Impact of Lean Construction Techniques on efficiency of Time and Cost in Commercial Buildings

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***Abstract*: The traditional construction practices have not been successful to deliver projects timely and with-in budget completion. That's the reason, more than 90 % of projects gets over budgeted or completely uncontrolled. This reason is enough to question the conservative industry and consider what possibilities there might be in the future to solve these problems. Thus, new methods like "Lean Construction" have been developed in recent years to overcome these problems. Lean construction focusses on the reduction of waste and effectiveness of time and cost of projects. Many developed countries have adopted lean construction techniques to overcome the planning and waste management issues. Pakistan has not yet planned to shift to lean construction techniques. So, this study focusses on identification of appropriate lean tools for construction industry of Pakistan and their implementation on existing project along with their benefits in construction management system. Moreover, this study provides a framework for the implementation of lean philosophy in construction industry so that one can attain maximum benefit out of lean as well as this study will be valuable to create consciousness among the professionals in the construction industry of Pakistan to plan for executing lean technology for pre-construction analysis, visual coordination and better performance of the project rather traditional approaches in order to reduce waste in terms of time and cost of the project.**

***Keywords*: Cost Conservation, Lean Construction, Lean Tools, Traditional Construction, Time Conservation**

I. INTRODUCTION

In 1993, International Group for Lean Construction firstly coined the term Lean Construction. Lean Construction is for all stakeholders like Owners, Engineers, Architects, Constructors, Suppliers and End Users. It's a new technique can be applied on any project, with any project delivery model. Lean Construction does not refer to the phase during construction is in process while it encounters the entire construction industry. Lean Construction encounters the concurrent and continuous improvements in all directions of natural and built environment like design, activation, construction, maintenance, salvaging and recycling. By this approach construction processes with minimum cost and maximum value can be managed by considering customers' needs and reducing the effort, time and waste.

Construction Management is a highly-discussed area now a day. How projects within the construction industry are managed has not changed significantly during the last decades. However, the traditional practices have often failed to deliver projects timely and within budget completion. That's the reason, more than 90 % of projects gets over budgeted or completely abandoned. This reason is enough to question the conservative industry and consider what possibilities there might be in the future to solve these problems. The ongoing most commonly traditional practices of construction failed to deliver projects on time, within budget and at desired quality not in Pakistan even all over the globe. By experiences on projects, rising litigation and endemic quality problems evidenced. It became evident that on-going construction governing principles must be revisited. Otherwise, these practices will be disastrous for construction industry.

Thus, new methods like "Lean Construction" have been developed in recent years to overcome these problems. Lean construction focusses on the reduction of waste and effectiveness of time and cost of projects. Many developed countries have adopted lean construction techniques to overcome the planning and waste management issues. Pakistan has not yet planned to shift to lean construction techniques. So, this study focuses on the identification of appropriate lean tools for construction industry of Pakistan and their implementation on existing project along with their benefits in construction management system. Moreover, this study concludes that implementation of lean tools can save significant amount of time and cost in construction projects as well as effective site management can also be done.

II. BACKGROUND STUDY

The lean construction was implemented on residential buildings and project comprises 18 houses that were financed by a private investor. After lean concepts implementation project achieved stable work flow and project completed before expected time. About 85% tasks started as planned time and 80% activities completed before due time and 20% activities on time completed. After achieving wide range of benefits, company management decided to apply lean concepts on all projects henceforth. (Mota, B. P., & Alves, T. 2008).
The traditional construction is characterized by high level of waste, which results in low performance, cost or delay overruns.

To cope up these issues, it's became ineluctable to introduce new techniques in construction industry and most relevant technique is lean construction concept which is inspired by lean production methodologies. A rigorous comparative study is carried out between traditional and lean construction techniques. It is demonstrated by implementing lean construction philosophy the construction industry can achieve wide range of benefits to improve organizational management system.(Bajjou, Chafi, & En-Nadi, 2017)

The Kingdom of Saudi Arabia witnessed a massive construction in last two decades. Most of projects experienced cost overruns, time delays and massive quantity of waste. To cope up with these challenges Lean Construction is introduced into the Saudi construction industry but still it is in its infancy. (Jamil Ghazi et al., 2017).

Lean Construction is still new concept to many construction industries around globe. Countries like UK, Brazil, USA, Australia have gained many benefits by adopting its concepts according to Ballard and Howell (2003). This concept is also new for Sri Lankan industry. Before implementing lean construction concepts in new setting, some certain tests like suitability and acceptability are prerequisite.(Senaratne & Wijesiri, 2008)

Construction sector is often characterized by budget overruns, deadline delays and barriers in maintaining quality of projects. To preempt these problems, it is contemplated to transfer the management methods which are being used in production industry. It was possible to implement lean management methodologies. Lean management methodologies are used to access risk problems and find viable solutions which will influence in reduction of time and cost of analyzed work. (Nowotarski, Pasławski, & Matyja, 2016)

Construction industry role is essential for economic growth of country. A number of techniques have been adopted to increase its performance. Lean construction is entirely new technique in this perspective providing customer satisfaction and value for money. Research results reveal that wastage, time and cost overrun are the driving factors for its implementation. Its implementation faces hurdles because of human reluctance and naive knowledge. (Shehzad, Qadeer, Ayub, & Thaheem, 2017)

There is philosophy that by reducing construction waste and improving productivity the project cost is reduced in construction industry. With low expenses, lean construction emphasizes the minimum cost of project. Globally, in construction sector this philosophy has gained wide range of popularity. The practitioners of lean construction are benefited by applying its tools and techniques at different stages of construction project. Following global trends, lean construction tools and techniques implementation in Pakistan has been analyzed. But organization lack of support and fewer researches in lean construction are barriers for the implementation of its tools and techniques.(Memon, Akhund, Laghari, Imad, & Bhangwar, 2018)

People are demanding high quality projects with economic development and betterment in living standards. But traditional quality management methods own lot of drawbacks and it leads to problems in construction quality management which pose the threat for entire construction industry and people living standard. Lean construction can improve the construction project quality evaluation system.(Miao, 2014)

A. Lean Principles

There are five basic principles of lean thinking which has to be followed to gain maximum benefits and to gain maximum lean success (Aziz & Hafez, 2013). The five-step thought process for guiding the implementation of lean techniques is easy to consider, but not always easy to follow and achieve the end results.
The implementation of lean construction involves the application of these five fundamental principles of lean thinking. Lean principles assistance in inspecting the project and thus reduce the unnecessary cost and time overruns. These lean principles clearly define the goals of lean system. Five fundamentals of lean thinking are (Womack & Jones, 1997):

1) Specify Value

Value can be defined only by the customer. Specify value means thinking from customer's point of view and considering only those activities which generate value to the end-product, nothing more or nothing less.

2) Map the Value Stream

All the actions that are needed to bring the product to customer are Value Stream. Identify the value stream by the elimination of waste, especially those activities which do not add to the value of end-product. This means stop the execution of an activity when something goes wrong and change it immediately. Processes like miss production, overproduction, storage of unnecessary materials, transport of materials, movement of labor etc. which does not generate value to the customer should be avoided.

3) Create Flow

Ensure that there is a proper flow and continuous movement in the process or execution of work by managing the supply chain. Focus should be on the process rather than the product. This was value stream would be added and end-product would be according to the will of customer.

4) Establish Pull

Use pull planning instead of push planning in construction/management processes. This means that the work should be according to the customer. Produce exactly what the customer needs and exactly on time and always be prepared for the changes made by customer.

5) Seek Perfection

Target the perfect solution and continuous improvement. Deliver a product that is up to the mark and up to the expectations of the customer within agreed time schedule and in a perfect condition without mistakes and defects. The only way to achieve this goal is by having direct communication between customer/client, manager and employees.

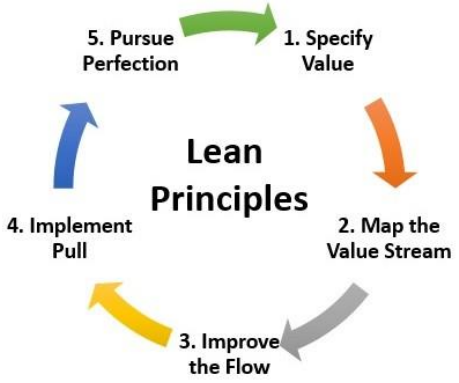

Fig 1 Five Principles of Lean Source: Bertelsen, (2002)

B. Lean Project Delivery

Lean project delivery method is a type of integrated project delivery method. This process is illustrated in the figure below:

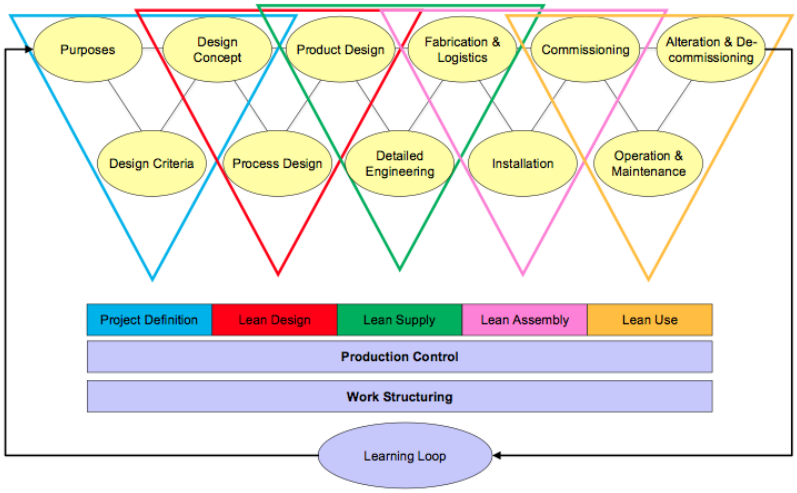

Fig 2 Different phases and their collaboration in Lean Project Delivery System, Source: Ballard and Howell (2003)

C. Deficiencies in Traditional Method

Traditional project management in construction industry incompetent because it does not lay on a theoretical framework (Koskela and Howell, 2000). Starting from the beginning, construction projects are managed by breaking them into several activities and tasks, estimating the money and time for the completion of each task, applying CPM (Critical Path Method) to identify the critical activity. In each case, activities and tasks are dealt with much the same. Project managers make a schedule to decide when each activity should start and then push for work to start on the promptest begin date. The cost and schedule limits of each activity is determined by project controls. Different actions are taken to speed-up the activities in case of any delays. In most of the cases, additional labors are hired to speed the completion, but this increases the cost while reducing the productivity.

According to lean construction perspective, current management method or traditional construction practices lies on a faulty model of the project, the work included and its control. Simple the current project management fails to manage the activities and tasks and does not focus on the management of the work flow. In the present age, projects are getting more complexed, uncertain and quick (CUQ) (Shenhar and Laufer, 1995). Every project is desired to be completed in even shorter durations. Complexity arises from the changing nature of the client and technology. This creates a pressure on the construction manager and adds burden. In this environment, activities are not linked with each other in simple consecutive chains. Each activity is treated as an individual instead of linking all the activities. The co-ordination work in such types of projects cannot be guaranteed even when

considering the highly-detailed CPM schedules. These schedules do not make a proper flow of work within the activities. The work flow is ignored. The work from one phase to another phase is either assumed or ignored. Project managers who count on such schedules fight with ambiguities (Tommelein et al., 1999). Managing by this method usually fails to ensure the consistent work flow (Howell and Ballard, 1996).

Current project management fails to add value to the client. It certainly tries to do so at the beginning of the project. Basically, delivering value to the client means to increase the ability of the client to achieve their purposes at the end of the project. The change in choices is difficult to handle through current techniques that push for the early decisions. The study of failures of the traditional project management approach helps in defining the requirements for introducing new approaches like lean construction.

D. Lean Construction

There are many problems with the present construction industry such as low productivity, cost overrun, time overrun, insufficient quality, poor safety etc. These problems create the project to fail and do not let all the stakeholders to gather on one platform and discuss the project. Implementation of lean manufacturing principles in the construction industry is a reliable approach to minimize the drawbacks of traditional management approach (Koskela et al, 2002).

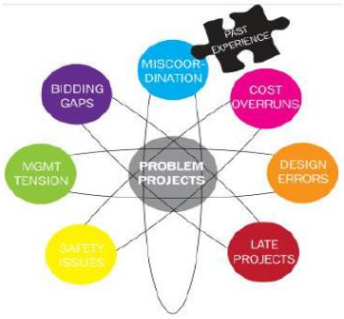

Fig 3- Project Problems, Source: Howell and Lichtig (2008)

Like manufacturing principles, the elimination of waste at the beginning leads to better quality of project and thus it improves the cost and time of the project. Visible changes have been felt in the manufacturing industry after the adoption of lean principles. The construction projects now a-days are more complex that in the past. Traditional method is suitable for the projects with less complexity and small budgets. Lauri Koskela (1992) is the one who open-up to lean principles and thought to apply those principles in the construction industry to deal with the complexity of projects. He illustrated different types of wastes associated with the construction industry as non-value adding activities and waste of materials which lead to the waste such as transportation, delays, materials etc. (Senaratne and Wijesiri, 2008). Some research conducted in different countries show that during the flow process of construction, waste is generated. Flow deficiency increases the consumed cost.
According to Koskela (1992) percentages of consumed costs due to flow deficiency is: 'poor material management' instigates 10-12% of the total labor cost, 'non-conformance quality costs' uses up to 13% of total project cost, time consumed by 'non-value adding activities' adds up to 2/3 of the total time of the project and 'lack of protection management' causes 6% of total project cost (Senaratne and Wijesir, 2008). By the elimination of cost increasing flow activities, Lean principles provide several advantages including the cost reduction when implemented in construction industry successfully (Senaratne and Wijesir, 2008). Implementation of Lean approach in the construction industry is itself a difficult task. The main barrier in its implementation in to change the working nature of labors and other stakeholders involved.
Manufacturing plants and constructions sites differ in many ways (O. Salem, et al., 2006). From literature, lean principles proved to be helpful in construction industry in improving the cost and time overrun along with the quality of the project.

E. Wastes in Lean Construction

The main determination of Lean Construction is to reduce waste or eliminate it (Sacks, et al., 2010, Garrett and Lee, 2011). These are as following: Transport, Inventory, Motion, Waiting, Over-Processing, Overproduction and Defects.

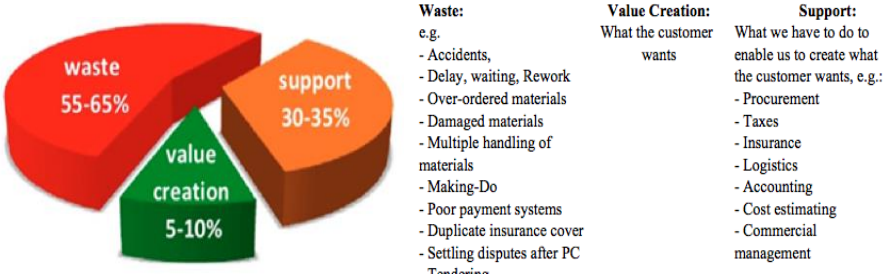

Fig 4 - Analysis and examples of Waste in Construction, Source: Mossman, A (2009)

F. Lean Construction Tools

There are several tools and techniques of Lean thinking which can be applied to the construction industry in ever phase to improve its performance and productivity. These tools can be implemented in the pre-construction phase of the project to the maintenance phase of the project.

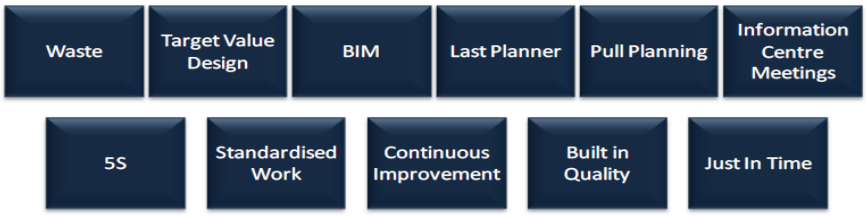

Fig 5 - Lean Construction Tools, Source: Lean Construction Institute (LCI)

Description of some tools mentioned above is given below:

1) Last Planner System (LPS)

Last planner system is the most important tool of the Lean Construction which is based on the pull approach instead of push approach. The essential part of Last Planner System exchange optimistic planning with the realistic planning by considering the abilities of the workers to achieve their goals. The Last Planner is a group of people or the supervisor who ascribes works to the workers as it increases the communication between the site management and the labor on site.

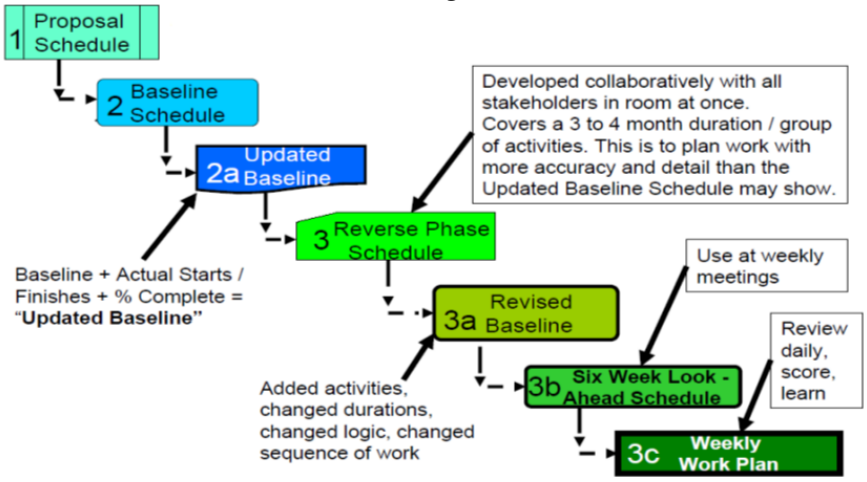

Fig 6 - Last Planner System, Source: Zettel (2008)

Principal decision maker in last planner system is client who is involved in pre-construction phase i.e. the planning stage. Appearance of last planners suggest the reverse planning in this system moving from final to initial stages. And this kind of planning is named as pull planning.

2) Five S'

The 5S's are key to reduce waste in the industry. It reduces treasure hunts, leading to improved productivity. They are:

Sorting; Sorting means to sort out the necessary from the unnecessary and discard the unnecessary.
Simplifying; Simplifying is to create and identify place for everything (that we determined necessary in Sorting) to maximize effectiveness and safety.
Sweeping; In sweeping, the physical and visual control of the work area is checked and deliberately all the parts and materials are picked up that are out of place and each material or item is returned to its assigned place.
Standardizing; Standardizing means to create standard ways to keep the work areas organized, clean and orderly, and documenting agreements made during 5S's.
Self-Discipline; Self-Discipline assures tall the activities follow through with the 5S's agreements.

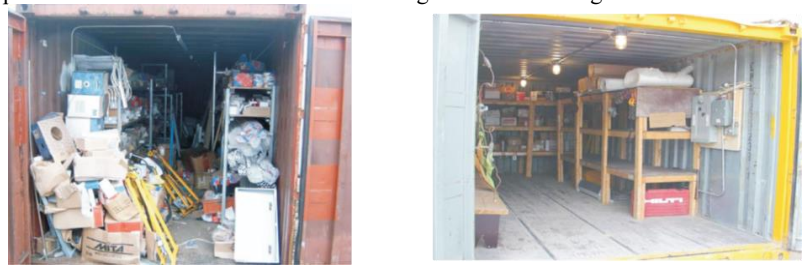

Fig 7 - 5S approach (the left picture store before 5S & the left picture after 5S), Source: O' Connor and Swain (2013)

3) Visual Management

Visual management is important tool in the construction process to prevent any uncertainties in the information. Visualization helps in recognizing the work flow and in creating awareness among the workers on site (O. Salem, et al. 2006). Visual management contribute meticulously in upholding Lean Approach in construction industry if implemented in an appropriate way on site. This tool incorporates demonstrating the work finishing status of the preceding activity, the accessibility of the materials, alterations in the layout and the location of different resources. Implementation of the mentioned steps can improve the productivity of planning and control and reduces the tendencies to errors. (Sacks et. al. 2009).
Some of the practices through which visualization can be done include mobile signs, PPC Charts, sign boards, electric wiring, safety signs and project milestones (O. Salem, et al., 2006). Computer aided visualization can be employed to support the Lean approach and Lean requirements (Sacks et. al. 2009).

Fig 8 - Site Communication Center for All Parties to Access Vital Project Information, Source: O'Connor and Swain (2013)

4) BIM (Building Information Modelling)

Construction, the most progressing field in the present world of information and technology where regeneration, evaluation, debugging, designing, planning, scheduling and developing alternatives in a very short duration can be easily aided by the programmed software. And with the use of technology other management techniques are recommended by experts who used both technology and management techniques side by side on different projects. Results with the combination of both technology and management were time, quality and cost effective.

For many years technology had been a continuous aid to the field of construction but there are always some constraints which made the technology some points backward from the real practices in field because ultimately the final product is the real object to be visualized by the customer. “Building Model” as technology term had been used since 1970s and its concept has been revolving around the area of construction. Computer scientist together with engineers and architects have been working on building modeling tools to get close to practicality. BIM as term (Building Information Modeling) is first used in 1992 in paper by G.A van Naderveen and F.P Tolman, then years of working gave us a lot of Tools like Archicad, graph iSOFT which can work both on 2d and 3d modelling with integration. The research work extended towards a lot of user friendly Tools to be used for BIM and Autodesk played a great role in the development of BIM by publishing papers and working on tools like Autodesk AutoCAD and Revit. So, BIM is a digital visualization of an architecture, function and behavior of a facility, which extends the concept of modelling from three dimensions to fourth (time) and fifth (cost) dimensions. While doing the in-depth study of BIM and Lean. Both revolve around eliminating waste and adding value to the customer. So, using BIM software as tool in implementing Lean construction techniques fulfilled the idea of using technology which works with the integration of management techniques.

a) Levels of BIM

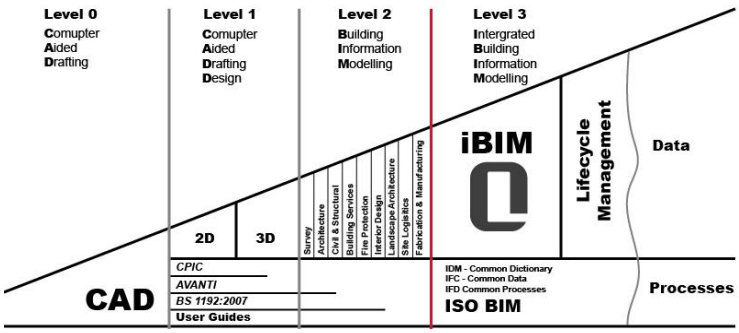

Fig 9 - Levels of BIM, Source: Wong, Johnny & Yang, Jay (2010)

III. MATERIALS AND METHODS

The research methodology comprises of Literature Review and Case Study. For the practical and tentative evidence to create the research base for this project, lean tools and techniques were selected depending on their user approachability and productivity, compatibility towards fresh beginners and accessibility. Afterwards, the selected lean tools were implemented on the building to check its impact and effectiveness on time and cost.

Following is a brief description of the research methodology.

A. Literature Study (Developing the concept of lean Construction)

For this research, a primary understanding of Lean Construction was essential to proceed with the scope and objectives. Lean is a new and complete approach. An idea of lean thinking, wastes, lean tools, lean project delivery, lean implementation etc. was developed with the help of literature study. Lean implementation barriers were also identified from pervious researches and literary work. The literature study was done through different multidimensional resources like: books, articles, journals, research papers, reports published by government and industry, project, Lean related websites and magazines.

B. Case Study

After that, different case studies were selected, studied and then examined. The case studies were related to the research objectives of this study. They were selected from international projects that were carried out using Lean techniques. The case studies set a base for the implementation of lean tools on existing building in local environment of Pakistan.

C. Selection of Lean Tool

Lean construction consists of multiple tools that have different uses. One tool cannot control each aspect or area of design and construction. The different tools of Lean (BIM, 5S', LPS and Visual Management) were selected based on criteria. The tools must fulfill these requirements: it must have applicability across different project phases from initial feasibility to handover and maintenance, it can be applied easily in the construction environment of Pakistan, that tool has an Impactful effect on time and cost of the building, it should be easy to use and understand and it should have a remarkable effect on project flow and performance.

D. Selection of Building

Following criteria were taken into account before selecting the building for analysis:

- Traditionally constructed building
- Multi-story building
- Project Ahead on schedule
- Over budget
- Having planning execution problem related to services

For the data collection of building, frequent visits and interviews were carried out with the respective departments. Mainly Architect and Contractor were consulted for this purpose.

The site selected for implementing lean tools was "Sukh Chayn Shops and Apartments." It is located in Block-B at Sukh Chayn Gardens Multan Road, Lahore.

The consultant of the project was Shagufta and Munir Associates. The building was constructed by RIZ Builders. It was a mixed-use building. Total area of the plot was 15000 sft. Total no. of floors was 6 with one basement. The top three floors are dedicated to the apartments. The rest of the floors have shops while open parking is provided for the cars and motorcycles.

The project was started in April 2015. The expected completion time was July 2016 according to the schedule developed on MS Project, but the actual completion time of the Project was December 2016. Originally, the total cost of the project was Rs. 114,235,784 as estimated but at the end the total actual cost of the project Rs. 134,567,987.

E. Data Collection and Collation

All the data collected so far was then collated and organized. The tools and building selected based on their respective criteria were analyzed.

F. Problem Identification

The problems in the building were then identified which caused the delay in time and cost overrun through interviews with the contractor and manager.

G. Implementation of selected Lean Tool

The tools selected were then implemented on the selected building on the basis of different software: Touchplan,io, Autodest Revit 2012, Naviswork 2012 and Autocad 2013.

H. Analysis and Discussion

The results were analyzed and obtained after implementation. Discussions were carried out based on the results.

I. Comparing Results

After this, the last step of the research system was to reach exact determinations in the light of information gathered. With a specific end goal to streamline the execution of building data, two structures were produced. First structure containing actual time and cost. The other structure containing time and cost obtained after the implementation of selected Lean tools. These two were then compared to get the results. At the end, a couple of suggestions were advanced for future research and pragmatic utilizations of this work.

J. Framework Development

At the end, a framework model was developed to act as a reference model for the implementation of lean in construction industry of Pakistan.

IV. DATA ANALYSIS

Data collection and organization is the logical and efficient approach to collecting and measuring information from different sources to get a whole accurate picture of the research work. It enables an individual or organization to assess outcomes and make predictions about future likelihoods and drifts. The purpose of this chapter is to give detailed information about the building and problems in the building that caused cost overrun and project delay. It also emphases on the application of lean tools on the building to overcome these problems.

A. Implementation of Lean Tools

i Identification of Problem Faced in Existing Building

- Due to small area available for material and tools, proper planning of material or tool placement was not made.
- The material was stacked without order
- The basic tools and needs had no proper place allotted but instead they were mixed with the rest of the stuff.
- The site was not cleaned daily but after some long intervals

ii Process of Implementation of 5S

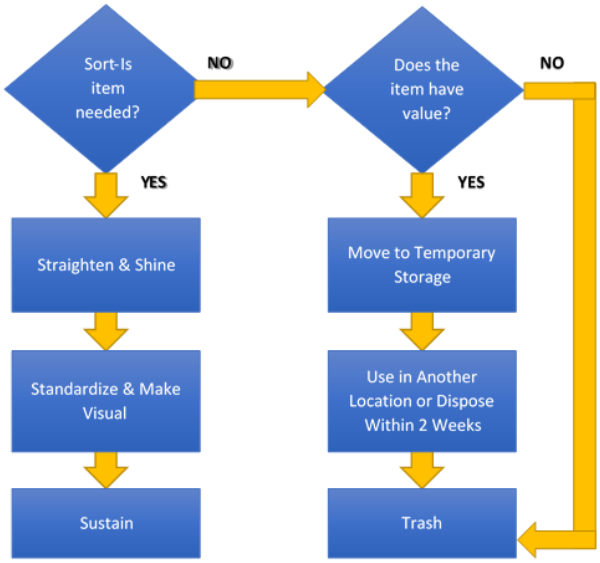

Fig 10 - 5S' Flow Chart

iii Observations and Calculations

Avg. time usage with actual site arrangement	=	22 min
Avg. time usage with lean 5s arrangement	=	2 min
Time Difference	=	20 min
Average No. of employees per day	=	15
Total Time Saved	=	300 min saved per day
Avg. Worker rate	=	1.85 Rs/min
	=	1.85 * 300
Total Saved Cost	=	551 Rs/ Day
Savings in Whole Project	=	551 * 417
	=	229,767 Rs

(Factors applied are from the results obtained in similar case study of 5s)

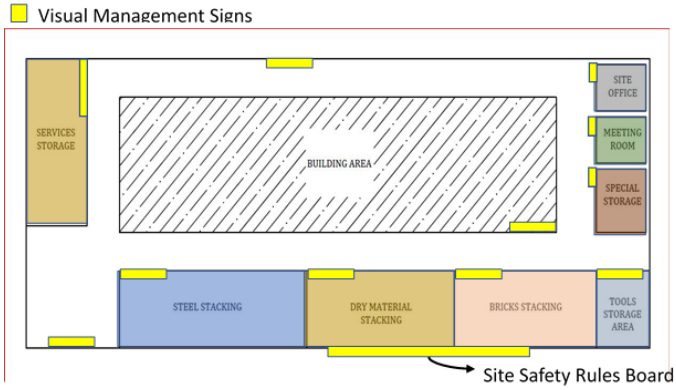

Fig 11 - Application of Visual management in 5S'

It saved 229,776 Rs by providing transparency between the labor and materials and tools.

Benefits of Implementing 5S

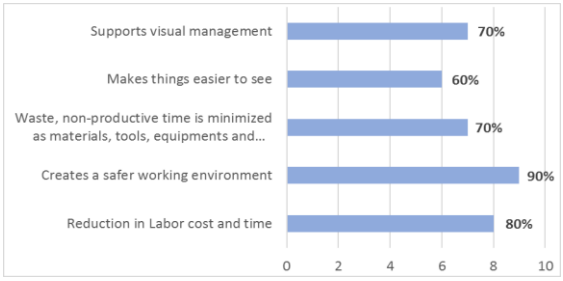

Fig 12 - Benefits of 5S'

After the implementation of 5S tool on the building, the workers have more clear idea of what is done and what needs to be done. This act of sequencing and straightening the materials and tools provides transparency between them that is essential for fast performance of labor. Thus, reducing the un-value motion activities for finding the materials and tools before 5S was applied.

iv Process of Implementation of BIM

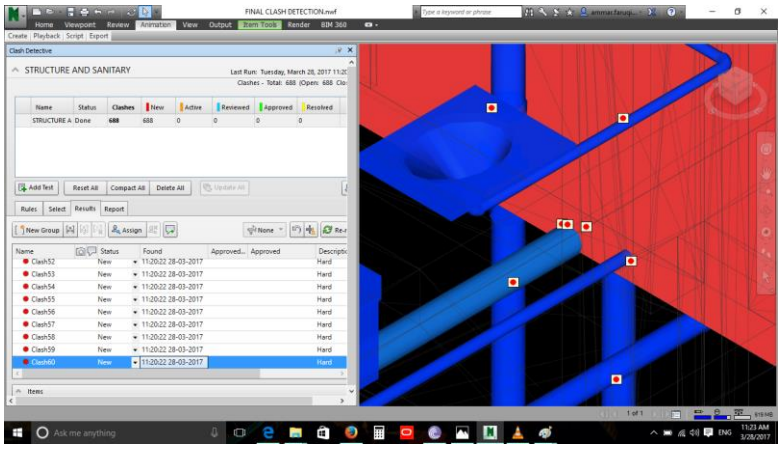

Fig 13 - Clash Detection between Plumbing and Architectural Model

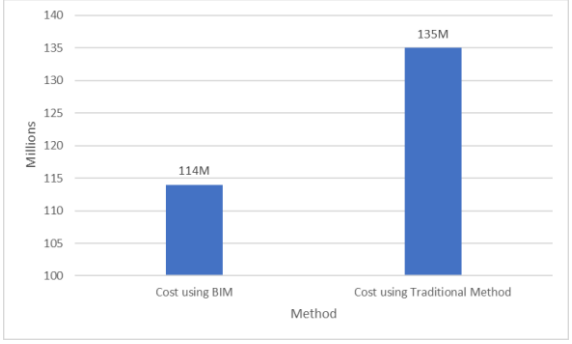

Fig 14 - Cost saved using BIM

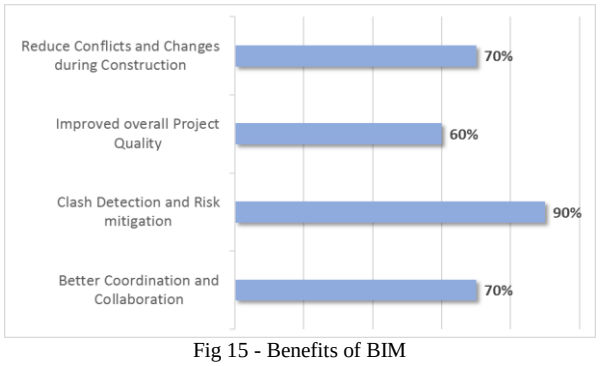

Fig 15 - Benefits of BIM

The use of Building Information Modelling in the Project gives more visual perspective of the architecture, structure and services of the building. This quality of BIM helped identify the clashes between plumbing and structure and within the plumbing itself before the execution of the Project. This reduced much of the rework cost and time.

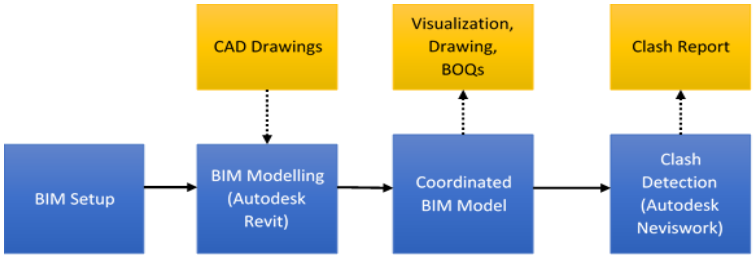

Fig 16 - BIM Flow Chart

Notes are checked off when the tasks are. Last Planners collectively revise the Look Ahead Plan to acclimate actual progress and new progress. Percent Plan Complete (PPC) reports assess the reliability of the Schedule time to time. Variance report helps to identify the risks before time and improves progress of the project.

v *Implementation of LPS*

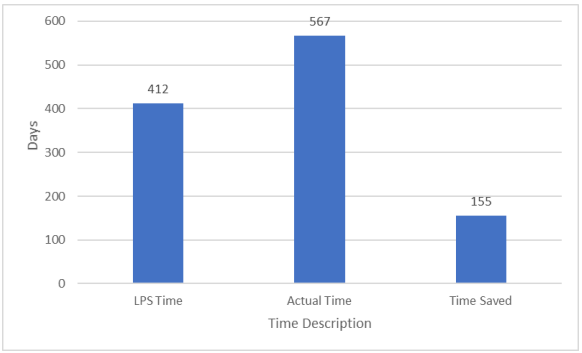

Fig 17 - Time saved through LPS

After the implementation of LPS tool on the building, the risks during construction reduced due to advanced collaboration between all the major parties involved in the construction. The frequent meetings and check and balance of all the activities reduces the chances of delays. Furthermore, the use of pull planning in last planner system helps to identify the constraints and risks before time and helps to take measures to overcome it.
Thus, the delays were removed, and the project completed ahead on schedule. So, after the implementation of all tools total 15% cost was saved and project was completed on time without any delay.

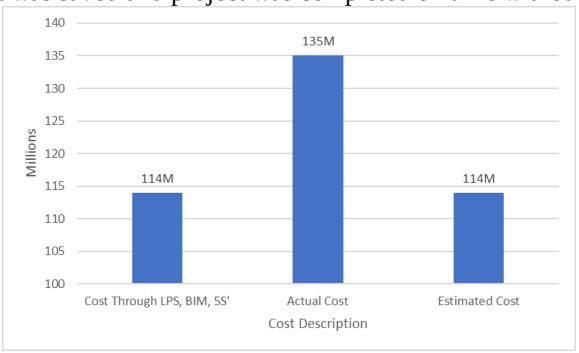

Fig 18 - Combined Cost Graph

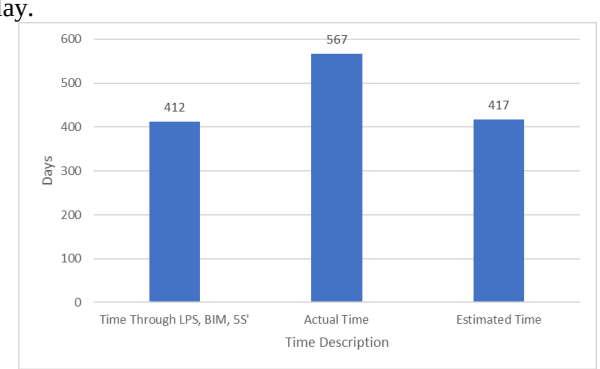

Fig 19 - Combined Time Graph

Framework Model Development
To prove the feasibility of Lean construction in Pakistan, we must adapt its implementation flow with in the flow of traditional phases in the construction of any project.

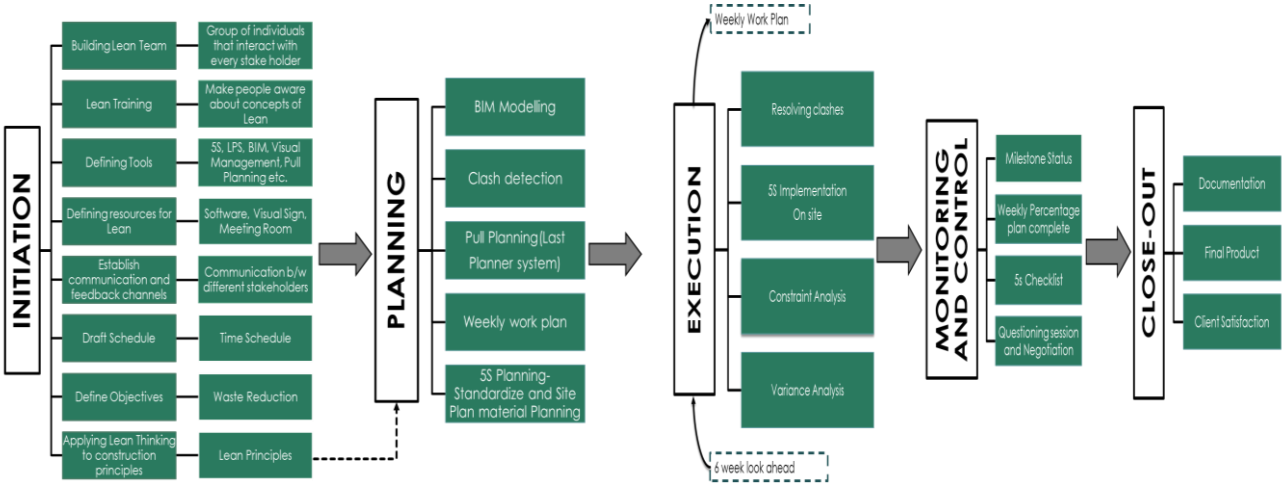

Fig 20 – Framework of Lean Construction Tools Implementation during Project Life Cycle

V. CONCLUSIONS

Conclusion are the result or value of our completely developed case which summarizes the objectives and working of the research. Following were the different conclusions drawn from our research.

In-depth study of Lean construction and management clarified the concept of lean tools and techniques. Implementation of lean tools in different case studies identified the conditions necessary for applying this technique. Lean techniques can be merged into the traditional project delivery methods by conveying the idea of Lean in the market. It doesn't require a work load of technology. Most of the issues like cost and time overrun can be resolved using Lean construction together with BIM which are the main cause of the downfall in the industry.

In implementing the lean techniques, the major barrier was found to be the culture of our construction industry which needs a lot of time and struggle to change or adapt according to new techniques. It was found to be about 25.8%

4. The implementation of Lean tools, 5s, LPS and BIM which we used on existing building eliminated waste and saved 15% of cost savings and 25% of cost savings which in the large scale can be very much effective.

VI. RECOMMENDATIONS

Following are some recommendations for future study:

A great deal of is needed in the arena of lean in construction. Further investigation of tools for diverse projects could be done as an addition to this project. More case-studies could be done to get more knowledge of lean productivity and its proportionality with the implementation of lean in different types of project. The effectiveness of the framework must be tested. Any addition or subtraction in the framework will be exceedingly respected. Awareness about lean construction need to be provided in the construction industry. Lean Training need to be promoted. Industries must form lean capacity

REFERENCES

[1] Aziz, R. F., & Hafez, S. M. (2013). "Applying lean thinking in construction and performance improvement." *Alexandria Engineering Journal*, *52*(4), 679–695.

[2] *Bajjou, M. S., Chafi, A., & En-Nadi, A. (2017). A Comparative Study between Lean Construction and the Traditional Production System. International Journal of Engineering Research in Africa, 29(March), 118–132. https://doi.org/10.4028/www.scientific.net/jera.29.118*

[3] Gao, S. & Low, S. P. (2013). "The Toyota Way model: an alternative framework for lean construction." *Total Quality Management & Business Excellence*, Vol. 25 Iss: 5-6, 1-19, ISSN: 1478-3371

[4] Howell, G. A., and Lichtig, W. (2008). "Lean Construction Opportunities Ideas Practices". Lean Construction Institute's "Introduction to Lean Design" Workshop.

[5] Jørgensen, B. & Emmitt, S. (2008). "Lost in transition: the transfer of lean manufacturing to construction." *Engineering, Construction and Architectural Management*, Vol. 15 Iss: 4, 383398, ISSN: 0969-9988

[6] *Sarhan, Jamil Ghazi, Xia Bo, Fawzia Sabrina, Karim Azharul (2017). Lean Construction Implementation in the Saudi Arabian Construction Industry. Construction Economics and Building,17(01), 2204-9029. https://search.informit.com.au/documentSummary*

[7] *Memon, A. H., Akhund, M. A., Laghari, A. N., Imad, H. U., & Bhangwar, S. N. (2018). Adoptability of Lean Construction Techniques in Pakistan's Construction Industry. Civil Engineering Journal, 4(10), 2328. https://doi.org/10.28991/cej-03091162*

[8] *Miao, Y. H. (2014). Construction Project Quality Evaluation System from Lean Construction Perspective. Applied Mechanics and Materials, 687–691, 4438–4441. https://doi.org/10.4028/www.scientific.net/amm.687-691.4438*

[9] *Mota, B. P., & Alves, T. (2008). Implementing Lean Construction Concepts in a Residential Project. (February 2014).*

[10] McLean, Virginia. (2012). Construction Management Association of America (CMAA). "An Owner's Guide to Project Delivery Methods: Advancing Professional Construction and Program Management Worldwide"

[11] Mossman, Alan. (2012) "Last Planner – collaborative short-term production planning." 2012.

[12] *Nowotarski, P., Pasławski, J., & Matyja, J. (2016). Improving Construction Processes Using Lean Management Methodologies - Cost Case Study. Procedia Engineering, 161, 1037–1042. https://doi.org/10.1016/j.proeng.2016.08.845*

[13] O'Connor, Richard, and Brian Swain. (2013) "Lean tools and techniques-an introduction." CIRIA, 2013.

[14] O. Salem, M., J. Solomon, A. Genaidy, and M. and I. Minkarah. (2006). "Lean Construction: From Theory to Implementation." *Journal of Management in Engineering © ASCE / October*, 2006.
[15] Rojas, Eddy M. (2008). "Single versus Multiple Prime Contracting." *Journal of Construction Engineering and Management*, American Society of Civil Engineers, Vol. 134, No. 10, 2008, pp. 758-565.s
[16] Sacks, R., M. Treckmann, and O. Rozenfeld. (2009). "Visualization of Work Flow to Support Lean Construction." *Journal of Construction Engineering and Management © ASCE / December*, 2009.
[17] Sacks, R., Radosavljevic, M. and Barak, R. (2010). "Requirements for building information modeling based lean production management systems for construction", *Automation in Construction*, 19 (5) 641-655.
[18] *Senaratne, S., & Wijesiri, D. (2008). Lean construction as a strategic option: Testing its suitability and acceptability in Sri Lanka. Lean Construction Journal, 2008, 34–48.*
[19] *Shehzad, A., Qadeer, A., Ayub, B., & Thaheem, M. J. (2017). Implementation of Lean Construction in Construction Industry of Pakistan : An Exploratory Study. (November)*
[20] Senaratne, S., & Wijesiri, D. (2008). "Lean construction as a strategic option: Testing its suitability and acceptability in Sri Lanka". *Construction Management and Economics, 2008*, 34-48.
[21] Womack, J. P., Jones, D. T. & Roos, D. (2007). "The machine that changed the world: the story of lean production" -- Toyota's secret weapon in the global car wars that is revolutionizing world industry, New York, Free press ISBN: 9780743299794.
[22] Zettel, George. (2008) "Transforming Turner Projects with Last Planer System". *Turner Construction Company, 2008.*