ISSN: 2278-4632
Vol-10 Issue-6 No. 16 June 2020

A Conceptual Framework for Handling the Performance of Construction by Lean Techniques

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Abstract

The goal of this study is to test the effectiveness of some lean construction tools, in particular, those tools that can be applied in medium size construction firms. Due to the success of the lean production system in manufacturing, the construction industry has adapted lean techniques to eliminate waste and increase profit. This study provides a history of evolution of production practices and philosophies through the construction industry from the traditional techniques to current lean production. The differences in production philosophies, their limits, and their impacts in the construction industry are also reviewed. A field study will be conducted to evaluate the effectiveness of some lean construction techniques including last planner, increased visualization, daily huddle meetings, first run studies, the 5s process, and fail safe for effective project management and site implementation.. The data collection methods included direct observations, interviews, questionnaires, and documentary analysis. The effectiveness of the lean construction tools will be evaluated through the lean implementation measurement standard and performance criteria.

Keywords: Lean Construction, Last Planner, Implementation Framework.

1. INTRODUCTION

1.1 General

Lean Construction recognizes that desired ends affect the means to achieve these ends, and that available means will affect realized ends. Essentially, Lean Construction aims to embody the benefits of the Master Builder concept. Lean Construction is a way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount of value. Designing a production system to achieve the stated ends is only possible through the collaboration of all project participants (Owner, A/E, contractors, Facility Managers, End-user) at early stages of the project. This goes beyond the contractual arrangement of design/build or constructability reviews where contractors, and sometime facility managers, merely react to designs instead of informing and influencing the design.One can think of lean construction in a way similar to macroeconomics. Lean construction draws upon the principles of project-level management and upon the principles that govern production-level management.

1.2 Research problem

Most of the construction projects in the Pune are characterized by inefficiencies, large variability and low performance and thus wasting time, money and other resources. In this thesis, we will show the expected benefits of using some lean tools in Pune construction industry in order to reduce or eliminate waste and eventually satisfy customer needs.

1.3 Aim and Objectives

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ISSN: 2278-4632
Vol-10 Issue-6 No. 16 June 2020

The main of this study is to apply lean techniques in middle size construction organization to test its effectiveness

To fulfil this aim the following objectives will be achieved:

1. To identify the criteria of lean as they apply to construction projects.
2. To identify basic lean tools for process improvement.
3. To identify methodology for application lean tools
4. To investigate the impact of lean practices.

1.4. Lean Construction Management:

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. This approach tries to manage and improve construction processes with minimum cost and maximum value by considering customer needs, while it helps to achieve and maintain sustainability in construction sector.

1.5 Scope of this paper

The scope of this research work is to extent the implementation of lean construction and to explore the influencing factors of lean construction.

1.6 Need of this paper

1. The main purpose of Lean management is creating value to the customer by optimizing resources.
2. Lean management principles aims to create a stable workflow based on actual customer's demand.
3. Continuous improvement is a major part of Lean management, ensuring that every employee is involved in the process of improving.

1.7 Objectives:

To fulfil this aim the following objectives will be achieved:

1. To identify the criteria of lean as they apply to construction projects.
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1.8 Motivation for the study

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ISSN: 2278-4632
Vol-10 Issue-6 No. 16 June 2020

India's rapid economic growth over the past few decades has placed a tremendous stress on its limited infrastructure. Construction industry is one of the largest industries which support the economy of a country. Since construction has a major and direct influence on many other industries reducing waste in construction can go a long way in helping the economy of the world.

2. LITERATURE REVIEW

1) Sam Solaimani, Mohamad Sedighi (2019), Toward a holistic view on Lean sustainable construction: a literature review:

The literature is reviewed on the lean principals to focus on efficiency of the construction system, the practices have been revisited used to create and preserve social and environmental values. The aim of the author was to provide a comprehensive understanding of how Lean helps achieve and maintain sustainability in construction sector. Author focused on stakeholders, construction phases, and profit. The economic values were properlyanalyzed in this study while more researching regarding social and environmental aspects of construction.

2) Nowotarski, Jerzy Paslawskia, Jakub Matyja (2016), Improving Construction Processes Using Lean Management Methodologies – Cost Case Study:

The author researched on the construction processes improved by using lean management. The author investigates on the factor influencing the total cost of selected process of managing storage area on the construction site. As per system construction deals with the deadlines, budget overruns etc. In this author taken a case study of construction office building in Poznan city center (Poland) with this new management system was introduced and analyzed. Author used this process where storage area management was used for the economic aspects and showed the influencing costs in management. Thus the methodology was used to improve the risk problems in construction management on using leans management. With this effects will overcome by reduction of the total time and cost of analyzed works. Thus as results the lean management implementation was possible and efficient on the analyzed construction site.

3) Shuquan Li, Xiuyu Wu, Yuan Zhou, Xin Liu (2016), A study on the evaluation of implementation level of lean construction in two Chinese firms:

The literature reviewed by the author on evaluating of implementation level of lean construction in two Chinese firms. The author describes the study to manage the construction industries system in China on implementing the lean construction technology. As China wasnot well aware of lean construction management so the objective of the research was to improve and extent the lean construction in China and improvise the factors of lean management in China's construction firms. So author considered two firms to analyze and evaluate the system of construction. So the forms will have different sizes, organizational scope and culture which tend to implement the levels of lean construction, its organizational structure and market focus. As results, the influencing factors of lean construction implementation are the main aspects of that helps in managing the factors of large companies in China.

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4) Bhargav Dave, Sylvain Kubler, KaryFrämling, Lauri Koskela (2015), Opportunities for enhanced lean construction management using Internet of Things standards:

The author researched on the opportunities for enhanced lean construction management. The lean management in this study is discussed on the base of using internet on controlling the production control on construction sites. The author was looking for the communication framework underlying such construction management systems can be further improved. The improving of the management can be done fully or partially across the construction project lifecycle. Author enables lean and close to real time reporting of production and control information.

The study shows the various construction scenarios to find the possible framework that will be beneficial for construction business and sites for managing the entire life cycle of construction management. Fig represents the communication loop between locations in a project.

5) Ahmad HuzaimiAbd Jamila, Mohamad SyazliFathi (2016), The Integration of Lean Construction and Sustainable Construction: A Stakeholder Perspective in Analyzing Sustainable Lean Construction Strategies in Malaysia:

The author researched on the lean construction and sustainable construction. The main aim of the author is to improve the concepts of accomplishing the reduction of waste deals with both positive environment and economic outcomes. The author used the construction industry in many countries to check and improve the poor condition by using the lean construction management system. Thus main focus was to lay the groundwork for future empirical study by investigating on various dimensions of SC and LC, where the theoretical and practical findings provided a foundation for integrating the two initiatives to yield the efficient use of valuable resources.

6) David Carvajal-Arango, Sara Bahamon-Jaramillo, Paula Aristizabal-Monsalve, Alejandro Vasquez-Hernandez, Luis Fernando Botero (2019), Relationships between lean and sustainable construction: Positive impacts of lean practices over sustainability during construction phase

The author researched on relationships between lean and sustainable construction. The author studied the increasing interest in sustainability in developing of construction projects. In this various practices framed under the lean management in reducing environmental, economic, and social impact during the construction phase.

7) Matthew Goh, Yang Miang Goh (2019), Lean production theory-based simulation of modular construction processes:

The author researched on improving the efficiency of site operations using lean production theory. The author mentioned the lean principles have been widely applied to improve the construction operations and productivity. The method enhanced the analysing and benefits of lean management. The management aimed to manage the modular construction operations with researching the barriers and adoption of prefabrication this study includes Total Quality Management; E-Kanban based Just-In-Time deliveries, cross training and the use of construction robotics. As modular construction shows various benefits over traditional construction methods the total quality management reduces the presence of

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ISSN: 2278-4632
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defects which minimize the cycle times.as results the baseline stimulation model, cycle and process times decreased by 81.27%. Thusthis study includes a more comprehensive study on other factors of productivity in construction sites.

8) Richard HannisAnsah, Shahryar Sorooshian (2017), Effect Of Lean Tools To Control External Environement Risks Of Construction Projects:

The author researched on the control external environmental risks of construction projects. The author used the existing management concepts and methods implemented for solving construction project. The main aim of the author was to control framework based on AHP method for the evaluation of lean tools application in the external environment including political, economic, social, technological, legal and environmental aspects of the construction projects.

9) Algan Tezel, Lauri Koskela, Zeeshan Aziz (2017), Current condition and future directions for lean construction in highways projects: A small and medium-sized enterprises (SMEs) perspective:

The author researched on the lean construction in highways projects for the current and future conditions. The main aim of the author is to identify the parameters defining how Lean Construction (LC) is being implemented (current condition) and how LC can be further promoted (future direction) from a Small-Medium Sized Enterprises (SMEs) perspective.

10) Qing Gao, Rongbo Shi, Gang Wang (2016), Construction of Intelligent Manufacturing Workshop Based on Lean Management:

The literature is reviewed by the author on lean management construction system based with intelligent manufacturing workshop. The main purpose of this study is key elements based on the informatization and industrialization which deals with the transformation of enterprises, use of technology and scientific management. The author the flow chart of the process management. In this the intelligent manufacturing workshop achieves the goal of dynamic management, information tracking of parts from assigning plants to production. The production process, collecting and analysing production data, enterprises establish digital manufacturing resource management system, production performance and the manufacturing data management system, realizing the goal of NC workshop production plan management, job scheduling, resource management and digital closed-loop management of field management.

11) Edgar P. Small, Khaled Al Hamouri, Husameddin Al Hamouri (2017), Examination of Opportunities for Integration of Lean Principles in Construction in Dubai:

The author researched on the Examination of Opportunities for Integration of Lean Principles in Construction in Dubai. The main aim of the author was to implement lean construction management to overcome the impact of construction projects in Dubai. The author considered few projects related to commercial sectors by using lean concept. As author research on previous records, the barriers and working of professional was surveyed and implemented. Thus the application was learned by the author to improve the system and manage the lean management according to the principals.

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12) MattiTauriainen, PasiMarttinen, Bhargav Dave, Lauri Koskela (2016), The effects of BIM and lean construction on design management practices:

The author researched on the effects of BIM and lean construction on design management practices. The main aim of the author to improve the methods and implementations on typical structures and building services design management problems. Lean management and BIM methods are derived by practicing the design methods and communication between designers. The author interviewed designers and design managers related to three case projects in this study.

13) Lianying Zhang, Xi Chen (2016), Role of lean tools in supporting knowledge creation and performance in lean construction:

The literature is reviewed by the author on the analyzing the performance in lean construction by understanding the role of lean tools. The author analyzed to cover up the gap and establishes a linkage between techniques in lean construction and knowledge management through the socialization, externalization, combination, internalization modes. Author shows the techniques that will help in utilizing the system in the constructions aspects. Author surveyed on asking questionnaire on the assumptions which will result to get a perfect decision to get on the lean management.

14) Bhargav Dave, Sylvain Kubler, KaryFrämling, Lauri Koskela (2015), Opportunities for enhanced lean construction management using Internet of Things standards:

The author researched on enhancing lean construction management. Author used lean construction method as the Last Planner System have partially tackled this problem by involving site teams into the decision making process and having them report back to the production management system. The main focus of the author was to investigate how the communication framework underlying such construction management systems can be further improved so as to fully or partially automate various communication functions across the construction project lifecycle. The improvement needs to be understood that how the internet of things will provides the evidences and the contribution related standards.

15) Remon Fayek Aziz, Sherif Mohamed Hafez (2013), Applying lean thinking in construction and performance Improvement:

The literature is reviewed on lean management applied for improving the system. The Lean construction results from the application of a new form of production management to construction. Author aimed to maximizing performance for the customer at the project level, concurrent design, construction, and the application of project control throughout the life cycle of the project from design to deliver. The author researched to understand the principles, methods, and implementation phases of lean construction showing the waste in construction. Author made some strategic planning from production planning as mentioned in the above table.

3. METHODOLOGY

3.1 General:

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Vol-10 Issue-6 No. 16 June 2020

This study presents an overview of the key Lean tools and activities that have proven to deliver real benefits to the performance and delivery of construction projects. Each tool will be introduced and sufficient detail provided to understand what it is, when and where to apply it and the associated benefits. Many of the tools in this report can be used in isolation to help resolve a specific issue or to make an improvement. However, the tools provide maximum benefit if they are used as part of a Lean end-to-end project delivery strategy and system of improvement for construction companies to develop their people, their supply chains and improving performance.

3.2 Research Methodology:

This research presents a study of a construction project in which specific lean construction elements will be tested on a middle sized construction organization. Each technique is evaluated in terms of its impact on the performance of the project. Based on the findings of the study, a new "lean assessment tool" is proposed to quantify the results of lean implementations through performance management framework. The study will test and evaluate six lean construction tools for possible improvements. They are last planner, increased visualization, daily huddle meetings, first run studies, the 5s process, and fail safe for quality. The data collection methods in this research include direct observation, interviews and questions, and documentary analysis, and these three methods are applied to each of the tools. Observational data is to be collected directly from surveys, and huddle meetings, and the construction process. The Lean Construction tools or techniques and the methods that are used in the first run study and the productivity study are generally decided upon by the vice president of the general contractor (GC) and the Research Team (RT).

3.3 Research Gap:

Although this technique much consolidated in India, various countries around the world are now in the quest of seeking more value with this thinking. However, numbers of structural and cultural barriers are to be seen that are militating against its successful implementation despite of the geographical area. Despite these continuous efforts, studies show that the presence of lean culture in the large construction companies in India is still less than what is professed by literature.

3.4 Research Strategy

Quantitative and qualitative methods are used in this thesis. Quantitative data has been collected to measure the proportion of non-value added and the value added for time and steps in each process. This was measured by standardization tools, while qualitative data was used in order to understand the reasons of non-value added in the process by using the five why tools and giving solutions and suggestions for reducing the non-value added in construction.

3.5 Data Collection

To achieve the objectives of the current study, the researcher has used several sources. These include:

3.5.1 Primary Sources

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Productivity data was obtained from Company. Moreover 30 crafts men who have more than 10 years' experience were interviewed. The results obtained were compared with productivity data reported in SP construction Pune. Minimum, the most likely and the maximum productivity of the resources are shown in. In addition, the 5 why were used to determine the causes of waste.

3.5.2 Secondary Sources

The secondary sources include books, references, journals and magazines, and papers related to the research subject.

3.6 Application of Lean Principles in Construction

Standardization was used to reduce the waste in the process by using the data. The five why tools were used to identify the causes of waste and reduce the number of steps. The following ten points were used to define the biggest non- value added process in the project by using arena simulation in order to reduce non-value added.

1. Select all non-value-added activities in the simulation model (candidates for improvement).

2. Set the task durations of the improvement candidates to zero (one at a time). Although, in many cases, eliminating these activities is not possible or practical, doing so will allow one to determine their significance on the model output.

3. Produce simulation results (run the simulation).

4. Sort the candidates in order of their significance to the simulation model. This will enable the improvement process to focus on those activities that have the greatest impact on model outputs.

4. RESULT AND DISCUSSION

1.1. Project Description

This project is executed at SP Construction Pune. Lean has been applied on a completed construction project of the construction because there is a lack of projects under construction. The project data are available and the project is of a medium size. The lean tools (standardization) are applied on this project and simulation has been applied to analyse the processes and activities duration.

4.2 Project Activities

Lean construction has been applied on the following project activities in mobilization, plain concrete, foundation, neck column, isolation, back filling, ground beam works, column for ground floor, ground floor, ground floor slab, first floor column, second floor slab, building for ground floor, and building works for first floor. The execution of the project is divided into three blocks A, B and C.

4.3 Lean Criteria Procedure

The procedure of applying the lean principles is as follows:

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- Defining the customer, the customer value, all resource required for construction, and all activities required for construction.

- Identify non value added process (steps, time).

- Removing or reducing the wastes in process by using the standardization and the five why tools to identify the cause of failure.

- Identifying non value added activities by applying the points in figure 4.1 on the construction of Building project.

- Improving the project until reaching perfection.

4.4. 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 (Convey et al., 1991).

- Activity that "converts material and/or information towards what is required by the customer" (Koskela et al., 1992).

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 (Saukkorriipi et al., 2004).

- Activity which takes time, resources and space but does not add value" Koskela et al., 1992).

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

- Value added time is the time that increases the value duration of the process without any waste.

- Non-value added time is the time that does not increase the value added of the process without waste.

- Value added steps are the steps that increase the value of the work steps without any kind of waste.

- Non-value added steps are the steps that do not increase the process value without waste.

- Waste is a kind of seven wastes over- production, defects, inventory, transportation, waiting, motion and over- processing.

This are the steps for execution-

4.4.1 Mobilization and excavation

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ISSN: 2278-4632
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4.4.3. Foundation

4.4.4 Neck column

4.4.5 Isolation

4.4.6 Back filling

4.4.7 Ground beam

4.4.8 Ground floor column

4.4.9 Ground floor

4.4.10 Ground floor slab

4.4.11 First floor columns

4.4.12 First floor slab

4.4.13 Ground floor building

4.4.14 First floor building

4.5 Remove or Reduce the Influence of Waste as it is observed

Computer simulation is defined as the process of designing a mathematical-logical model of a real world system and experimenting with the model on a computer. Simulation has proved to be a valuable analytical tool in many fields. Particularly, it is powerful when studying resource-driven processes since it provides a Fast and economical way to experiment with different alternatives and approaches. Furthermore, key factors in the process can be identified through an in-depth understanding of the interactions of resources and processes. Construction operations include many processes. The flow between processes and the resource utilization at every step thus determines the performance of the whole project. To understand the interaction of construction processes and the impact of resource supply, the construction project planner can experiment with different combinations of construction processes and varying levels of resource supply in a simulation environment to seek the best performance for their construction operation. Arena software (Rockwell Software Manual, 2000) is used to simulate and represent the real system which allows the planners to observe the behavior of the system when changes are made in the system. Also Arena enables the planners to bring the power of modeling and simulation to their planning.

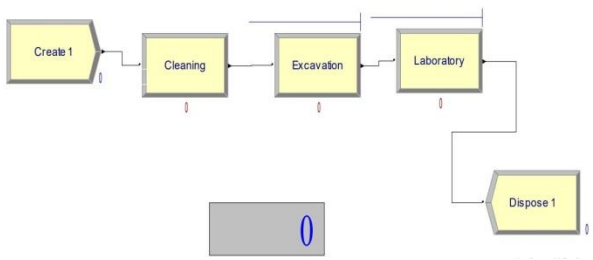

Figure 4.1 Arena simulations of mobilization and excavation

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ISSN: 2278-4632
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Secondly, applying productivity to three processes. Cleaning lasted for 48 hours, demolition took 32 hours and building engineer's office took 32 hours. These three processes may start at the same time. Since the project was ready, the duration of cleaning is supposed to be 48 hours. This is considered non-value added process. In the second quarter, a slight improvement in value added steps led to the same improvement in value added time. The ground beam activity raised by 17% in value added steps and 11% in value added time. The plain concrete activity increased by 3% in value added time because the percentage of non-value added activity of the formwork and removing it, isless than value added activity. In the third quarter, the big improvement in value added steps gave only a little improvement in the value added time. The value added steps in the slab activity has risen by 23% and the value added time raised by 8%. The value added steps for the columns activity raised by 40% and value added time 3.6%. The number of the steps of the neck columns improved by 25% and the value added time did not improve. The number of steps of building activity improved by 29% and value added time by 1%. This all happened because the non-value added processes (form work and removing it) had a big time value inside the activity.

In the fourth quarter, a big improvement in the value steps produced big improvement in the value added time. The number of steps in the isolation activity of the value added steps rose by 50% that also raised the value added time by 18%. These rises happened because cleaning process was done after removing the formwork. It was done during the work of the contractor because of the lack of workers and the cleaning material.

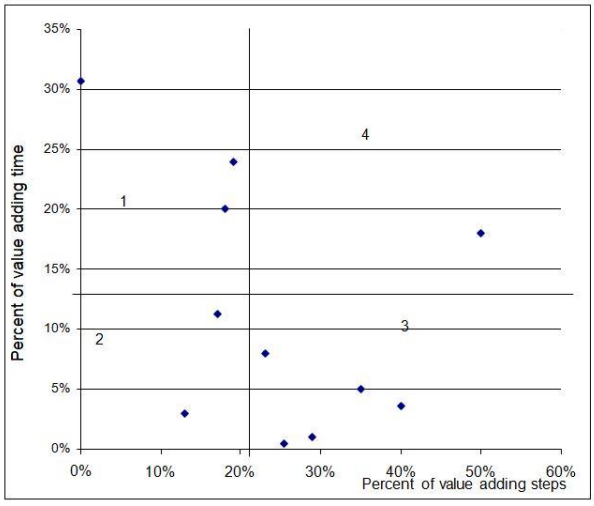

Figure 4.2 Comparing value added steps to value added time

Regarding the causes of delays of activities, using the five why tools showed the following results:

- The failure due to design error was 30.7%.
- The failure due to work error was 24%.
- The failure due to lack of experienced management was 20%.
- The failure due to lack of resources was 18% due to lack of permanent resources

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- The failure due to lack of material formwork was 8% because the contractor had to divide the project into many stage because of lack of the formwork. The solution is to save enough formwork. Figure (4.10) shows the percentage of the causes of a failure as in the diagram.

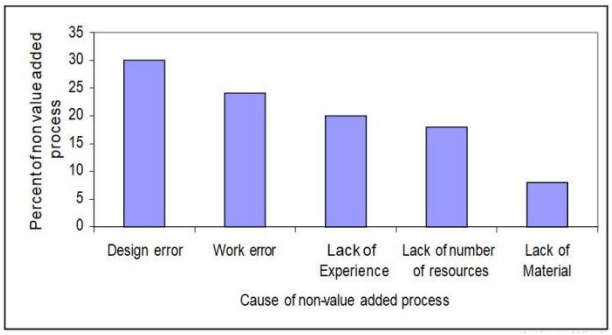

Figure 4.3 Cause of failure

4.6 Finding the Largest Non-Value Added Process

The eight points that were mentioned in the methodology (4.3) were applied using arena simulation in order to find the biggest non value added process. The whole non value added process is shown in by putting 0 non value added process in turn and calculating the time period in the end of the project (run the simulation Figure (4.11).

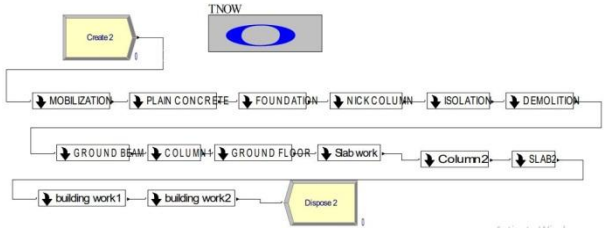

Figure 4.4 Simulation model

Figure (4.12) shows that duration of the foundation formwork process is 129.6 hours. This is far from the other processes (shown as number eight). Ground floor columns formwork process duration are 163.82. First floor columns formwork process duration was 157.51 hours. These are longer than the other processes (shown as number 34, 53). The duration of the building processes took 173.29, 133.2, 173.69, 172.75, 132.67, 172.21 hours. These numbers correspond to 42, 43, 44, 61, 62, and 63. These duration are larger than those in the other processes

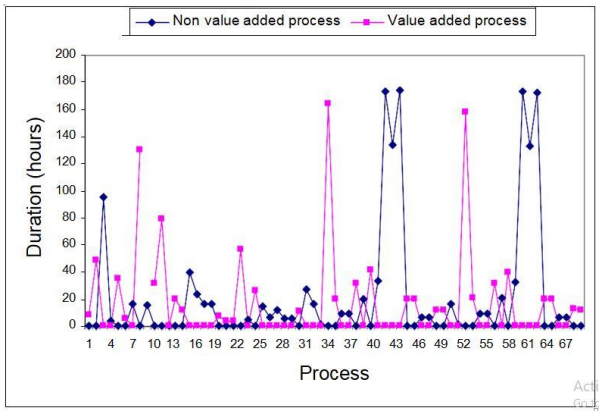

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Figure 4.5 Duration variability before introducing buffers and after applying lean tools

It shows the balance improvement into the process by decreasing the duration of processes. Foundation formwork process duration decreased from 129.6 hours to 42.6 hours by increasing the number of resources from 9 to 27 workers shown as number eight in Figure (4.13). The duration of excavation process decreased from 95.29 to 45 hours by using 2 excavators shown as number three. The duration of the ground floor columns formwork decreased from 163.82 hours to 56.49 hours by increasing the number of workers to12 workers shown as number 34. The first floor columns formwork duration decreased from 157.51 hours to 56.49 hours by increasing the number of workers to 12 workers shown as number 53. The ground floor building duration decreased from 173.29, 133.24, 173.96 hours to 65.9, 66.07, 66.37 hours by increasing the number of workers to 13, 10, 13 workers shown as number 42, 43, 44. The first floor building duration decreased from 172.75, 132.67, 172.21 hours to 65.9, 66.07, 66.37 hours by increasing the number of workers to 13, 10, 13 workers shown as number 61, 62, 63. The result of introducing buffer is that the non-value added time decreased by 55% (from 1906.15 hours to 846.5 hours).

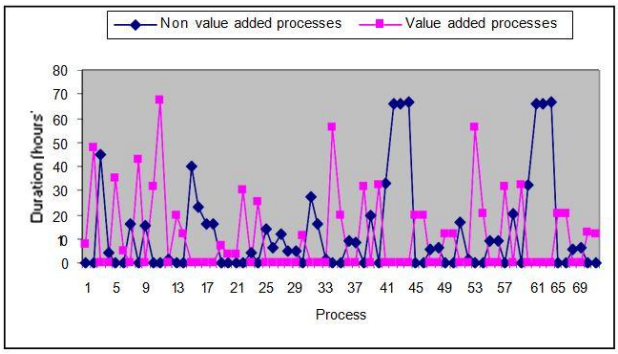

Figure 4.6 Duration variability after Introducing buffers

The contracting time duration was 2920 hours. After applying lean tools the total duration was 1503.15.

It shows the cycle time decrease from 6000 hours to 1503.43 hours (reduction by 75%)

Table 4.1 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%

4.7 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

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ISSN: 2278-4632
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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.

Applying the above points to the mobilization and excavation activity described in project studied: cleaning work, cutting trees, demolition existing wall in the site, building an engineering office, excavation work first layer, excavation second layer, and excavation third layer. It shows the process completed and the process assigned in the master schedule of a real project.In the 1st, 2nd, 3rd week there are two assigned process (cleaning, cutting trees) and only one was completed. In the 4th and 5th week there are three assigned (cleaning, cutting trees, demolition) and only two processes were completed. In the 6th and 7th week there are four assigned and only three processes were completed. In the 8th and 9th week, there are five assigned and only four processes were completed. In the 10th week, there are 6 assigned and only 5 processes were completed. In the 11th week there are 7 assigned and only 5 processes were completed.

Table 4.2 Process assigned and process completed

Date	1st Week	2nd Week	3rd Week	4th Week	5th Week	6th W.	7th W.	8th W.	9th W.	10th W.	11th W.
Process Assigned	2	2	2	3	3	4	4	5	5	6	7
Process Completed	1	1	1	2	2	3	3	4	4	5	5

Figure 4.7 shows the real percentage plan complete of each week.

PPC= (Number of processes completed / Number of processes assigned) X 100

In the 1st, 2nd, 3rd weeks, the PPC=1/2 x100=50%. In the 4th week, 5th week the PPC = 2/3 x100 = 66%, in the 6th week, 7th week the PPC= 3/4x100= 75%. %. In the 4th week, 5th week the PPC = 2/3 x 100 = 66%, in the 8th week, 9th week the PPC= 4/5 x 100 =80%. In the 10th week the PPC = 80%, in the 11th week the PPC= 70%. This needs to determine the main reasons of failure.

Using the five why tool, the cause of failure is the lack of experienced management and the lack of number of resources.

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ISSN: 2278-4632
Vol-10 Issue-6 No. 16 June 2020

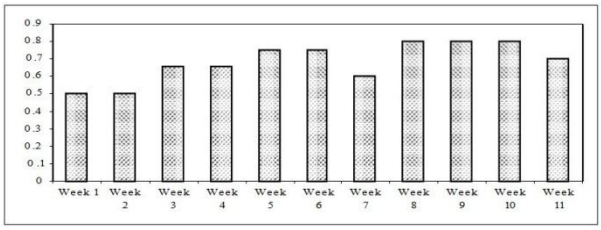

Figure 4.8 Actual percent plan complete of each week (PPC)

Figure (4.15) shows the average of percent plan complete is smaller than 80% which requires finding out failure reasons in each week. By the application of the five why tools and the 10 points described in part (3.6)

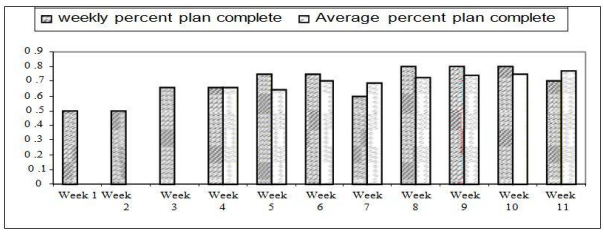

Figure 4.9 Average percent plan complete of each four week

CONCLUSION

This study of Lean Construction Practices in the SP Construction shows the influence of applying the lean construction. This study was conducted by identifying criteria of 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.

2. The used lean tools decrease the cycle time from 6000 hours to 1503.43 hours (decreased by 75%).

3. The value added can be enhanced to 74% by improving the form work material in foundation (using prefabricated) and column activities (steel form work).

4. The number of steps decreased from 161 to 69 (a reduced by 57%).

5. Non -value added duration of total process was 4892.17 hours (81%) it decreased to 846.5 hours (14% decrease).

6. Lean construction through standardization tools reduces the variability of the process, example the excavation work for one hour (57m3, 62m3, 68m3).

7. 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.

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ISSN: 2278-4632
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8. 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. It is favourable 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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