business Process Re-engineering (BPR)	Improvement through rapid and substantial gains in organisational performance by starting from scratch in designing or redesigning the foundation business development.	Small et al. (2011) George and Jones (2008)
	Business process involved any activity that was fundamental for fast delivery of goods and services to customers, or that promotes high quality and low cost.	
Concurrent Engineering (CE)	Deal primarily with product design base, incorporating the constraints of subsequent phases into the conceptual phase and tightening of change control towards the end of the design process	Koskela (1992)
Last Planner System (LPS)	To achieve lean goals of reducing waste, increasing productivity and decreasing unpredictability mainly throughout a social process, by trying to make planning mutual attempt and by increasing the reliability of commitments of team members	Seppanen et al. (2010)
	In construction, LPS was a method that forms workflow and deal with project variability.	Salem et al.(2005)
Teamwork	Teamwork was complementary skills groups of people with who were committed to a common purpose and hold themselves mutually accountable for its achievement, in which they develop a different identity and work together in a co-ordinated and mutually supportive way	Excellence (2004)
Value Based Management (VBM)	Value based management approach in which indicate that product value for the customers is considered product value while value for the workers and project participants was termed process value.	Bertelsen (2004)
OHSAS	Steps taken to improve existing features, or the consistency of their application and elimination in frequency if particular undesired incidents	Mohd Yunus (2006)

3. Lean Construction Application

The primary objectives of this project are to observe the barriers to implementing lean construction concepts through an empirical study of a concrete construction project and to develop practical solutions to facilitate the implementation process. The study was focused on waste productivity enhancement at the field operation level. In the context of lean principles, waste is defined as any resources consumed by activities that do not add value to meet a client's needs.

At the project level, waste due to the poor coordination among the subcontractors was also identified. Effective look-ahead scheduling and management of handoff points between different disciplines are the keys to eliminating this type of waste. The study reviews the current industry practice and proposes a look-ahead scheduling approach that utilizes the last planner concept. At the operation level, inefficient sequencing of work procedures and unnecessary movement of labourers and other resources contribute to schedule delays. This project uses a systematic approach of waste identification, work procedure re-design, and employee training to reduce wastes found in the field operation. A major obstacle in applying lean concepts at the operation level is the resistance to changes on the part of employees, so this project uses digital explanation of the procedure of different techniques to improve the understanding by field personnel of the re-designed work procedure in order to reduce such resistance.

The study reviews on current industry practices and recent daily graphic schedule is also used to further improve communication of scheduling information on a daily basis at the crew level. A set of graphic schedule daily graphic schedule is also used to further improve communication of scheduling information on a daily basis at the crew level.

4. Lean Construction at the Project Level for Case Study 1.

Case Study 1: Comprises of study of Productivity.

Observations at the operation level involve monitoring work procedures, movement of resources, and information available on the job site. Various types of waste were observed in the sample project that is similar to those that have been identified in many other similar studies; they include crane waiting, double handling of materials, and rework. Suggestions have been made to redesign work procedures and to eliminate or reduce the different types of waste.

During the course of this study, resistance to change was perceived to be the major obstacle to implementing lean concepts at the operation level. Proper training to the foreman and workers was given to install "Aluform" shuttering. About how the panels are placed according to the design, and the numbers and the arrows that are written on the panels how the placement should be done.

As the training is given beforehand a lot of time is saved as there is no scope for confusion. The panels that are placed on one floor after deshuttering the same panels are used for the floor above. A proper utilization of space is done so that the panels from a particular section can be placed exactly above the existing section. Here the last planner plays the important rule, even though the training is given to the workers how to tackle the current technical problem can be done by the last planner. Which helps in the effective yield of time, the saved time can be used in other operations on site by the particular worker.

As compared to traditional formwork the aluform can be placed in the faster way and if an more effective way id applied for placing of aluform a lot of time can be saved. Which is one of the crucial factor of any construction project. For application of lean techniques in a construction project a co-ordination is required. Communication also plays a very vital rule in the application of lean techniques.

5. Questioner which was answer by the Project Manager of the site

Table no.2 Data collection instrument

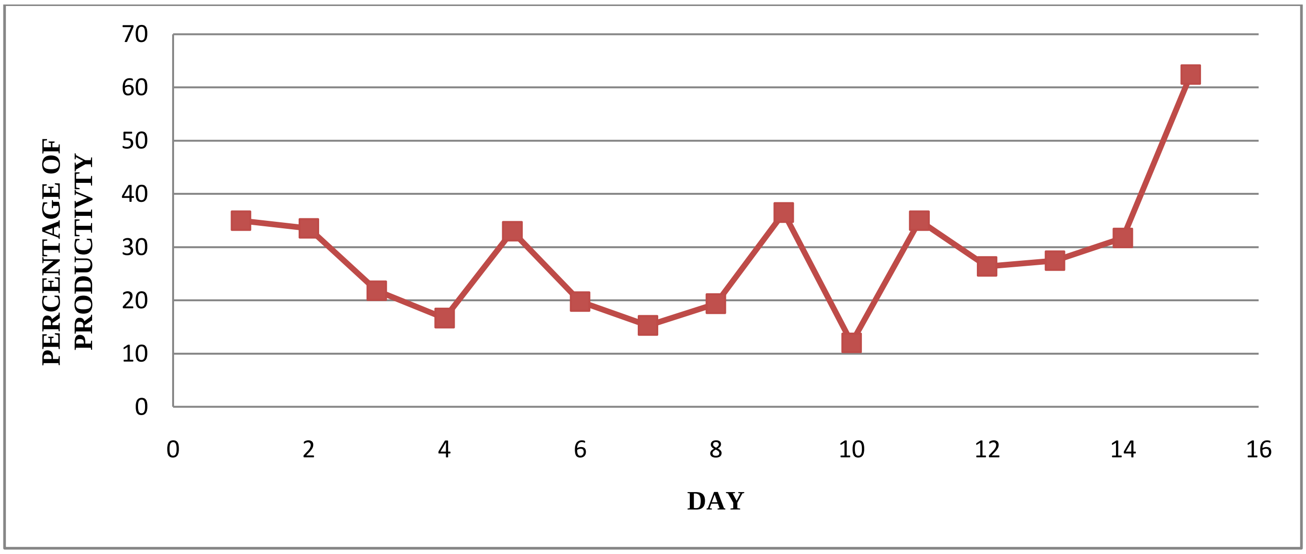
Questions	Answers
Are Lean practices implemented in your organization?	Yes
What Lean Techniques are used?	Last Planner System.
Main obstacle found in the system?	Material Shortage(Natural sand)
Flow of work (whether continuous or not)	Continuous
Waste minimization practiced or not?	Yes
Time Saved by the use of latest technologies at every stage of work?	Yes
Rework reduction by priorly instructing the workers about the new techniques used?	Less problems are occurring.
Transportation Cost reduced?	Yes (As the RMC plant is present on site)

Are Multiple activites/task going on a particular work?	Yes
Is completion of individual task at operational level carried out?	Yes
No. of meeting carried out?	Weekly,Monthly & Quaterly.
If any problem is caused during execution is it soved immediately?	Mostly the problem is solved (but depends on the nature of problem)
Rate the following on the scale of 1 to 5. (The planned work is going on & by the observation if the collegues and workers are working accordingly) 1.Safe work environment. 2. Good site cleaning. 3. Commitment and partication. 4. Good communication and feedback. 5. High Trust amongst participants. 6. Focus on continous process implementation. 7. Focus on reducing waste 8.Fast decision about design change. 9.Focus on proper functioning.	 4 3 4 4 4 4 4 4 4

(Reference: Case study on residential buildings)

6. Data Analysis –Graphical

Figure No. 1 -Daily % of productivity



To calculate a daily percentage of productivity for 15 days. 8 buildings were taken and in general work that happens on the site daily. The 8 buildings which were considered for the study in those buildings aluform was used, as a technology to reduce the time which is usually wasted in traditional method for shuttering and deshttering. So that the work that is done can be carried out on a faster rate. The work combining which is done in the 8 buildings and the site overall is calculated and then the productivity of the labours is shown in the graph above. Hence, the total work that was done daily on the site accordingly a percentage for productivity was calculated for 15 days and that is shown in the graphical format.(graph no.1)

The calculation for Day 1 are shown in the table below and similary the data was collected for 15 days and the the graphical analysis was done. (where P= productivity and WD= work done).

The formula used was P=Work done/toal no. of workers.

7. Data collected :

Table -03 – productivity calculations

SI No	Detail of Works	Quantity of WD		No of Labour	Hrs	Total (H/d)	P
#	**C1A (Old 4A1) Building**						
1	Concreting,Material shifting,Leveling,House keeping etc			0			
2	Shear Walls & Slab Casting,LINTELS	0.00	CUM	0	12	0.00	0
3	Alu-Form Shuttering & R/f Work.	0.00		0	12	0.00	
4	PCC(M15)	0.00	CUM	0	0	0.00	
#	**C1B (Old 4A2) Building**	0.00			.		
1	Concreting,Material shifting,Leveling,House keeping pcc	0.00	CUM	12	0	18.00	
2	OHWT Wall casting	0.00	CUM	0	12	0.00	
3	Column	0.00					
4	Alu-Form Shuttering	112.00	sq.m	10	0	15.00	11.2
5	R/f steel For Footings,Column,Shear Wall	300.00	kg	15	0	22.50	20
#	**C1C (Old 4A3) Building**						
1	Footing Pcc	0.00	CUM	0	12	0.00	0
2	Footing casting	8.50	CUM	14	0	21.00	0.607143
3	Column Casting	4.20	CUM	15	12	22.50	0.28
4	Alu-Form Shuttering	127.00	sq.m	15	0	22.50	8.466667
5	R/f steel For Footings,Column,Shear Wall	675.00	kg	30	0	45.00	22.5
#	**C1D (Old 4A4) Building**					0.00	0
1	For PCC/Plum Preparation (Surface Dressing,Stone			10		15.00	0
2	Footing pcc W42,W35,W38,W11		CUM		12	0.00	
3	Footing Casting SW W9,W11,W35	7.15	CUM	10	12	15.00	0.715
4	Plum Concrete For	0.00	CUM	0	12	0.00	
5	Casting of Footing Casting + Stap Beam	0.00	CUM	0	12	0.00	
6	Casting of Column	1.05	CUM	10	12	15.00	0.105
7	R/f steel For Footings,Column,Shear Wall	390.00	kg	15		22.50	26
8	Shuttering For PCC,Footings/Strap	60.00	sq.m	15	12	22.50	4
#	**C1E (Old 4A5) Building**						
1	Footing casting		CUM	10	12	15.00	0
2	Casting of Beam Casting	68.76	CUM	5	12	7.50	13.752
3	Plumn Concrete	0.00	CUM	0	12	0.00	
4	Shuttering For PCC,Footings/Strap			0	12	0.00	
5	Alu-Form Shuttering & R/f Work.	170.00	sq.m	12		18.00	14.16667
6	Concreting,Material shifting,Leveling,House keeping etc			10		15.00	0
7	PCC	0.85	CUM	5	12	7.50	0.17
#	**C1F (Old 4A6) Building**						
1	For PCC/Plum Preparation (Surface Dressing,Stone			14			
2	PCC/Plum for Footings Strap Beams etc.for						
3	Floor PCC Block	0.00	CUM	0	12	0.00	
4	PCC	0.00	CUM	10	12	15.00	
4	Casting of Footing For	0.00					
5	Casting of Slab	166.14	CUM	20	12	30.00	8.307
6	Casting of Columns	0.00	CUM	0	12	0.00	
7	R/f steel For Footings,Column,Shear Wall			19	12	28.50	0
8	Shuttering For PCC,Footings/Strap			12	12	18.00	0
#	**C1G (Old 4A7) Building**						
1	Concreting,Material shifting,Leveling,House keeping etc	0.75		15	12	22.50	0.05
2	Flate no 1103,1106 Slab Casting	166.14	CUM	20	15	30.00	8.307
3	Flat no 1201,1202 Shear wall Reinforcement	0.00		15	12	22.50	0
4	Flate no 1104,1105 Shuttering Work & Also Reinforsment	0.00		10	12	15.00	0
#	**C1H (Old 4A8) Building**			0		0.00	
1	Concreting,Material shifting,Leveling,House keeping etc	0.22		14	12	21.00	0.015714
2	Shear Walls & Slab Casting	0.00	CUM		12	0.00	
3	Alu-Form Shuttering	52.00	sqm	9	12	13.50	5.777778
4	R/f steel For Footings,Column,Shear Wall,SLAB	350.00	kg	11	12	16.50	31.81818

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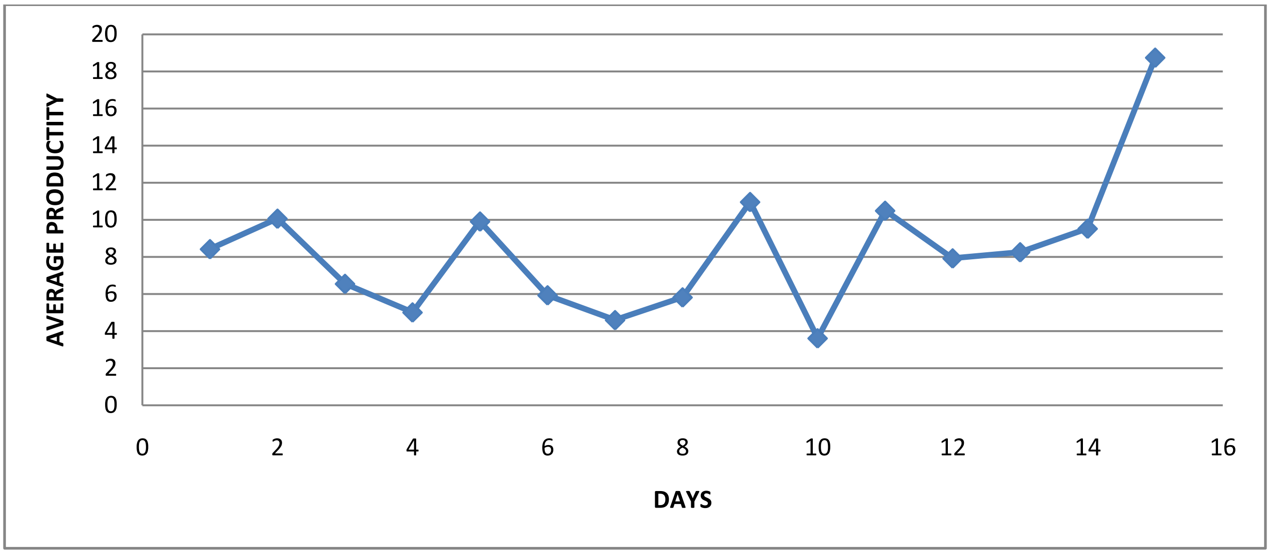
#	**Retaining Wall Work**					0.00	
1	For PCC/Plum Concrete Preparation (For RW at W9-			10	12	15.00	0
2	Plum In Retaining Wall	0.00	CUM	0	12	0.00	
3	Slab Steel & Shuttering Work			0		0.00	
5	Shuttering For PCC & Plum of R Wall at			7			0
#	**Podium Work**						
1	Concreting,Material shifting,House keeping etc			10			0
2	PCC/Plum For Footings	0.00	CUM	0	12	0.00	
3	Casting of Footing For	0.35	CUM	5	12	7.50	0.07
4	Casting of Cloumns	2.35	CUM	14	12	21.00	0.167857
5	Slab Casting Balance Pour2 (M40 PT)	85.00	CUM	0	12	0.00	
6	slab casting (Ramp Nr 4A1)	35.00	CUM	0	12	0.00	
7	R/f steel For Footings,Column,PT Slab,PT beam			15		22.50	0
8	Shuttering/De-Shuttering For Footings,Slab,Columns,PT			11		16.50	0
#	**U.G.Water Tank Work**						
1	Concreting,Material shifting,House keeping etc			10			0
2	Casting of Top Slab						
3	R/f steel For Column,Walls etc.(Cutting,Binding,Placing)						
4	De-Shuttering of Wall/Beam Sides Btm,Shuttering of			0			
#	**STP Work**						
1	Material shifting,Surface Dressing,Cleaning			5	12	7.50	0
2	Staircase	0.35	CUM	5	12	7.50	0.07
3	Plum M30						
4	R/f steel For Footings,Column,PT Slab,PT beam	0.00		0.00	12	0.00	
5	Shuttering/De-Shuttering For Footings,Slab,Columns,PT			0.00	12	0.00	
6	Column Casting C36,C37,Starter2 Nos	0.00	CUM	0.00	12	0.00	
7	shear Wall M25 casting& Slab	0.00	CUM	0.00	12	0.00	
#	**Transformer Room**						
1	Material shifting,Surface Dressing,Cleaning	0.00	CUM	10	12	15.00	0
2	Slab Csting for	0.00	CUM	0	12	0.00	
3	R/f steel For Footings,Column,Shear Wall	0.00	CUM	0		0.00	
4	Shuttering For PCC,Footings/Strap	0.00	CUM	0	12	0.00	
5	footing Casting(M25)	0.50	CUM		12	0.00	
6	L.C.	0.00	CUM			0.00	
7	To Pride	0.00	CUM			0.00	
	Town Plaza					0.00	
1	Staging & Shuttering work for 1st Slab	0.00	CUM	20	12	30.00	0
2						0.00	
1	Labour Camp	0.80	CUM		12	15.00	0.08
		3.50	CUM	10	12		
		1.32	CUM		12		
		1.80	CUM				
1	New Plant	0.20	CUM	12	5	18.00	0.016667
	Slurry Consumpion On site	0.00	CUM				
#	**Site Work**						
1	Pipeline Agencies (For Concrete Pump)			7	12	10.50	0
2	Curing,Shuttering Material oiling Material unloading etc.			10	12	15.00	0
3	Office Boy			1	12	1.50	0
4	Safety/Surveyor Helper			2	12	3.00	0
5	QA/QC Lab Helper			2	12	3.00	0
6	Welder + Plant helper			3	12	4.50	0
7	Safety Net Fixing			3	12	4.50	0
8	Taccha Work			2	12	3.00	0
9	Hole Grouting Work 4A1/4A2			3	12	4.50	0
10	Cover Block Making(25MM)	0.00	NO.	2	12	3.00	0
	Cover Block Making(30MM)	0.00	NO.	2	12	3.00	0
	TOTAL QTY			563			8.411556

(The data was collected in this format similary for te next 14 days)

Figure No-02 –avaerage productivity daywise



8. Assumptions:

The assumptions to prepare the average productivity are: From the literature survey and the questions that were asked to the managers and site engineers on site. The conclusion from the survey comes that the productivity of the conventional methods comes to at the maximum of 5. So considering the constraints from the case study 18 is the maximum productivity achieved.

To show the obtained results in percentage consider 30 as the 100% productivity.By considering 30 as the number the productivity comes to 17% in conventional methods.

Table -04 - average productivity analysis

DAY	Avg Productivity	No. consider to conver in %	% Result
1	10.48644	30	34.9548
2	10.05336	30	33.5112
3	6.543159	30	21.81053
4	5.0029	30	16.67633
5	9.9002	30	33.00067
6	5.925939	30	19.75313
7	4.588432	30	15.29477
8	5.813545	30	19.37848
9	10.95028	30	36.50093
10	3.60855	30	12.0285
11	10.4864	30	34.95467
12	7.914347	30	26.38116
13	8.2444	30	27.48133
14	9.514963	30	31.71654
15	18.7279	30	62.42633

9. Conclusions:

Major Outcomes from the study: From Figure (1, 2) we can interpret the outcome of this experiment is as follow, average daily productivity from the 15 days data is graphical represented above. The observation from the study is that the productivity enhances with the use of advanced technology and day to day monitoring. Mainly the productivity of reinforcement is more due to the availability of number of machinery required and skilled labour. And even the formwork productivity is more due to the use of aluform. As a lot of time is saves once the technique so known to the labour, that comes with proper training and supervision In concreting the productivity is low because in some buildings use of traditional methods like bucket pulley is used which slows the transportation process while at many buildings pumps are been used. The last planner focuses on assignment-level planning and determines the amount of work that should be done based on the master project plan. The constraints of performance, such as work sequence and resource availability, determine what can be done. There are many factors which contribute to construction materials waste generation on site.

Waste may occur due to one or combination of many causes. Sources of waste can be categorized in five categories:

- Design
- Procurement.
- Handling of materials
- Operation
- Residual usages.

The barriers to implementation of Lean Construction identified from literature and confirmed by industry practitioners.

a. Fragmented nature of the industry
b. Extensive use of subcontractors.
c. Lack of long term relationship with the suppliers.
d. Delays in decision making.
e. Waste accepted as inevitable.

10. Future Work:

There is no standard definition of productivity and any current misunderstandings about productivity appear to stem from at least nonstandard terminology.It appears that choosing a measure that is appropriate to the purpose is very important. The effectiveness of lean and barriers to it are identified in this case study. Workstructure needs to be revisited for enhancement of efficnecy (Tsao 2000) State-of-the-art methods and techniques of productivity measurement are presented. The key for productivity improvement is not to complete as many tasks as possible or to maximize workload, work output, or work hours without following the work plan. Rather, the key is to focus on maintaining a predictable work flow and thus be able to match the available workload with capacity (work hours).This project showed that, lean principles can be applied at both project and operation levels of a construction project. Future research should quantify the benefits of lean applications by collecting and analyzing performance data from actual construction projects. The data analysis should objectively and quantitatively measure the effectiveness of lean applications and assist future decision making on investing in lean construction concepts.

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