To Study The Optimization Of Waste Material In Construction Project

Ghumare Pawan Namdeorao
Department of Civil Engineering
SNJB's LSKBJCOE, Chandawd, Dist- Nashik,, Maharashtra, India.

Prof. Wankhede P.J
Department of Civil Engineering,
SSGBCOET, Bhusawal, Dist- Jalgaon, Maharashtra, India.

Abstract:- The chronic problems of construction are well known such as low productivity, poor safety, inferior working conditions, and insufficient quality. The phenomenon of the poor performance and conditions in construction industry had long been witnessed and recorded by academics and practitioners throughout the world regardless in developed countries or in developing countries. Increasing foreign competition, the scarcity of skilled labour and the need to improve construction quality are the key challenges faced by the construction industry. Responding to those challenges imposes an urgent demand to raise productivity, quality and to incorporate new technologies to the industry. A lack of responsiveness can hold back growth, and to development of the needed infrastructure for the construction industry.

Keywords – Lean, Justified-in-time workflow, value added steps

I. INTRODUCTION

Construction is a key sector of the national economy for all countries around the world, as traditionally it took up a big portion in nation's total employment and its significant contribution to a nation's revenue as a whole. However, until today, construction industries are still facing numbers of contingent problems that were bounded to be resolved since the past time. The chronic problems of construction are well known such as low productivity, poor safety, inferior working conditions, & insufficient quality. The phenomenon of the poor performance and conditions in construction industry had long been witnessed & recorded by academics & practitioners throughout the world regardless in developed countries or in developing countries. Increasing foreign competition, the scarcity of skilled labour and the need to improve construction quality are the key challenges faced by the construction industry. Responding to those challenges imposes an urgent demand to raise productivity, quality and to incorporate new technologies to the industry. A lack of responsiveness can hold back growth, and to development of the needed infrastructure for the construction industry. The new construction production philosophy is laid on the concepts of conversion and flow process. Therefore, performance improvement opportunities in construction can then be addressed by adopting waste identification, reduction strategies. New lean construction concepts especially those on wastes and values most of the times are not well understood by construction personnel. Particularly, waste is generally associated with waste of materials in the construction processes while non-value adding activities such as inspection, delays, transportation of materials and others are not recognized as waste. As the result of that, the productivity of construction industry cannot be fully optimized due to the narrow interpretation on the concept of waste which is currently adopted. Lean construction practice has the goal of better meeting needs while using less of everything. But unlike current practice, lean construction rests on management principles

II. OBJECTIVES OF STUDY

The research seeks to confirm four objectives, which are:-

1. Examine the general perceptions of the local construction industry with the lean construction principles and practices.
2. To identify basic lean tools for process improvement. Source of wastes (classified under lean construction) for activities at a construction site and relate them to the waste identified in local construction industry.
3. To Study& identify methodology for application of lean tools for construction project by reducing Cost and eliminating the wastes.
4. Recommendations for the control of the waste by reducing the non-value adding activities in the construction projects.

Need For Lean Construction

As construction industry gets competitive, thinking and applying Lean to Construction activity is critical to winning customers and ensuring profitability. The aim of Lean Systems is to design, produce and deliver products/services, which exceed customer expectations in terms of Cost/ Quality/Time/Performance. The participants will be able to experience how different management concepts are integrated and can be applied to build a Lean Organization focused on Customer Value Creation. Develop insights into creating Lean Systems in a Construction project environment. Cost reduction through process Simplification, inventory reduction, development of managers with acute awareness of creating customer value for top line growth. Lean construction is a new way to manage construction. The standard demands a new form of production management. Zero time delivery of a car meeting customer requirements, with nothing in inventory required that the rapid movement of each car down the line be tightly coordinated with the arrival of parts from supply chains. Rework would have to be eliminated as it reduced throughput, the time to make a car from beginning to end, and caused workflow to be unreliable. Eliminating the unreliable workflow is the key to both throughput and minimizing inventory cost. Reducing the cost or increasing the speed of any one activity is likely to inject uncertainty into the flow of work and thus rarely contributes to increased throughput or lowest total cost. Rapid completion and low cost require high throughput resulting from matching the arrival of resources "Justified-in-time" with the flow of work.

The procedure of applying the lean principles is as follows:

1. Defining the customer, the customer value, all resource required for construction, and all activities required for construction.
2. Identify non value added process (steps, time).
3. Removing or reducing the wastes in process by using the standardization and the five why tools to identify the cause of failure.
4. Identifying non value added activities.
5. Improving the project until reaching perfection.

III. Experiment and Result

The duration for the process and the bill of the quantities of project. The following resources are available throughout all the project period: - Project manager-1, Site engineer-2, Foreman-1, Surveyor -1.

Calculation in the last column was done as follows:

Duration (hour) = Quantity/ (Number of resources x Productivity x 8 hours) Maximum duration of the excavation process = 6000/ (1x 57x 8) = 13 hours.

Most likely duration of the excavation process = 6000/ (1x 62x 8) = 12 hours. Minimum duration of the excavation process = 6000/ (1x 68x 8) = 11 hours.

The remaining processes were calculated in the same way.

Table 3.1 Productivity of the project activities

Main Activity	Process	Unit	Quantity	No of resource	Productivity/1hrs	Duration1day=8 hrs
Mobilization & excavation	Excavation work	M^3	6000	1 Excavator	57, 62, 68	11,12,13 days
Plain concrete	Form work	M^2	140	5 workers	0.6, 0.8, 1	3.5,4.5,5.5 days
	Cast plain concrete	M^2	140	5 workers	0.7, 0.8, 1	4,5,6 hours
	Remove formwork	M^2	140	5 workers	0.6, 0.7, 0.9	3,4,5 days
Foundation	Form work	M^3	935	9 workers	0.6, 0.9, 1	11.5, 15, 21 days
	Fix neck column	M^3	935	9 workers	6, 8, 10	1.5, 2, 2.5 days
	Cast foundation	M^3	935	9 workers	6, 7, 12	12,16,18 hours
	Remove form work	M^3	935	9 workers	2, 3, 4	3,4,5 days

Neck column	Formwork	M^3	60	8 workers	0.07, 0.08, 0.15	51,90,103 hours
	Cast concrete	M^3	60	8 workers	0.08, 0.1,0.12	60,75,90 minute
	Remove form work	M^3	60	8 workers	0.3, 0.4, 0.5	16,20,24 hours
Back filling	First layer	M^3	1000	2 excavators	18,21,22	2.5,3,3.5 days
	Second layer	M^3	1000	2 excavators	25,31,41	1.5 , 2, 2.5 days
	Final layer	M^3	1000	2 excavators	25,31,41	1.5 , 2, 2.5 days
Ground beam	Form work	M^3	180	8 workers	0.3, 0.4,0.6	4.5, 7,10 days
	Cast concrete	M^3	180	8 workers	0.08, 0.1,0.12	60,75,90 hours
	Remove formwork	M^3	180	8 workers	0.7,0.9,1	2.5, 3, 4 days
Column work	Fix steel column	M^3	145	4 workers	1.8, 2, 3	1.5, 2, 2.5 days
	form work	M^3	145	4 workers	0.1, 0.2,0.3	102,180,206 hrs
	Cast concrete	M^3	145	4 workers	0.4, 0.5,0.6	60,75,90 minute
	Remove form work	M^3	145	4 workers	1.5, 1.8, 2	16, 20, 24 hrs
Ground floor	Preparati on work	M^2	2000	5 workers	33, 36, 40	10, 11, 12 hours
	Steel work	M^2	2000	5 workers	14, 15, 16	26, 27,2 8 hrs
	Mechanic work	M^2	2000	5 workers	60, 80,100	4, 5 ,6 hours
	Cast concrete	M^2	2000	5 workers	60, 80,100	4, 5 ,6 hours
Slab work	form work	M^2	1180	9 workers	6, 7, 8	3.5, 4, 4.5 days
	Hollow cement block	M^2	1180	9 workers	10, 12, 15	2, 2.5, 3 days
	Steel work	M^2	1180	9 workers	6, 7, 8	3.5, 4, 4.5 days
	Electric work	M^2	1180	4 workers	6, 8, 12	6, 8, 12 hours
	Cast concrete	M^2	1180	9 workers	8, 9, 10	8, 9, 10 hour
	Remove form work	M^2	1180	9 workers	5, 6, 7	4, 5, 6 days
Building work	Building under the window	M^2	5730	5 workers	2, 2.5, 3	20, 22, 23 days
	Lintel work under window	M^3	5730	5 workers	16, 19, 24	2, 2.5, 3 days
	Cast lintel under the window	M^3	5730	5 workers	48, 64, 95	4, 6, 8 hours

	Removeformwork	M^2	5730	5 workers	24, 32, 48	1, 1.5,2 days
	Building behind the windows	M^2	5730	5 workers	2.5, 2.8,3	15, 17, 18 days
	Lintel work behind window	M^3	5730	5 workers	16, 19, 24	2, 2.5, 3 days
	Cast lintel up the windows	M^3	5730	5 workers	48, 64, 95	4, 6, 8 hours
	Remove form work	M^2	5730	5 workers	24, 32, 48	1, 1.5,2 days
	Building up the windows	M^2	5730	5 workers	2, 2.5, 3	20, 22, 23 days

Non-Value Added and Value Added Process Identification

Activities can be classified as:

1. Activity that adds value and can be defined as follows:
   - Activity which contributes to the customer's perceived value of the product or service.
   - Activity that "converts material and/or information towards what is required by the customer".
2. Activity that does not add value and can be defined as follows:
   - Activity which, if eliminated, would not detract from the customer's perceived value of the product or service.
   - Activity which "takes time, resources & space but does not add value".

In the analysis of the project, the value added and non-value added times and steps of the process can be defined as follows:

1. Value added time is the time that increases the value duration of the process without any waste.
2. Non-value added time is the time that does not increase the value added of the process without waste.
3. Value added steps are the steps that increase the value of the work steps without any kind of waste.
4. Non-value added steps are the steps that do not increase the process value without waste.
5. Waste is a kind of seven wastes over-production, defects, inventory, transportation, waiting, motion and over- processing.

The value and non value added processes of the project activities. The non value added takes "0" whereas value added takes number "1" or a fraction according to the number of the steps in a process. For example section (3.2.) the excavation process took two steps so the value added steps equal 1/2 +1/2 = 1. If the excavation was performed in one step, the value added of step takes "1".

3.1 Mobilization and excavation

Table (3.2) shows seven processes where the number of value added steps is 1 out of 7 steps which corresponds to14% of total steps. The total duration of the mobilization and excavation in the daily report is 240 hours.

Table 3.2 Value and non-value added processes in mobilization and excavation

No.	**Process**	**Step**		**Duration**
		Step number	**Value added steps**	**1day = 8hours**
1	Site cleaning, includes removing trees	1	0	48
2	Demolishing the existing walling fence.	2	0	32
3	To setup the site engineer office	3	0	32
4	Excavation of the natural ground to the required levels	4	1/2	96
5	Laboratory	5	0	8
6	Expand the excavation	6	1/2	16
7	Laboratory	7	0	8
Total		**7**	**1**	**240**

Percentage of value added steps	**14%**	

3.2 Foundation

Table (3.3) shows thirteen processes that constitute the foundation. Where the number of value added steps is 2 out of 13 steps (15%) and the total duration in the daily report is 276 hours.

Table 3.3 Non-value added and value added processes in foundation.

No.	Process	Step		Duration /hrs
		Step number	**Value added steps**	**1day = 8hours**
1	Form work foundation concrete part "C"	1	0	88
2	Form work foundation concrete part "A &B"	2	0	80
3	Fix steel of neck column part "A"	3	1/4	28
4	Fix neck steel of neck column "B"	4	1/4	8
5	Cast foundation "A"	5	1/4	8
6	Remove formwork part "A"+ form work Part "C"	6	0	8
7	Fix steel neck column part "C"	7	1/4	4
8	Cast foundation part "B"	8	1/4	4
9	Steel work for foundation part "C"	9	1/4	8
10	Cast foundation part "B"	10	1/4	8
11	Remove formwork part "C"+ part "B".	11	0	8
12	Form work for 5 foundation part "c", back Filling	12	0	16
13	Steel work +cast 5 foundation part "C" + back filling + steel work + Laboratory	13	1/4	8
Total		**13**	**2**	**276**
Percentage of value added steps		**15%**		

3.3 Neck column

Table (4.8) shows thirteen processes that constitute the neck column. The number of value added steps is 1 out of 13 steps (7.6%) and the total duration in the daily report is 132 hours.

Table 3.4 Non-value added and value added processes in neck column

No.	Process	Step		Duration (hours)
		Step number	**Value added steps**	**1day= 8hours**
1	Reinforced concrete basement, remove walls form work	1	0	08

2	Form work neck column , wall concrete	2	0	54
3	Justify the defect in the column.	3	0	04
4	Cast wall concrete "A"	4	0	02
5	Form work "B"	5	0	08
6	Remove formwork "A" neck column wall concrete	6	0	08
7	Neck column "B".	7	0	16
8	Cast neck column "B"	8	1/3	02
9	Remove formwork wall	9	0	08
10	Form work part " C"	10	0	10
11	Cast neck column part B.	11	1/3	02
12	Cast neck column part C	12	1/3	02
13	Remove formwork + Chaining	13	0	08
Total		**13**	**1**	**132**
Percentage of value added steps		**07.6%**		

3.4 Isolation

Table (4.9) shows two processes that constitute the isolation. The number of value added steps is 1 out of 2 steps (50 %) and the total duration in the daily report is 48 hours.

Table 3.5Non-value added and value added processes in isolation processes

No.	Process	Steps		Duration (hours)
		Step number	Value added steps	1day = 8hours
1	Cleaning	1	0	0
2	Cleaning , isolation work	2	1	40
Total		**2**	**1**	**48**
Percentage of value added steps		**50%**		

3.5 Back filling

The six processes that represent backfilling are shown in Table (4.10). The number of value added steps is three out of six steps (50%) and the total duration in the daily report is 112 hours.

Table 3.6 Non-value added and value added processes in back filling

		Step	**Duration1day=8hours**

No.	Process	Step number	Value added steps	Duration Of process/ hours
1	Back filling layer1 + cleaning	1	1	48
2	Laboratory	2	0	08
3	Back filling layer 2	3	1	32
4	Laboratory	4	0	04
5	Back filling layer 3	5	1	16
6	Laboratory	6	0	04
Total		**6**	**3**	**112**
Percentage of value added steps		**50%**		

Remove or Reduce the Influence of Waste as it is observed

Simulation has been used in each activity to measure the duration and number of steps. Productivity data was used in the simulation model. Results are shown on Table (4.19).The results that were reached from mobilization and plain concrete are explained as follows (the other activities use the same methodology).Firstly by using the five why tool. The steps were reduced from. The seven steps are cleaning the site, demolishing existing walls, building engineer's office, and excavation work, checking soil, extended excavation and checking the new extension excavation land. The first three steps can be reduced to one step by coordinating cleaning, demolition and building. These three contractors can begin work at the same time. The sixth and seventh steps can be avoided because there is a design error.

Table 3.7 Simulation results

No.	Activity	Process	V.A. Time[1] (hours)	N.V.A. Time[2] (hours)
1	Mobilization	Cleaning	0	48
		Excavation	95.29	0
		Laboratory	0	8.06
2	Plain concrete	Casting	3.97	0
		Form work	0	34.83
		Remove formwork	0	5.03
3	Foundation	Fix steel	15.94	0
		Form work	0	129.6
		Casting	15.55	0
		Remove formwork	0	31.34
4	Column neck	Form work	0	79.23
		Casting	1.26	0
		Remove formwork	0	19.92
5	Back filling	Layer 1	23.47	0
		Layer 2	16.46	0
		Layer 3	15.82	0

		Laboratory	0	7.1

3.6 Mobilization and excavation

Table (4.20) shows that mobilization and excavation duration is equal to 151.35 hours. Before applying lean tools, it was 240 hours, and the percentage of value added time was 63%, the actual percent value added duration was 39%, and value added steps after applying the five why tools is 33% (before applying lean tools was 14%). Step1 and 3 are merged.

Table 3.8 Waste elimination in mobilization

No.	Process	Step		Duration	
		Step number	**Value added steps**	**Duration of process (hours)**	**Value added time (hours)**
1	Site cleaning, includes removing trees	1	0	48	0
2	Demolishing the existing walling fence, rooms and any obstructed item existing in the proposed area				
3	Excavation of the natural ground to the required levels	2	1	95.29	95.29
4	Laboratory	3	0	8.06	0
Total		**3**	**1**	**151.35**	**95.29**
Percentage of value added		**33%**		**63%**	

3.7. Plain concrete

Table (4.21) shows that plain concrete duration is equal to 41.09 hours. Before applying lean tools, it was 63 hours, and the percent of value added time 9%, the actual duration was 6%, and value added step percent is 33%. It was 20% before applying lean tools.

Table 3.9 Waste elimination in plain concrete

No.	Process	Step		Duration	
		Step number	**Value added steps**	**Duration of process (hours)**	**Value added time (hrs)**
1	formwork concrete for "A-B"	1	0	34.83	0
2	Cast plain concrete	2	1	3.97	3.97
3	Remove formwork	3	0	5.037	0
Total		**3**	**1**	**43.83**	**3.97**
Percentage of value added		**33%**		**9%**	

3.8 Foundation

Table (4.22) shows that foundation duration is equal to 192.43 hours. Before applying lean tools, it was 276 hours and the percent of value added time was 16%, the actual duration was 10%, and value added step percent was 50%.

It was 15% before applying lean tools.

Table 3.10 Waste elimination in foundation

No.	Process	Step		Duration	
		Step number	Value added step	Duration of process (hrs)	Value added time (hours)
1	Form work foundation Concrete "A-B-C" & steel.	1	0	129.6	0
2	fix neck column "A-B-C"	2	1	15.94	15.94
3	Cast Foundation "A-B-C"	3	1	15.55	15.55
4	Remove formwork	4	0	31.34	0
Total		**4**	**2**	**192.43**	**31.49**
Percentage of value added		**50%**		**16%**	

3.9 Neck column

Table (4.23) shows that neck column duration is equal to 100.41 hours, before applying lean tools was 132 hours, and the percent of value added time 1.2%, the actual duration was 0.8%, and value added step percent is 33 %, It was 8% before applying lean tools.

Table 3.11 Waste elimination in neck column

No.	Process	Step		Duration	
		Step number	Value added steps	Duration /hrs	Value Added time/ hrs
1	Form work neck column	1	0	79.23	0
2	cast wall concrete "A"	2	1	1.26	1.26
3	Remove formwork	3	0	19.92	0
Total		**3**	**1**	**100.41**	**1.26**
Percentage of value added		**33 %**		**1.2%**	

3.10 Isolation

Table (4.24) shows that isolation duration is equal to 39.86 hours. Before applying lean tools was 48 hours, and the percent of value added time 100%, the actual duration was82%, and value added step percent is 100 %. It was 50% before applying lean tools.

Table 3.12 Waste elimination in isolation

No.	Process	Steps		Duration	
		Step number	Value added steps	Duration (hours)	Value added time (days)
1	Isolation work cleaning	1	1	39.86	39.86
Total		**1**	**1**	**39.86**	**39.86**
Percentage of value added		**100 %**		**100 %**	

3.11 Back filling

Table (4.25) shows that backfilling duration is equal to 69.93 hours. Before applying lean tools was 112 hours, and the percent of value added time 79.7%, the actual duration was 49%, and value added step percent is 100 %. It was 50% before applying lean tools.

Table 3.13 Waste elimination for back filling

No.	Process	Step		Duration	
		Step number	Value added step	Duration (hours)	Value added time (days)
1	Back filling layer1, cleaning site.	1	1	23.47	23.47
2	Laboratory	2	0	7.1	0
3	Back filling layer 2	3	1	16.46	16.46
4	Laboratory	4	0	3.57	0
5	Back filling layer 3	5	1	15.82	15.82
6	Laboratory	6	0	3.51	0
Total		**6**	**3**	**69.93**	**55.75**
Percentage of value added		**50%**		**79.7%**	

3.12 Identify the Cause of Waste

Table (4.34) shows the difference between activity before and after applying lean in order to demonstrate the effect of lean on the activity and also to identify the activities that can be improved.

Table 3.14 Difference between activity before and after lean application

No.	Activity	Before applying lean		After applying lean		Difference	
		PVAS[3] (%)	PVAT[4] %	PVAS (%)	PVAT %	PVAS (%)	PVAT %
1	Back filling	50	49	50	79.7	0	30.7
2	Mobilization	14	39	33	63	19	24
3	Ground floor	57	57	75	77	18	20
4	Isolation	50	82	100	100	50	18

Table 3.15balancing the process

Activity	Process	Before introducing buffers			After introducing buffers		
		New resources number	VA hours	NVA hours	New resources number	New V.A.	New NVA
	Check	-	0	8.06	-	0	8.06
	Cleaning	-	0	48	-	0	48

Mobil.	Excavation	1Excavator	95.29	0	2Excavat	45	0
Plain concrete	Casting	5	3.97	0	5	3.97	0
	Form Work	5	0	34.83	5	0	34.83
	Remove Form	5	0	5.03	5	0	5.03
Found.	Fix steel	9	15.94	0	9	15.94	0
	Form work	9	0	129.6	27	0	42.6
	Casting	9	15.55	0	9	15.5	0
	Remove Formwork	9	0	31.34	9	0	31.3
Neck Column	Formwork	8	0	79.23	14	0	67.29
	Casting	8	1.26	0	8	1.26	0
	Remove Formwork	8	0	19.92	8	0	19.9
Isolation	Cleaning	2	0	11.86	2	0	11.8
	Isolation Work	2	39.86	0	2	39.86	0
Backfilling	Layer 1	2Excavator	23.47	0	2Excavator	23.47	0
	Layer 2	2Excavator	16.46	0	2Excavator	16.46	0
	Layer 3	2Excavator	15.82	0	2Excavator	15.82	0
	Laboratory 1	-	0	7.1	-	0	7.1
	Laboratory 2	-	0	3.57	-	0	3.57
	Laboratory 3	-	0	3.51	-	0	3.51

Table 3.16 Cycle time compared

Activity	Actual duration hours	Application of lean tools		Cycle time after introducing buffer	
		Duration (hours)	%	Duration(hours)	%
Total duration	6000	3013.98	50%	1503.43	75%

Application of Lean Construction for Future Construction Project

In order to apply lean construction on future projects, we have to apply the following points:

1. To improve master schedule of the project by using standardization tool
2. To hold a weekly meeting and to determine percent plan complete (PPC) of the process of the assignment by evaluation of the steps. Advancement of the project can be measured every 4 weeks or 6 weeks according to the size of the project. The average must be more than 80%. Later on the change of average may become very simple.
3. To apply the 5 why tool to identify the main reasons of failure.
4. Correcting and avoiding any previous failure in the following week.
5. To measure the average of the percent plan complete in each 4 weeks, the weekly meeting will be good if the percent plan complete is more than 80%.
6. To identify, remove or reduce the non-value added process
7. To make a continuous improvement.

IV.CONCLUSION

Lean construction and applying standardization tools, 5 why tools, 10 point to achieve the lean principle in reducing the activity steps and duration by eliminating the non value added process in the activity by using the arena simulation. The following consequences have been reached:

1. Value added time increased from 49% to 63% as a result of applying lean tools. The used lean tools decrease the cycle time from 6000 hours to 1503.43 hours (decreased by 75%).The value added can be enhanced to 74% by improving the form work material in foundation (using prefabricated) and column activities (steel form work).
2. The number of steps decreased from 161 to 69 (a reduced by 57%). Non-value added duration of total process was4892.17hours (81%); it decreased to846.5 hours (14% decreases). Lean construction through standardization tools reduces the variability of the process, example the excavation work for one hour ($57m^3$, $62m^3$, $68m^3$).The rate of no value added process related to the design error was 30.7%. This has been considered the biggest value of the no value added in the process since it happens during the stage of design, therefore, we must apply the lean in the design to avoid waste during the construction.
3. The percentage of the no value added in the process due the above mentioned reasons were as follow: Rework 24% lack of experience management 20%, lack of number of resources 18%, lack of material 8%. This requires training workers. Engineers, other managers, supervisors should begin suitable courses in management.
4. It is favorable to work with a permanent technical staff in the company. Efficient resources, sufficient materials should be provided and saved for the project.

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