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Application of Lean Principles and Performance Improvement of Construction Projects.

Master Thesis

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2nd Supervisor: Ammar Al-Saleh

Conceptual Formulation

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Topic: Application of lean principles and performance improvement of construction projects.

Background

In the mid of 19th century, the Toyota company has evolved and implemented a production system which was later became known as the lean production or the Toyota Production System. The lean production system or the Toyota production system was successfully implemented by the Toyota motor company in their production line.

The term "lean" was later coin by the researchers who were working on the international auto production to study the waste reduction nature of the Toyota production system and differentiate it with the traditional mass type of production system (J. Womack, D. Jones, D. Roos,, 1991). This all started with efforts of reducing the machine setup time and some objectives were identified for the design of the production system including (1) eliminate all the non-adding value elements (2) making production as a continuous flow (3) pursue perfection: delivering the product according to the customers' requirements. In the early 1990, the production philosophy was known by different names like: world class manufacturing, lean production, and new production system.

Researchers have studied the impacts of lean construction to identify the significance and value of implementing the lean principles in the construction industry all over the world such as Nigeria by Adamu and Hamid (S. Adamu, R. Hamid, 2012), Ecuador by Fiallo and Revelo (C.M. Fiallo, P.V.H. Revelo,, 2002), Chile by Alarcon et al. (F.L. Alarco´ n, S. Diethelmand, O. Rojo, 2002) and Malaysia by Marhani et al. (M.A. Marhani, A. Jaapar, N.A.A. Bari, 2012).

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Additionally, various attempts have been made to apply lean techniques to all project management processes, including the project delivery system, production control, work structuring, design, supply chain, project controls, and overall construction project management.

Abdel-Razek studied the impact of lean construction principles to improve the construction labour productivity in Egypt (R.H. Abdel-Razek, M.H. Abd Elshakour, M. Abdel-Hamid,, 2006). Various attempts were made by the researcher to study the application lean production principles and practices in the design and construction process to maximize the value and reduce the waste (Remon Fayek Aziz, Sherif Mohamed Hafez, 2013). Related to the enhance the productivity and improving the performance variability should be reduced as lean construction principles (H.R. Thomas, 2002). Building information modelling techniques or process (BIM) was proposed based on lean production system (Sacks et al, 2010). Lean principles were evaluated on construction using the computer simulation and from study it is find out the performance was significantly enhanced when all the principles were applied simultaneously (Al-Sudairi et al, 1999). Owing to the effectiveness of lean production system in manufacturing industry some of the principles were adopted in a medium size construction firms to eliminate the waste and increase the profit. The results of the lean implementation were evaluated and find out that last planner system, increase visualization, and daily huddle meetings have achieved more better results than the expectations (Salem et al., 2005). A field study was conducted to find out the effectiveness of lean techniques that include: Last Planner, more visualization, daily huddle meetings, first run-studies, 5s process, and fail safe for quality (Salem et al., 2005). Additionally, a lean technique was applied on the panel stacking, panel sequencing, stack locating, and erecting. A lean approach was applied to minimize the quantity of stacks, handling distance, and the efforts required in erecting the panels. The procedure resulted in the improved performance (Shewchuk and Guo, 2012).

The duration of the activity is divided into three different types of duration for instance, value adding activity (VA), and the other two were called wastes because they do not add value to the activity. One of these wastes of duration is essential non-adding value activity (ENVA) and the other one is waste which are not essentially occurring and can be removed (Kivistö et al., 2013). Kivistö, Ohlsson and Jacobsson explained in detail the eight types waste in construction projects that are normally occurs. Fullalove, explained the successful implementation of lean concept in major road projects in UK and its benefits like cost saving and material waste reduction (Fullalove, 2013). Gaio and Cachadinha, explained the main barriers in application of lean concept in construction industry or the factors due to which lean is applied in a wrong manner (Gaio and Cachadinha, 2011).

Research Questions

After intensive literature review it is finding out that, related to the performance and the impact of lean on construction project has significant amount of literature is available. From the review it is find out the performance improvement related research is in enough amount but some of the topics related to the performance improvements of construction project are not very significant. So, some of the question for the research work are developed which would be solution or answers for and its impacts on construction projects.

1. How the Value stream mapping principles can affect the cashflow of a conventionally planned projects?
2. Significance of Visual management (VM) and its effects on the construction project?
3. What are the possible reasons and factors that hinder the application Lean concept in United Arab Emirates and Pakistan?
4. Possible ways of Lean principles application on Joint Venture projects?

Research Objectives

- The research will compare the conventional construction management with Lean construction management techniques to determine the impacts on the cashflows of the project through the application of value stream mapping principle. Additionally, will help to understand the volume of optimizing the conventionally managed projects.
- To identify the practical significance of Visual Management (VM) and its impacts of construction projects overall.
- To determine the main barriers and hinderances in the application of lean principles on construction projects in United Arab Emirates (UAE) and Pakistan and the

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possible solution for the successful application of lean principles to enhance the productivity of construction industry.

- To determine best possible options of lean principles for the Joint Venture (JV) projects and its success ratio compared to the conventionally applied on construction projects.

Methodology

The research question will enhance the confidence level of the customers on the application of lean principles in construction industry and its performance on construction projects. The research work will begin with case study of building projects from UAE and Pakistan to analyse the impact of Value Stream Mapping (VSM) as the projects were conventionally planned. The mainly, the lean principle of VSM will be applied, to identify the significance of Value Stream Mapping and its impacts on the cashflows of the project through streamlining the activities of the projects using Vico Control software. Additionally, about 100 questionnaire will be conducted to find out the importance of Visual Management (VM) on construction site and its significance on the performance of the project. The statistical data collected through questioner will analysed using the SPSS program. Moreover, approximately 100 questionnaire will conducted to find out the main factors that hinder the application of lean construction principles in the construction industry of UAE and Pakistan. The date collected will be reviewed and analysed using the SPSS program and find out the main factors that delay the application of lean principles and determine the possible solution to implement the lean principles in the industry. Also, a detail literature review will be carried out to find all the possible ways of application lean principles on Joint Venture (JV) construction projects and to find out the shortcomings of lean principles application on joint venture projects and find possible and most efficient lean principle for JV projects.

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Signature of the Supervisor #1
Name:

Signature of the Supervisor #2
Name:

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Abstract

The productivity of the construction industry all around the world has been in decline from the previous two decades. To improve the situation of the construction industry, researchers and scientists succeeded in developing a new approach of lean construction. The concept of LC was adopted from the manufacturing industry to maximize the performance of the construction industry, but the implementation of LC is still in initial stages after two decades. LC promises a much better performance by eliminating waste and enhancing the value of the product. A high quantity of construction academics and professionals had successfully optimized the construction projects with the application of LC tools for reducing variability, reducing waste, reduction of time overruns with the application of LC. Major problems of the construction industry are the cost overrun and time overruns, which caused due to the huge amount of waste in the construction process. Due to the number of wastes in the stream of the construction process, the total cashflow of the projects is generally negative, causing failures of projects. This research will discuss principles, tools, and barriers to LC implementation and its impacts on the performance of the construction projects in the form of cash-flow improvements. Also, will try to quantify the assumption of performance improvement with the implementation of VM on construction projects. Additionally, the study will try to find out the main factors of failures of Joint Venture (JV) projects and find out which tools and principles of LC can help in solving the problems of JV projects. The study aims to identify the barriers to LC implementation in the construction industry of Pakistan and UAE, to carry out future research to solve those barriers.

Keywords

Value Stream, Lean Construction, Lean Tools, Waste, Visual Management, Cash-flow, Barriers

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List of Abbreviations

AEC	Architecture, Engineering and Construction
BOQ	Bill of Quantities
CBA	Choosing by Advantages
CVS	Current Value Stream
DEM	Dirham
FVS	Future Value Stream
GDP	Gross Domestic Product
JIT	Just in Time
JV	Joint Venture
LBMS	Location Based Management System
LC	Lean Construction
LCI	Lean Construction Institute
LPS	Last Planner System
LPDS	Lean Project Delivery System
MGI	Machesney Global Institute
PPC	Percent Plan Complete
PET	Percent Expected Time-overrun
PKR	Pakistani Rupees
PMBOK	Project Management Body of Knowledge
RII	Relative Importance Index
SPSS	Statistical Package for Social Sciences
T.F.V	Transformation-Flow-Value
UAE	United Arab Emirates
VSM	Value Stream Mapping
VM	Visual Management

1. Introduction

The construction industry, in the last few decades, had thrived significantly and performed an important role in the development of the world economy in terms of gross domestic product (GDP) and providing employment. But, owing to the significant growth in the industry, it also produced a high amount of wastes, for instance, material, time, and money. But, comparing the productivity of the industry with the manufacturing industry and other sectors, the efficiency of the construction industry is not very much fascinating. The construction industry spends around $10 trillion all over the world on construction-related activities, but still, the industry had a shortfall of $1.6 trillion. The main reason for the shortfall is the productivity of the sector, which is not at par as compared to other sectors.

The productivity of the construction industry is low owing to lack of proper planning and management, lack of innovation and the hesitation to adopt the new techniques are the factors of low productivity compared to the manufacturing industry. The overall lagging of construction productivity costs the global economy of $1.6 trillion per year, in which the major contributors are the developed countries (MGI, 2017).

The poor performance of the construction industry is very common all around the world, and the most well-known reasons for this poor performance are the delay and cost overruns of the construction projects. These problems attracted the concentration of the researchers and scientists (Mansfield,N. R., Ugwu,Doran, 1994) (Meng, 2012). Also, the complexity of the projects is claimed to be the main reason for poor performance, delay, and cost overruns, and, ultimately, the failure of the projects (Afshin Jalali Sohi et al., 2016). No doubt, the construction industry in Dubai is remarkably developed, but still, the productivity of the industry is not at par, and the share of the construction industry has declined. According to the statistics, the construction sector shrank by 0.7% in 2016 compared to an increase of 0.5 % in 2015. This development caused the share of the sector to GDP has dropped from 6.7% in 2015 to 6.4% in 2016 (Dubai, 2017).

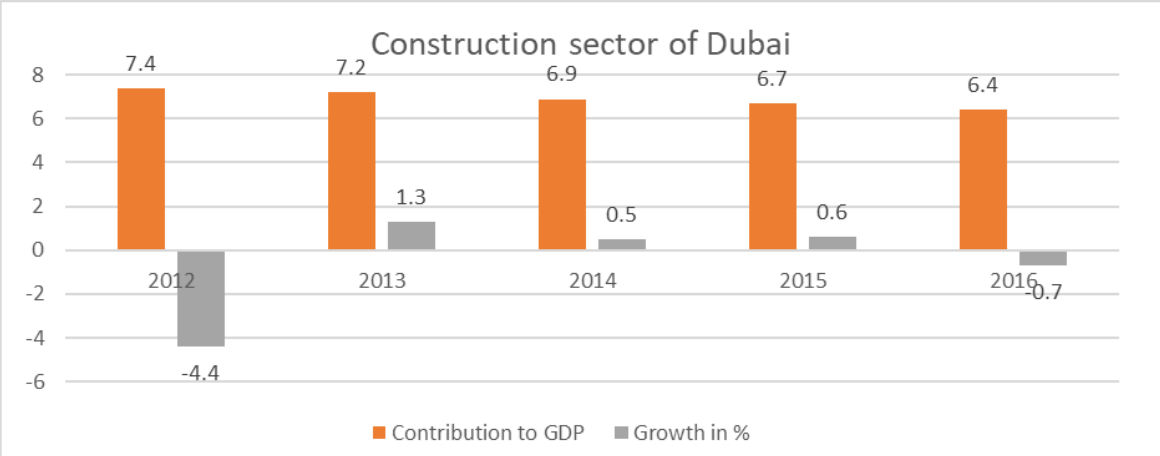


Figure 1:Dubai construction industry statistics

The construction industry is the second largest industry in Pakistan, owing to the increase in infrastructure activities. The industry is also one of the main contributors to employment, providing 6.1% of the total used labor force or about 2.43 million persons. However, the industry had shown fascinating growth, but still, compared to other developing countries, the per capita consumption of cement is at the lowest level. The role of the construction industry has increased significantly in the last decade; in 2006, the record lowest was 186380.00 Pakistani Rupee (PKR) million to record highest in 2018 of 343183.00 PKR million (Economics, 2018).

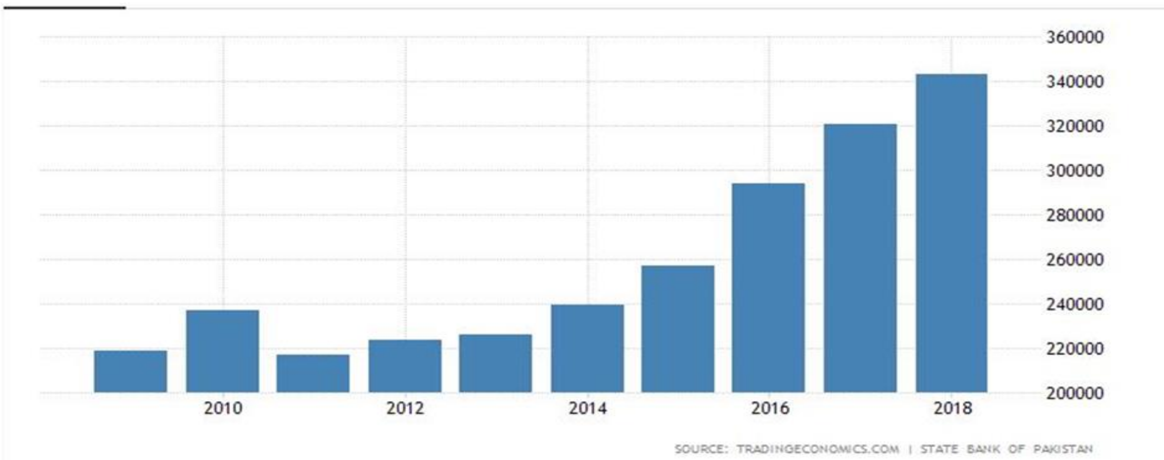


Figure 2: Pakistan GDP from the Construction industry (Economics, 2018).

The study aims to find out how the performance of the construction projects can be enhanced using the principles of LC in construction projects. The study has focused on the performance of the projects through a reduction of the wastes in the value stream of the project and to improve the total cash-flow pattern of the projects. Also, how the Visual Management (VM) technique of LC can enhance the performance and what are the main barriers to the implementation of LC in the industry of Pakistan and

UAE. Also, how high is the failure rate of joint venture projects, and how can the bad performance problems of JV projects possibly be solved with the implementation of LC techniques and principles.

The construction industry in developing countries is facing a variety of problems, which has significantly affected the productivity and the performance of the construction industry. The due high amount of negative total cash-flows in the projects resulted in the delay or failure of the projects. Due to limited research and study on the value streaming application in construction projects and especially related to the improvement of cash-flows with VSM has attracted the researcher to find a possible solution for cash-flow problems. The research was carried to find out the impacts of the value streaming principle of LC on construction projects in the form of total cash-flow improvements and performance improvement. Additionally, the performance of the construction projects can also be possibly improved with the application of Visual Management (VM) of the LC principle to increase transparency and communicate information and instruction more easily. Lack of transparency on the construction site is the main factor of the poor performance of the projects and especially the Joint Ventures (JV) projects. JV technique currently widely adopted all around the world, mainly to reduce the risk of failure and share the resources and experiences to accomplish an objective. Although there is a possibility of enhancing the performance of construction projects with the implementation of LC principles, the industry has not yet adopted the principles in its entirety due to various kinds of barriers to the implementation of LC in industry.

The study will address the impact of value streaming on the total cash-flow of the projects and how significant is the VM for construction projects and how much the VM implementation on construction projects can enhance the performance of construction projects. Additionally, the study will try to find out what are the main barriers to the implementation of LC in the construction industry of Pakistan and the UAE. Also, the study will focus on the implementation of LC principles on the JV projects to enhance their performance and what possible techniques of LC can be applied in JV projects to reduce the failure rate in JV projects in the future.

1.1. Background

Lean construction or Lean is a project management approach to plan and manage the projects more efficiently than the conventional or traditional management technique. This approach is more efficient and reliable on projects which are more complex and on the fast track construction projects. Some of the key distinctions between traditional construction management and the lean construction management approach are listed below, which are discussed in the literature (Swefie, 2013).

- The controlling aspect of lean makes sure that the workflow is undisrupted and continuous, while the traditional approach is more corrective approach, for instance, to act after detecting or finding some issues during the workflow.
- In the Lean construction management approach, the focus remains on increasing the value of the whole process, while the traditional approach only focusses on the optimization or improving each activity or process.
- Lean is a pull-driven method, while the traditional technique is push-driven.
- The reduction of variability is also the main aim of the lean approach right from the start, while the traditional method does not consider the variability factor.
- Identification of clear objectives for the delivery process.
- Concurrently design the product and the processes.

1.1.1. Lean Production

The philosophy of Lean management was developed by Ohno, a young engineer in Toyota company, from the Japanese manufacturing industry, from the Toyota Production System (TPS). The system was introduced in Japan after World War II to produce small batches of cars, which is contrary to the mass production system (A. Conte, 2001). Toyota concluded that the mass production system is not any more efficient; hence, they decided to introduce a new system, known as Toyota Production System or Lean production. The main purpose of introducing this production system was to make the production more efficient to get high value and reduce the cost. The objective of the system was to make the production continuous and eliminating the inventories, and produce what is demanded by the customers, which can be achieved by eliminating all non-adding value activities and processes to produce a product, which will enhance the efficiency and productivity of the company and will reduce the cost of production (A. Conte, 2001).

In the mid 19^{th} century, the Toyota company has evolved and implemented a production system which was later became known as the lean production or the Toyota Production System (TPS). The Toyota motors company successfully implemented the lean production system or the Toyota production system in its production line.

The term “lean” was later coined by the researchers who were working on the international auto production to study the waste reduction nature of the Toyota production system and differentiate it from the traditional mass type of production system (J. Womack, D. Jones, D. Roos,, 1991). This all process started with efforts of reducing the machine setup time and some objectives were identified for the design of the production system including (1) eliminate all the non-adding value elements or processes (2) making production as a continuous flow (3) pursue perfection: delivering the product according to the customers’ requirements. In early 1990, the production philosophy was known by different names like world-class manufacturing, lean production, and new production system.

In early 1990, various kinds of principles were established that had possibly enhanced the flow of the production line and supported the Lean Production Theory or TPS. Some of the principles were identified in various fields, which had enhanced the flow and the overall process of production, and these were identified and presented by Koskela (koskela l. , 1992).

1. Decrease non-value adding activities.
2. Establish production as a continuous flow.
3. Increase output value through an organized understanding of customer requirements.
4. Decrease Inconsistency (Variability) .
5. Simplify by reducing the number of steps, parts, and linkages.
6. Improve output flexibility.
7. Improve process transparency.
8. Focus on the entire process .

9. Continuously upgrade the process.

10. Try to decrease cycle time (Takt-time).

11. Benchmark.

These all were the main ideas of emerging the lean approach, and it is practiced by all the major manufacturing companies in America and Europe. This new approach was also customized in other fields like services, administration, and product development. Due to the lean production application, the manufacturing industry attained significant improvement and development.

1.1.2. Lean Construction

Lean construction is defined as a production management approach for realising significant continuous improvement in the performance of the entire business process of a contractor through the removal of wastes of time and other resources that do not add value to the product or services to the customers.

The concept of lean in the construction industry was first presented by Koskela, in 1992, and presented a production management model where production was considered in three critical ways, namely as, Transformation, Flow, and Value generation, which is called the TFV theory of production (Remon Fayek Aziz etal, 2013). This TFV theory of production gives birth to lean construction as a discipline that changed the contemporary construction management field.

Lean construction can also be defined as a management approach for realising visible continuous improvement, in the performance of the whole business process of a contractor through the elimination of all waste of time and other resources that do not add value to the product or delivered service to the customers (Issa, 2013).

Lean construction is the application of all the techniques that eliminate all the waste that does not add value to the product or service but requires time and capital. The primary purpose of the research work is to remove all those non-adding values that have a direct impact on the performance of the project. The focus is to find out all those non-adding value activities, time, processes, resources, and products which were not considered in the traditional construction management and find out their impact on the cost of the construction project. Figure # 3 shows the quantity of wastes generation in the construction industry and manufacturing industry.

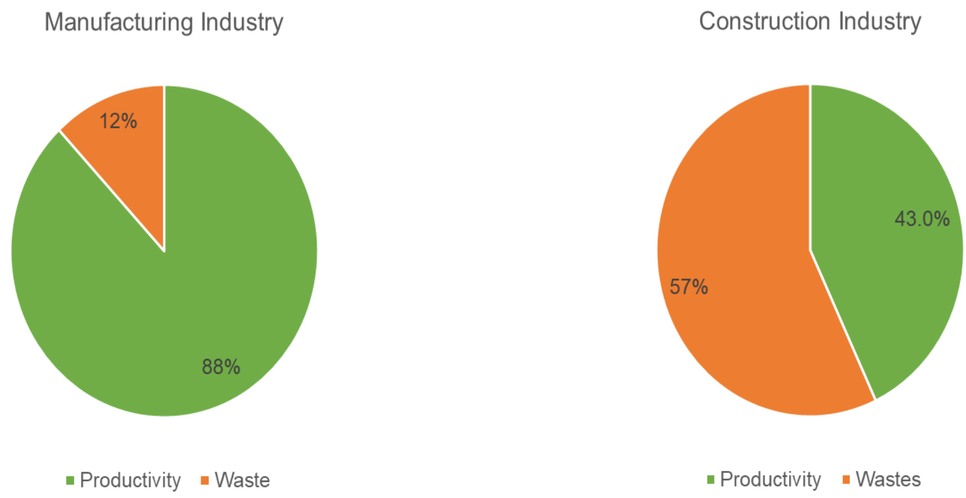


Figure 3: Waste percentages in manufacturing and construction (Remon Fayek Aziz etal, 2013).

Lean management consists of various practices and techniques like just-in-time, pull-driven scheduling, a decrease of inconsistency in labor productivity, improvement of flow reliability, removal of waste, simplification of the operation, application of benchmarking, and the removal of non-adding values (Issa, 2013). Some of the conventional and most important tools used in the construction industry for lean are Lean Project Delivery System (LPDS), Last Planner System (LPS), Takt-Time Planning, Six Sigma, 5´S, Visual Management, Kanban, Choosing by Advantages (CBA) and Genchi (Go and See).

While in the traditional method of management, during the whole construction period, the same plan is implemented without involving the introduction of improvements in the process. Recent studies and researches presented that lean has excellent potential in the construction industry, considering the waste analysis and workflow.

1.2. Problem statement

More than two decades of research on lean principles and its application in the construction industry has shown some results of success. But, the application of the lean in the construction project is still in the initial stages, the application of lean principles is still limited and majorly used to improve the flow of the process or activities, reducing the waste, reducing the cycle time. Value stream mapping is one of the tools which mainly used to identify the waste in the process. It also a method to define the sequence of activities or process which creates value and eliminate all the non-adding value activities or process. VSM also identifies who or what resources will create value during the process. Until recently, the concept of the value stream in the construction industry is adopted to make the sequence of activities to deliver the product or services, mostly not considering the intermediate wastes during the process and its impact on the cash-flows. Studies show that almost 20% of construction-related businesses were failed between 1990 to 1997, and about 80,000 contractors got out of the market in the USA due to the high liabilities, and one of the leading causes of failure was the cash-flow problem (Lucko, 2011). But, after all the efforts of developing a value stream of activities, i.,e. Development of a better work plan for the project, still, the companies and contractors are facing the problem of negative cash-flow, which ultimately affects the performance of the project.

The principle of visual management on the construction project, which is traditionally planned, can help in managing the project and how it possibly help in enhancing the performance on-site and the success of the project. The fact about visual management, it's a topic that has no literature related to its impact on the performance of the project. Although, limited research is available about its implementation for communicating the sensory information to understand and increase the process transparency on the construction site (Tezel and Aziz, 2017). All the information related to the visual management on the site is subjective, and little knowledge and studies are carried out to find the impact of visual management on the project performance.

Various researchers and authors identify a variety of barriers in the implementation of lean practices in the construction industry, and bundles of literature related to the implementation of lean are available. But, unfortunately, the concept of Lean in Pakistan and Dubai is entirely new, and its implementation in the construction projects is limited. The objective is to identify those barriers that impede the application of lean principles in the construction industry for further research and find solutions to reap the benefits of lean in the construction industry in the mentioned countries.

Owing to the globalization trend and also due to the crises related to the lack of availability of skilled workforce, material, and various kind of economic-related risks companies develop a partnership or agreement to share the resources, knowledge, skills, and risk to deliver a product and this agreement or partnership is called Joint Venture (JV). It is a type of contract in which the partners share the risk, resources, skills, experience, and knowledge to accomplish a project is called the joint venture (JV)(Daniel et al., 2016). According to the global construction dispute report, 1 out of 3 JV projects failed due to the dispute among the parent companies (Allen, 2015). In the UK, the Joint Venture type contract to deliver the infrastructure projects significantly increased due to the high risk and the top skills required in the execution. Also, to carry out the public sector projects, it is necessary to implement a lean technique such as LPS for better project performance (Daniel et al., 2016). LPS is the only lean technique or tool which is used on various contracting structures like the Integrated project delivery system, Lean Project delivery system, and Integrated form of Contracts. However, the concept is to find the possible ways of implementing lean techniques or tools on JV projects to avoid all kinds of risks and disputes and enhance the performance of Joint Venture (JV) projects.

1.3. Objective

The main goal of the study is to analyse the impact of VSM on the total cash-flow through improving the value stream of activities of the construction project, considering the aspect of eliminating waste. The elimination of waste from the current value stream and developing a new value stream and finding out its impact on the total cash-flow. From recent studies, it is found out the construction industry has a significant potential of lean implementation to optimize the process by eliminating the wastes. For removing waste in the construction process, VSM principles will be employed to find out how possibly the construction process can be improved. Also, to understand the benefits of lean principles, it is vital to implement the LC tools or techniques on a real project.

The research work will be conducted on a construction project in UAE and Pakistan as a case study which is traditionally planned without considering waste in the process or stream. Additionally, a survey will be carried out to find how much a construction project can benefit from the Visual Management principle of lean on construction sites. Also, a study will be carried out to find the barriers to the implementation of lean in Pakistan and the UAE construction industry. Furthermore, owing to several problems in Joint Venture (JV) Projects, possible methods would be found out to reduce or eliminate the conflicts in JV projects that are the leading cause of JV project failure. The tasks or objectives of the researcher will be to find out the following objectives.

- The research will compare the conventional construction management with Lean construction management techniques to determine the waste of waiting time and its impacts on the total cash-flows of the project through the application of value stream mapping principle. Additionally, it will help to understand how possibly the cash-flow can be improved.

- To identify the practical significance of Visual Management (VM) and its effects on the construction projects in the form of performance improvement.

- To determine the main barriers to the implementation of LC principles on construction projects in the United Arab Emirates (UAE) and Pakistan to improve the performance of the industry in mentioned countries.

- To determine the best possible options of lean principles for the Joint Venture (JV) projects to enhance their performance and how can we reduce the failure rate of JV projects with LC principles implementation.

1.4. Research Questions

The study aims to find answers to the following questions:

1. How can the Value Streaming principle affect the cash-flow of a conventionally planned project?
2. What are the significance of Visual Management (VM) and its effect on the project?
3. What are the possible reasons and factors that hinder the Lean application concept in the United Arab Emirates and Pakistan?
4. What are the possible ways or options of Lean Principles application on Joint Venture projects?

1.5. Research Methodology

To achieve the objective of the research, a detail literature review was carried out. Research for the literature related to LC has carried out on some major websites, for instance: Google Scholar, ResearchGate, and Academia. A variety of journals and articles pertaining to Lean Construction were researched to understand the concept of LC and its tools and techniques. Also, to understand the background of LC development in the construction industry and its impacts on the performance of the construction projects.

A case study was conducted on building projects in Pakistan and Dubai (UAE), which are traditionally planned, to find out the impact of Value Stream Mapping (VSM) application on the traditionally designed project on the total cash-flow of the project. VSM was applied to find the non-adding value activities or processes or resources in the traditionally planned project. And to find out how the VSM can affect the total cash-flow and improve the performance.

Two questionnaire Survey was carried out related to the LC in the construction industry. One quantitative survey was carried to find the significance of Visual Management techniques in construction projects related to performance improvement. The second qualitative questionnaire survey was conducted to find out the main barriers to the implementation of LC in the construction industry in Pakistan and Dubai (UAE). Only closed-ended questions were directed to the respondents. The questionnaires are divided into two sections. The first section was related to respondent background information (Professional qualification and Country). The second part of the surveys was limited to the information related to the VM and the barriers to implementation of LC in the industry in specified countries.

A quantitative questionnaire was be carried out to find out the significance of the VM and its effects on the construction projects in the form of performance improvement. The questionnaire was carried out with a Likert scale concept have scaled from 1 to 6. The scaling represents the different percentages and also with the option of “very Low” and “Very High” for 1 to 5 and the 6 for the “ No Answer” option. The questionnaire was distributed among 100 respondents through various platforms to get a maximum number of responses. The questionnaire data were analysed to predict the performance of VM on the construction projects, using the regression model.

Similarly, a qualitative questionnaire was carried out about the barrier to the implementation of the LC concept in the construction industry in Pakistan and UAE. The respondents were directed to show their level of agreement on the five-point Likert scale (from 1 = ‘Strongly Disagree’ to 5 = ‘Strongly Agree). The questionnaire was analysed, and the equation of relative importance index (RII) was applied to the received data to get ranking of barriers according to the concerns of the respondents.

Both questionnaires were shared with 100 respondents through various channels like personal E-mails, Website, LinkedIn, and Social Media to get the response. The survey was shared with all those respondents who have work experience and have some knowledge of the LC concept.

These questionnaires are used to present the respondent's perspective related to the VM implementation and barriers to LC implementation. A well-defined questionnaire survey was adopted, targeting construction professionals (civil engineers, architects, construction managers, project managers, and other senior management) who are affiliated with the construction industry. These questionnaires were shared with all those respondents who have work experience and have some knowledge of the LC concept.

Lastly, a detail literature review was carried out to find out all the possible options of LC that can be applied in Joint Ventures (JV) projects to enhance their performance.

1.6. Thesis Overview

The thesis consists of seven chapters after this presentation. Other sections are as follows:

Chapter two is a detail literature review of Lean production and its development and also Lean Construction development in the construction industry. Also, it explained the benefit of LC in the construction industry and the application of its tools and there possible benefits on the performance of the construction projects.

Chapter three explains the overall concept of this research in detail on how the lean tool can be applied and how it can affect the performance of the construction projects.

Chapter four demonstrate the two case studies of building projects in Pakistan and Dubai (UAE). This chapter is devoted to the description and analysis of the case studies and to find out the impact of lean application tool of Value Stream Mapping (VSM) on the case studies. After the application of lean on a case study, a comparative analysis of the total cash-flow will be carried out to find the impact of lean on the total cash-flow of projects.

Chapter five is dedicated to research questionnaires analysis regarding Visual management and its impact on the performance of the projects. Also, a questionnaire analysis related to the barriers to the implementation of LC in the Construction Industry of UAE and Pakistan.

Chapter six is dedicated only to answer the research questions in a way to summarize all the results found during the execution of this master's thesis.

Chapter seven presents the conclusion of this research work and recommendation for future research work.

2. Lean Construction Management

The construction industry is keeping the largest share in the world economy by spending every year around $10 trillion in construction-related services. Owing to the decrease in the productivity of the industry, the sector remains behind in comparison to other industries; there is still a shortfall of $1.6 trillion to reach the required status (MGI, 2017).

The key factors that played a significant role in the development of the construction industry are the construction management and the adoption of new technology. Over the past four decades, a variety of techniques have been adapted to enhance the efficiency of the industry, but, still, the industry is not performing according to the demand, and the construction industry is and has observed decline all over the world in the last few decades. The main factors that affected the construction industry all around the world are the project delay and cost over-runs.

According to literature, it is considered that the cost-overrun and time-overrun or delay of the construction project are caused by the improper planning and management of the construction projects. Moreover, the factor of complexity is also considered to cause delay and cost-overrun because the traditional approach of construction management is unable to manage complex projects due to the various interaction between activities. Although the traditional construction project management is good enough for small and less complicated projects. To manage complex projects more efficiently, the concept of lean thinking was introduced in 1992 (koskela l. , 1992).

2.1. Traditional Project Management

Owing to the complexity of the construction projects, many researchers and scientists sharply criticized the conventional project management approach and specified the method to be inadequate to deal with the complexity and uncertainty of the projects (Howell & Koskela, 2000). Before underling the loopholes and deficiencies in traditional project management, it is vital and utmost to define project management. According to the Project management body of knowledge (PMBOK):

"It is the appliance of knowledge, skills, tools, and techniques to project activities to meet or go above the stakeholder's needs and expectations from a project." To meet the stakeholder demand and expectation and for successful project completion and management, a balance must be developed among scope, time, cost, and quality as shown in figure # 4.

Figure 4: Project management triangle (PMBOK)

The project management body of knowledge also defines the project life cycle. The phases of a project that are specified in the PMBOK are as follows (Howell & Koskela, 2000):

1) Initiation phase
2) Planning phase
3) Execution phase
4) Monitoring and Controlling phase
5) Closing phase

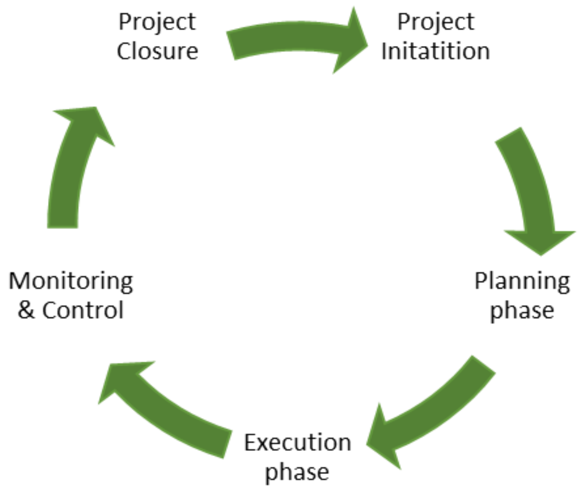


Figure 5: Project management life cycle (Swefie, 2013)

According to Howell and Koskela, the traditional project management deficiencies to be successfully applied to complex projects are owing to imperfect assumptions and theories developed. Some of the flawed or faulty assumptions, such as activities dependencies and relationships, are simple (Howell & Koskela, 2000). Morris explained the theory of project management as a discipline of utilizing the transformation model of production used earlier in manufacturing (Howell & Koskela, 2000). Howell and Koskela presented that it is possible to achieve the improvements and progress in the current or traditional project management through the application of a production management approach. By applying not only the transformation but also the management of workflow and value generation process. Means, lean production principles were employed in the construction process as well (Howell & Koskela, 2000).

As mentioned earlier, the traditional construction project management can produce positive results for small, simple, and slow projects, but in the current situation of massive, complex, and fast track construction projects, traditional project management is simply counter-productive. Owing to the counter-productivity of the conventional approach and decline in the productivity of the construction industry, the researcher and scientist tried to find out a solution to the problem. The researchers and scientists put forward the concept of implementation of lean production in the construction industry to increase productivity by maximizing the value and minimizing the waste, time, and cost of projects. The difference in the traditional approach and lean approach is discussed below in detail in the table

Table 1: Difference between the traditional approach and lean approach

Activity	Traditional PM Approach	Lean construction Approach
Control	Control is represented in monitoring the performance (Schedule & cost) and taking corrective actions after finding the variance, as shown in figure 6.	In the lean approach, control is to ensure reliable workflow through determining and refining the process (sicat, 2012).
Performance	All the energies and concentrations of management are on optimizing each activity separately, which reduces the overall performance (sicat, 2012).	The main target is to be maximizing the value and minimizing the waste at the project level to enhance the performance of the project (sicat, 2012).
Value	In the traditional approach, less cost considered a value. Also, the customers define the requirements without considering the market and technological changes (sicat, 2012).	Project is managed and considered as a value-generating process, where the customer's satisfaction is established or augmented over the progression of the project (Howell, 1999)
Work Technique	Push-driven schedules are used to communicate information and resources, e.g., materials (sicat, 2012). (The material is supplied to the project site before the work is carried out)	The information and resources are communicated under pull-driven schedules. All the works are carried out with the principle of Just-in-time (JIT) to avoid all kinds of inventories (sicat, 2012)
Centralization	The decision system is centralized, i.e., the manager is responsible for making all the decisions (sicat, 2012).	Decision making through transparency by getting the project.Members involved in the production control system and allowing them to take

		action (sicat, 2012).
Variations	Variations mitigation and management are not considered (Swefie, 2013).	Production unit capability is adjusted as well as inventory to be able to absorb fluctuations (Swefie, 2013)
Collaboration	The policy of collaboration is not applied or considered in the traditional approach	LC gives support to the suppliers through developing new contracts that provide the supplier's encouragement for reliable workflow and participation in the overall process enhancement (Howell, 1999).
Transparency	In the traditional approach, usually, the information is limited to the manager level, and all other participants of the project are not liable to make any decisions or get any information.	The factor of transparency in the lean approach encourages all the stakeholders to get involved in all kinds of decisions and the improvement of the whole process (Howell, 1999).
Continuous Improvement	The traditional approach is limited to the improvement of activity and does not consider the continuous upgrading of the process or product.	LC considers and believes in the continuous improvement of the process and the workflow to reduce or eliminate waste in the process (Howell, 1999).

Figure 6: *Quality control process in the traditional approach* (Swefie, 2013)

Figure 7: Project control process in a traditional approach (Swefie, 2013)

Owing to the mentioned short-coming in conventional construction project management, it is evident that it is not possible to manage the complicated and huge construction project efficiently. The traditional approach for complex projects is not only inefficient but also counter-productive. The incompetence of the traditional approach can easily be assessed nowadays because the majority of the construction projects are mostly facing the problems of cost-overrun and time-overrun. These problems of delay and cost-overruns are caused owing to lack of proper planning and management, i.e., by not considering the factors of wastes (time, money, resources, etc.) in the construction industry.

2.1.1. Wastes in Construction

Construction management is facing many problems that need to solve; owing to these problems, the industry is suffering a high ratio of delay and often experienced cost and time overrun. The main reason for delay or time overrun in construction projects is poor project management, so it is necessary to put all the efforts into the problems related to management to find a proper solution for an efficient method of operations. The introduction of new production philosophies in construction requires new measures of performance, such as waste, value, cycle time, or variability. (Remon Fayek Aziz etal, 2013).

According to studies, the contribution of wastes to the total cost of the project in the UK construction industry is accounted as 30%, for rework 40-60%, labor efficiency can account for 3-6%, and at least 10% of the material is wasted. Also, the contribution of rework in the Australian construction industry has been reported with significantly high figures that cost almost 35% of the total project costs and contribute as much as 50% of a total project cost overrun. Rework is one of the main factors of weak performance and productivity in the construction industry of Australia (Remon Fayek Aziz etal, 2013).

Generally, the wastes or non-adding value activities and resources in the construction project are hard to identify, and they cost a significant portion of the production cost. These wastes had meaningfully reduced the productivity and efficiency of the construction industry, and to rectify the situation more solid and concrete steps and measures are required.

Generally, waste in the construction industry can be defined as “an activity that consumes the resources (money, manpower, time, materials) without adding any value or improvement to the process or product.” According to the concept of lean, waste is referred to all the non-adding value activities (koskela l. , 1992). Alarcon also defines waste as “anything different from the absolute minimum quantity of resources, material, equipment, and manpower required to add value to the product.” In general, any wastages produced by activities that have a direct or indirect impact on the cost but do not add value to the product or process from the client perspective are called “waste.” Usually, in the construction industry, waste is measured in terms of costs; but other kinds of wastes are hard to be measured because the optimal efficiency is not always known, for instance, the effectiveness of the process, equipment’s or workforce (Remon Fayek Aziz etal, 2013).

Value-adding and non-value adding activities can be defined as “(1) Value-adding activities: Those which converts material and/or information to meet the client requirements and (2) non-adding value activities (wastes) those which utilize and consume time, resources, space, energies etc, but do not add value to the product or process (Alarcon, 1997). Usually, the people consider the wastes in the construction projects, the debris that is removed and dumped in landfills, and the main reason behind that is constriction of their view toward wastes. Formoso et al. divided the construction projects wastes into two groups based on the impacts of the wastes. These two groups are based on researches and studies carried out on the environmental and economic implications of the construction wastes. The investigations and studies focused on the ecological impacts that develop due to the generation of construction wastes and how to reduce the waste generation and alternative method of treatment for the waste to reduce the demand for disposal area. Likewise, researches and studies related to the economic impacts of waste in the construction industry and presented that there is a significant amount of wastes that can be reduced or eliminated through the adoption of simple procedures (Formoso, 1999).

In the last decade, research on the wastes in the construction industry was a significant subject in many countries, and the researchers are looking for possible solutions to minimize or eliminate the wastes in construction projects. According to studies, all parties involved in the construction process are responsible for the wastes, and it is also their responsibility to minimize the wastes (Skoyles, 1987).

In the lean production system, Tiachii Ohno identified or specified seven types of wastes, which were become eight later on. All the eight (8) types of wastes that were identified in lean production are:

I. Over-production
II. Waiting
III. Transportation
IV. Inappropriate processing
V. Re-works/ Defects
VI. Excess movement
VII. Unnecessary Inventories
VIII. Talent

2.1.2. Causes of wastes generation

Generally, there are various factors and ways of generating wastes in construction projects that affect the projects in various aspects like cost and duration. Some of the most common factors that cause the wastes in the construction industry are hardly considered in traditional project management are discussed below:

Over-production

It is the production or generation of quantity greater than or more than what is required. This causes the waste of material, but also working hours and machinery usage. It generally produces inventories of unfinished products, or they may lose entirely, in the case of material that can deteriorate or not appropriate to be used. For instance, the over-production of cement mortar that cannot be used on time (Remon Fayek Aziz etal, 2013).

Waiting

It is the duration or period during which the whole process paused, and all the resources (workforce, machinery) are idle owing to lack of synchronization of material flow and the pace of work or activity by various groups or equipment (Remon Fayek Aziz etal, 2013). Also, waiting time is considered as a delay; it refers to the duration or period when the resources are idle for unproductive activity owing to lack of information, material, decisions, or access (O´Cornnor, 2013). For instance, idle time caused due to lack of material or lack of workplace for labors or non-functioning of the equipment, etc.

Transportation

It is mainly related to the internal movement of material on site. It generates waste due to useless or redundant motion of materials or products on the site. It is mainly caused by the improper planning of material and equipment's flow and because of the lack of proper layout of the site. Excessive handling, use of inappropriate or insufficient types of equipment can cause such kind of wastes. It mainly generates waste of working hours, waste of energy, space on site, and the possibility of wastage of material during transportation (Remon Fayek Aziz etal, 2013).

Processing

It mainly concerned about the steps of the activity carried out or primarily focused on the process through which a product is produced. Sometimes the waste can be prevented by changing the construction technology. For instance, a significant amount of mortar is wasted during the plasterwork of the ceiling. Also, the soaking and dampening of bricks before the brickwork is also caused waste of working hours, water, energy, and space (Remon Fayek Aziz etal, 2013).

Rework/Defects

It refers to the process or product which does not match with requirements or specifications. It may lead to rework or addition of extra material to the product or process, for instance, increasing the thickness of plastering or covering the defects with expensive materials like epoxy in concrete. It can be caused by a variety of reasons, lack of skilled craftmanship, lack of planning and control, or lack of integration between design and production, etc. This kind of waste results in a waste of time, energy, money, material, and other related resources (Remon Fayek Aziz etal, 2013).

Movement

It is related to the excessive or useless movements made during their job. This might be caused owing to lack of proper planning and layout on-site, lack or inadequate equipment, and inefficient work method employed (O´Cornnor, 2013) (Remon Fayek Aziz etal, 2013). For instance, difficulty in the movement of labors or too much unnecessary movement of the workforce may produce waste like, waste of time, energy, and wastage of space.

Inventories

It refers to all the raw materials and steps that are non-adding value materials or steps to the process or product. In construction projects, inventories are referred to as the supply of excessive material and goods that are not required immediately. Inventories might lead to material waste (by deterioration, loss owing to the condition of stocking, robbery, etc.) and capital or monetary loss that is used to buy the excess of material and the rent paid for stacking. It is mainly caused by a lack of proper resource planning or a lack of appropriate quantities estimation (Remon Fayek Aziz etal, 2013).

Talent/Substitution

It is a wastage of money, time, materials, and energy. These kinds of wastes are produced owing to the replacement of material with another material which is more expensive and with unnecessary extra high performance than the requirements. Similarly, some tasks are required to be carried out by the skilled workers or by some highly sophisticated machinery, and those tasks were carried out by simple labor or simple equipment. This kind of situation generates waste of material, time, and money.

2.2. Lean Construction Management

The decline of the industry got the researcher and scientist's attention to find out a suitable solution to improve the productivity of the sector. The studies put forward that the application of the lean production approach in the construction industry was presented to be the most effective one to improve the condition of the construction industry. This approach was developed from the application of production management techniques in the construction industry. The use of production management techniques in the construction industry is called lean construction. The target objectives of lean construction are maximizing the value and minimizing the wastes (LCI, 2007).

The work on maximizing the value and reducing or eliminating the wastes has been thoroughly investigated in recent years, which discusses the implementation of lean production practices and principles in the design-construction process to enhance the value and eliminate wastes (Remon Fayek Aziz etal, 2013) (G. Howell, 1998) (Koskela, 1997). The desired result has been achieved in implementing the lean construction in some cases. Conte and Gransberg studied the successful application of lean construction principles in 20 construction companies in Brazil to find out performance improvement (A. Conte, 2001). Similarly, various other cases of employment of lean techniques on construction projects were presented to assess the performance of lean construction in the construction industry (Wright, 2009) (Remon Fayek Aziz etal, 2013) (Heng LI, 2015). To improve the application of lean construction in the industry, it is vital and imperative that all the relevant parties and stakeholders (contractors, subcontractors, and clients) are inclined to implement the principles in their entirety (C. Miller, 2002).

The main factor that affects the productivity of the Construction industry is the quantity of waste that is generally generated throughout the project life cycle. The implementation of LC can, however, improve the performance of the projects and industry through timely delivery of the project, using the right quantity and quality of resources, and within the budget for a project. According to Oguntona et al. (2018), the most significant benefit of implementing LC on a project is the reduction of waste and enhancement of value and the improved life cycle cost of the project (Oguntona and Aigbavboa, 2018).

Lean construction is defined as the process of generating value by designing the production process in such a manner that waste is eliminated. The time overrun and the amount of waste generated in the construction industry has significantly affected the productivity of the construction industry. This resulted in further research in the project management to find out the ways to reduce the cycle/lead time and enhance the process reliability. The construction project is usually a network of connected activities which are managed and controlled by its participant. But in the construction project, it’s difficult to define the activities that generate value because construction projects are unique (Rother and Shook, 1999). Value Stream Mapping (VSM) is the process of identifying the value-adding activities and non-adding values in the production process. VSM is a pen and pencil tool that uses flowcharts to define the production process, and it helps in highlighting the waste and bottlenecks and suggestions for improvement. VSM has two essential elements, namely: Current State Map and Future State Map. Current State Map defines the current situation of the process, where the Future State Map is prepared by analyzing and identifying the waste in the current state map of the process and eliminating them using lean principles (Rother and Shook, 1999). The main objective of the future state map is creating a continuous workflow, through the elimination of the wastes and constant improvement of the production process.

A case study was carried out on the construction process of a residential building construction project and tried to implement the VSM to achieve an enhanced lean construction system. Using VSM, a current state map of the production process was developed and analyzed for the potential waste, and an improved process map is developed. This enhanced process map called the future state map, which has minimum waste activities, and then the performance was analyzed to find the performance of the project (Barathwaj, 2017).

Similarly, another study was carried out on the construction of houses by implementing the lean tool of VSM to create a stable production flow rather than eliminating individual waste. To reduce the variability of production flow, various measures should be considered in future state mapping to enhance the construction project performance (Yu et al., 2014). Fontanini researched the concrete slab production with the application of VSM in the workflow to find out the inherent waste in the construction process. In his study, he made some adaptations to the reality of the construction. According to Fontanini, it is possible to identify the steps and non-logical processes that generate a lot of waste of material, mainly of concrete, and not add value to the customers (Fontanini, 2013).

Mainly the application VSM in the construction industry is limited to the material supply chain rather than the production process, i.e., the constructing process. The consideration of VSM in the construction process to produce a product is not similar to the manufacturing industry. The product in construction is the building, which is challenging to manage because of the interlinked activities — owing to that, the whole production is divided into several stages to produce a single product (component) of building. In such a case, a single product, which is a collection of activities to create a trade, is selected and considered as a product, for instance, Excavation work, Underground work, Superstructure work, Masonry work, Finishing work, etc. Then within these trades, various sub-activities are considered as value stream maps for those trades and try to improve the flow by eliminating non-adding value activities (Pasqualini and Zawislak, 2005).

Typically, in the manufacturing and construction industries, a flood of information needs to be handled by the management. A system of Visual Management (VM) are developed in the manufacturing industry to tackle this vast amount of information and also communicate with people in more easy form. This easy and understandable form of communication is called Visual Management. VM is a lean tool, which is an attempt to improve the performance of the organization through aligning the organization's goals, values, and objectives with the processes, workplace, and stakeholders employing sensory actions. Detail research was carried out on the VM implementation on the construction project to find out its impact on the transparency of the process. Also, how efficient the VM tool is on the construction site to communicate the information and what steps need to be taken to make the VM more efficient (Tezel et al., 2010).

Similarly, the most significant outcome of VM is an increase in the communication ability of the process elements, which is defined as the process transparency, and other aspects are the increased discipline in the workplace, job facilitation, on site training, and continuous improvement. Detail research was carried out by Tezel on VM techniques, commonly applied in the building construction, on the industrial construction to evaluate the application of those VM techniques on an industrial construction project. Some of the widely used VM techniques he employed in the Industrial construction are Workplace Standardization, Pull Control through *Kanban*, Production Levelling through *Heijunka Box,* Health and Safety Management, Visual Signs, Prototyping, and Performance management boards (Tezel et al., 2013).

Visual Management (VM) in the construction of highways in England had gain momentum owing to the official specification of implementation of lean on constructing the roads. The study was carried out to find the possible ways of implementing the VM on the highways and the most commonly used VM process in the construction of highways. The study finds out that Visual Performance Boards are mainly used in the construction of highways. The Boards are not used on the construction site but primarily used within the construction compound for communicating mostly the work progress, schedule, and mainly safety-related information. The study was carried out to find reasons that hinder the implementation of VM on the construction field rather than a construction compound. The study finds out the companies involved in the construction of highways in England mainly limited to Visual Performance Boards, 5´s, and Safety related VM because of a lack of clarity in quantifying the benefits of Visual Management (Tezel and Aziz, 2017).

A detailed study was carried out to find the benefits of the implementation of VM on the construction of highway projects in the UK. The study mainly focused on 5´s, and Visual Performance Boards to find the quantified data related to the project performance improvement. The two VM methods were applied on a highway construction project, and the application had significantly shown results related to reducing the time. Also, the Performance Boards were more effective in increasing the Percent Plan Complete (PPC), and it grew to 76%. The increase in PPC means the actualization of what had been promised by the teams after the implementation of Visual Performance Boards and the meeting system. Another aspect of Visual Performance Board installation is easy to understand and the transparency of the process. All the team members know who is doing what, and what is the progress level of each team member. Also, the visual boards make it easy to identify the root causes of performance variance and easy to find a solution for future action, which is usually not possible with conventional kinds of meetings (Tezel and Aziz, 2017).

The last planner system was employed for the construction of flour storage in Egypt. The expected time over-run owing to the probabilities of occurrence of the risk factors was calculated by using the quantification model of the time-overrun to find out percent expected time-overrun (PET) at the start of the project. During the study, some 13 risk factors were identified that were supposed to delay the project. For this reason, the techniques of the last planner system to manage the project, three weeks look-ahead schedules were prepared, which are called WWP which were updated on a weekly basis during weekly project meetings. On the other hand, PPC was also calculated during the project execution, which is a metric of the last planner system. After the application of the lean techniques on the project, the duration of the project has been reduced, but all the factors that were expected to delay the project were affected by using lean techniques. They are; (1) Change in material prices or price increase, (2) Delay in payments to the contractor, (3) Design mistakes and fitness to nature, and (4) Bad quality of regional materials. The remaining nine factors are influenced by lean construction techniques. The study showed that lean construction techniques could significantly affect the time-overrun risk in the construction project as the observation showed that out of 13 risk factors, nine factors were affected by lean construction techniques. The risk factor of time-overrun was significantly reduced, which represents about 67% of all risk factors that causing the delay in the project (Issa, 2013).

Likewise, various efforts are carried out for the application of lean techniques and principles to the project management process, for instance, project delivery system, production control, work structuring, designing, and supply chain, project control, and the most important is the construction project management. Labor productivity can be enhanced by applying two lean principles (benchmarking and reduce the variability of labor productivity) (R.H. Abdel-Razek, 2006). Ballard studied the impact of the applicability of lean concepts and techniques in the fabrication process and showed the benefits that can be achieved by improved management demand, reduced cycle time, increased productivity, enhanced labor force participation, and income and profitability (G. Ballard, 2002). This study showed the value of the lean concept and techniques and their applicability and utility to the fabricators supplying products to the construction projects. The efficiency of lean techniques is discussed in the design and installation of the metal doors frames for the construction of prison (C.Y. Tsao, 2000). Koskela studied the impact of lean techniques and principles on the construction of a fast-track office building project and found out the results that how the process of construction could be made faster and leaner (L. Koskela, 1996).

Similarly, a study on the application of lean in construction and performance improvement was carried out to determine the implementation of the lean ideal. Also, to identify the wastes in the construction industry and to find out the perception of the construction industry toward lean principles and techniques. The effectiveness of the last planner system was to eliminate waste to enhance the planning reliability and to analyze the relationship between lean construction and performance improvement in businesses (Remon Fayek Aziz etal, 2013). Lean construction principles and techniques can be used to reduce risk factors on time for construction projects in developing countries. A study was carried out on a project in Egypt to find out the risk factor on time objectives by applying lean construction principles to reduce the risk factor. The application of the principles had significant effects on the Percent Expected time-overrun (PET) and the Percent Plan Complete (PPC). The study should aim that the use of lean construction techniques in construction projects significantly reduces PET values and increase the PPC values (Issa, 2013).

The application of LC in the construction industry is still in the early stages and the coordination between the stakeholders is the prerequisite to implement the lean techniques in the industry successfully. For instance, the harmonization between the main contractors and the subcontractor is proposed to be an essential condition for the application of lean construction (C. Miller, 2002). Similarly, the use of lean construction for enhancing performance and improve the labor flow reliability and for high productivity, it is crucial to reduce the variability in the process (H. Thomas, 2002) (Mossman, 2005).

From the literature review, it can be concluded that the implementation of LC in the construction industry can significantly enhance the performance of the construction projects. Through the factors of eliminating the wastes, for instance, the non-adding value activities/processes, time, resources, workforce, material, and improvement in cost of the project, in the construction project, had shown positive results for improvement in the construction projects. But, this research will be carried out to find the percentage of improvement in the total cash-flow of the project by eliminating the waste of waiting time in the plans. Also, the author will try to find out how significant the VM techniques are and what are their effects on the construction projects in the form of performance improvement. Moreover, the study will find out the main barriers in implementing the LC principles in the construction industry of Pakistan and UAE. Also, the study will find out the possible methods of LC that can be employed in the JV projects to enhance their performance.

2.2.1. Lean Construction Principles

In the construction industry, the main reason or aim of approaching the project as a production system is to adjust the structure of work in design and construction to maximize the performance (Swefie, 2013). Generally, the lean principles that are widely adopted to get the maximum benefits are divided into five fundamental principles.

In 1996 Womack and Jones published the book “Lean Thinking” which put forward the five basic lean thinking principles: Value, The Value Stream, Flow, Pull, and Perfection.

1. *Specify Value:*

   Specify the value according to the customer's definition and needs and identify the value of the activities that are adding or generating value to the end product.

2. *Identify the value stream:*

   Recognize the value stream by eliminating all the processes and activities that do not add value or generate value to the end product. This means that, when there is something wrong with the process or the production, stop the process and change it or fix it immediately. Generally, the activities or process which has to be avoided are overproduction, unnecessary inventories, unnecessary movement of labors, transport of materials and products, and essential production of material or product is not according to needs and demands of the customers, and the unnecessary waiting time (Remon Fayek Aziz etal, 2013).

3. *Flow:*

   It is required to ensure that the flow of the process is continuous, i.e., the sequence of the activities in the process is continuous without any stoppage or break in the value chain by focusing on the entire supply chain. The focus should be retained to achieve the process that is continuous across the whole value chain and simultaneously minimize the waste production and increase the value of the end product or to get the value according to the customer demands or specifications (Remon Fayek Aziz etal, 2013).

4. *Pull:*

   It means to produce the product, what the customer wants, and when the customer wants. Employee the concept of pull in the production and construction process instead of push. The main idea of pull production is to reduce unnecessary production and unnecessary inventories to minimize the amount of waste production. For pull production, the management tool “Just-in-time” (JIT) is used to avoid over-production (Remon Fayek Aziz etal, 2013).

5. *Perfection:*

   The process of continuous improvement in the process of production aims to achieve perfection in the process and the product. It means to deliver a product to the customers according to his/her expectations and demands within the schedule and without any defects or mistakes. The only solution to achieve perfection is to have close communication with customers, managers, and the employees that are attached to the production process (Remon Fayek Aziz etal, 2013). Fig. 8 show the five lean principles cycle. The cycle shows that "Muda" is removed from one step to another, and all the measures are aimed to achieve perfection in the whole process.

Fig.9. Shows the lean principles which are used in construction sites and there suggested application in construction projects.

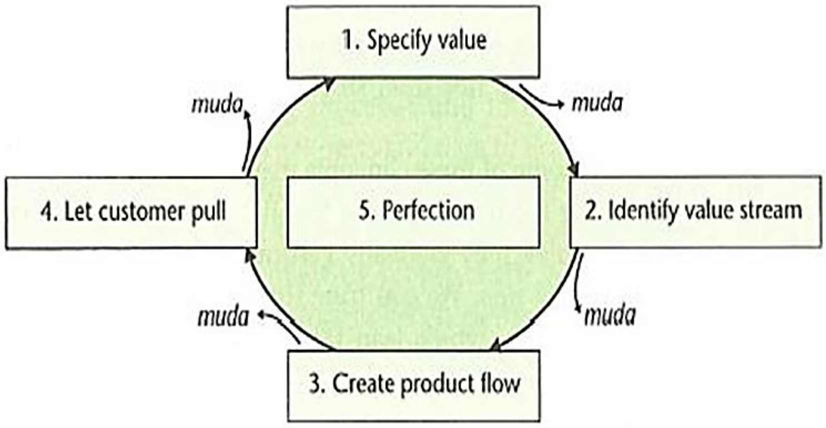


Figure 8: Lean principles (Womack and Jones, 2003)

According to Koskela, lean has eleven (11) principles which are specified below (L.koskela, 1992):

I. *Reduce the share of non-adding value activities (waste).*

All those activities or steps in a process to produce a product that does not add value to the product or the customers are called non-adding value activities. Expert suggests that only 3-20% of the activities in construction works are value-adding activities, and all the remaining are considered as non-adding value activities (koskela, 1992). Generally, three aspects are considered responsible for the non-adding value activities, which are improper management of the project, lack of awareness, and the old nature of production. According to Koskela, removal of non-adding value activities are the first principle of LC to be implemented (koskela, 1992).

II. *Increase the value by considering the customers' requirements.*

The value of the process or product is increased by keeping in mind the demands and requirements of the customers. There are usually two types of customers for an activity, one is the next activity, and the other one is the final customer. The practical approach to this principle is to develop an integrated and systematic flow design, wherein all the customers are defined at each stage, and their requirements are analyzed, and maximum possible value is added to the project (koskela, 1992).

III. *Reduce variability.*

In the construction industry, processes vary because all the products used in construction processes come from different locations, and the techniques used in construction have specific characteristics. But by standardizing the construction process will reduce the variability and ensures the continuous flow of the processes.

IV. *Reduce cycle time.*

Cycle time is the amount of time required for a process to begin and complete. According to Koskela:

Cycle time= processing time + inspection time + wait time + move time.

The cycle time can be reduced to the processing time, but by assuring the quality of the process, its impact on the cost, time, and quality of the product. The figure below shows the order of reduction of cycle time.

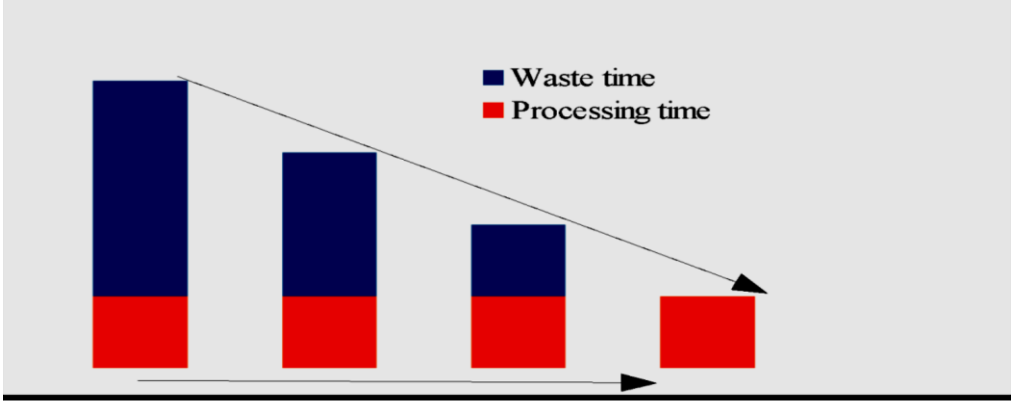


Figure 9: Cycle time reduction (koskela l. , 1992) re-draw from Fig. 4, pg. 20

V. *Simplify the process by reducing the steps, parts, and linkages.*

The complexity of the process or the product has a direct impact on the cost. It is usually challenging to understand the complex process or product easily and more challenging to understand its parts and flow, which has an impact on the reliability of the process or product. In the context of simplifying the process means to eliminate all the non-adding value steps from the process and arranging the activities and measures in a value-adding sequence.

VI. *Increase output flexibility.*

The concept of output flexibility at once appears to be contradictory to the simplification concept. But many companies have worked in following both goals or concepts simultaneously Koskela quotes Stalk and Hout (1989). Some of the practical approaches to increase flexibility are (koskela, 1992):

- Minimize the lot sizes to match demand closely.
- Make setups and changeovers easy.
- Customize as late in the process as possible.
- Training multi-skilled workforce to increase flexibility.

VII. *Increase process transparency.*

VIII. *Focus control on the process.*

IX. *Continue the improvement process.*

X. *Balance flow improvement with conversion improvement.*

XI. *Benchmarking*

Lean tools applications Suggestion for wider and integrated lean tools applications:

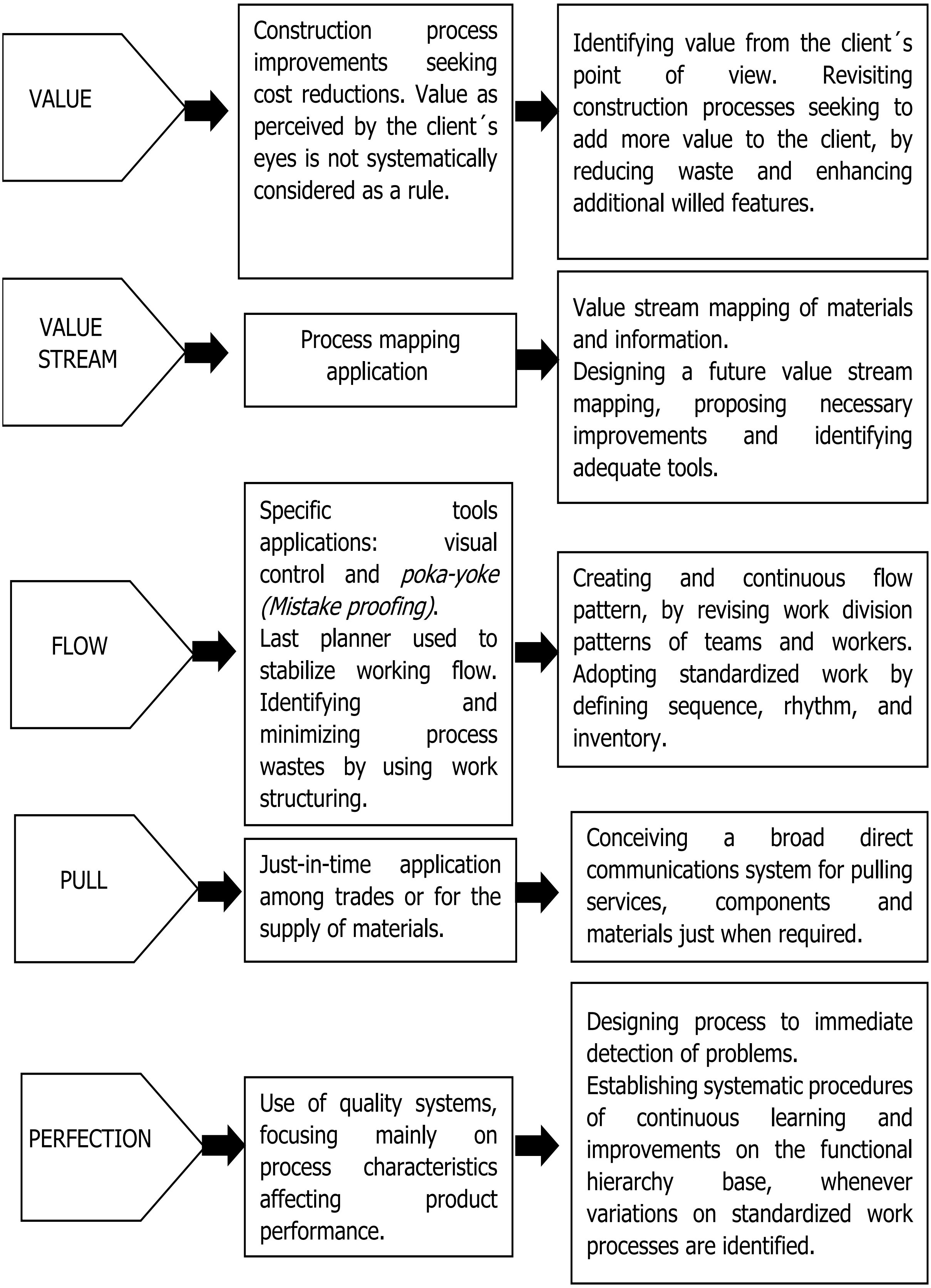


Figure 10: Examples of lean tools and principles in construction implementation and suggestions. Adopted from (Remon Fayek Aziz etal, 2013).

2.2.2. Lean Construction Application Tools

Various kind of tools is specified in the literature, which is capable of improving the productivity of the construction process and construction industry. Some of the tools are briefly discussed in this section, which is mentioned in some of the IGLC studies and some of the known journals related to the lean construction performance in Construction Projects.

2.2.2.1. Lean project Delivery System (LPDS)

Glenn Ballard first introduced the lean Project Delivery System in 2000. LPDS is a delivery system in which the project teams help the customers what they want precisely, not only realize or carry out the activities(LCB, 2019). LPDS was described as a " project-based production system" because it is a temporary production system. As compared to the traditional project delivery system LPDS ask for what has to be done and also specifies the roles and responsibilities at the very beginning of the project. It is a collection of mutually dependent functions, decision-making rules, a method for the execution of tasks, implementations aids and tools, that include the software and the concept developed by Ballard to help in smooth employment of LC on a project-based production and manufacturing system (Ballard, 2000). Some of the critical characteristics of LPDS are:

- Projects are structured and managed as a value-generating process.
- Stakeholders are involved at the very early stage of the project to plan and design the project steps.
- Pull approaches are used to handle the information and material amongst the stakeholders.
- Buffers are used to absorb the variation in the production process.

Each project phase consists of three steps, and each triangle represents a project phase that overlaps with another phase by one step, i.e., some steps are part of two phases. Thus each project phase is influenced by the previous phase and successive phase. If a decision is made in one phase, it will also affect the other phases. In a traditional project delivery system, such relation dependencies between project phases are often ignored (LCB, 2019). The delivery system was shown as a model consisting of five main phases, and each phase is further divided into three modules, as shown in Fig 11.

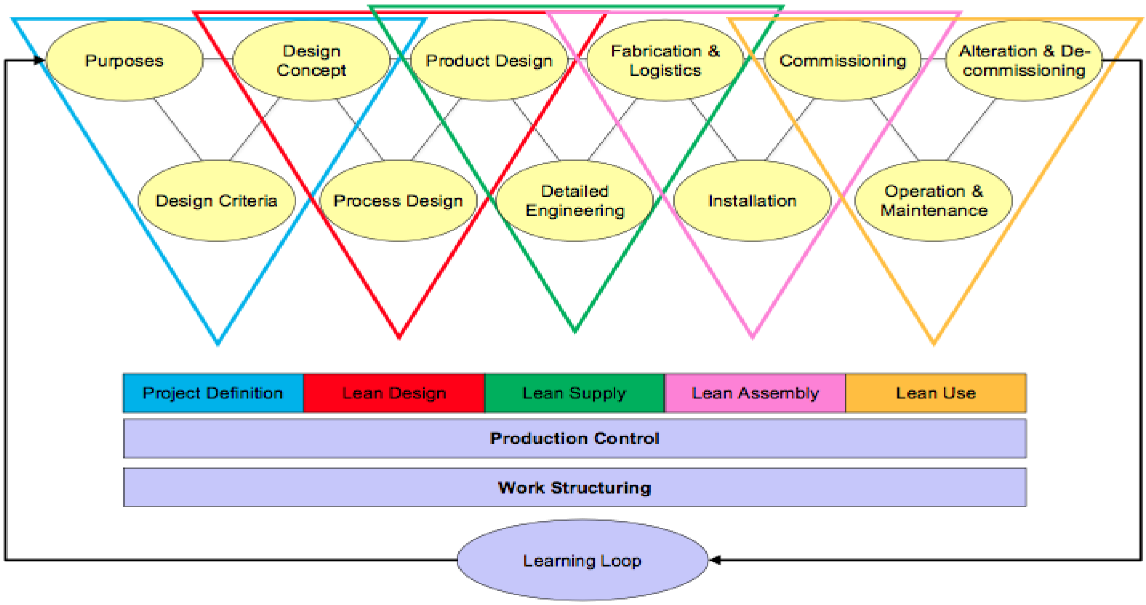


*Figure 11: Lean Project Delivery System Model (Remon Fayek Aziz *, Sherif Mohamed Hafez, 2013)*

All the phases are interdependent upon each other by sharing one module between the two consecutive phases, the production control and the lean work structuring are extended through all the phases, and the learning loop was introduced to identify the lessons learned during the process.

The LPDS model consists of 15 modules, out of these 11 are organized and arranged in the five phases, while the rest of the 4 are arranged in such a manner that they are shared or interconnecting the five phases from project definition to design to supply to assembly to use and also the production control and the work structuring module and even the learning loop that connects the end of one project with start of the next project (Remon Fayek Aziz *, Sherif Mohamed Hafez, 2013).

In LPDS, the stakeholders are closely connected right from the beginning of the project to enhance the value and reduce the wastes, some of the advantages of LPDS are:

- Maximize the value and reduce the waste, cost, and increase the quality through constant improvement of process
- Clear communication among the stakeholders and increase collaboration among the stakeholders.

- Defining the targets from the early stage of the project to reduce and minimize the wastes through reliable flows of activities and information.
- The process improvement with the help of feedback system incorporation.

2.2.2.2. Last Planner System (LPS)

The majority of the problems in construction projects come across because of the bad planning and control process. To enhance the efficiency of the construction industry, proper planning and control processes are necessary to maintain the operations during the project. Precise and efficient planning defines the strategies and criteria to achieve the specified goals, targets, and objectives and control make sure that each process or event occurs according to the planned series or sequences (Remon Fayek Aziz *, Sherif Mohamed Hafez, 2013).

Last Planner System is also one of the connected technique to pull approach. LPS is one of the most useful tools for the management of the construction process, and for continuous monitoring the efficiency of the planning, assist in developing a foresight plan, that helps in streamlining the workflow, by reducing the variation and uncertainties that can harm the construction process (Remon Fayek Aziz *, Sherif Mohamed Hafez, 2013).

The Last Planner System (LPS) is a technique to focus on the project variables and helps in developing and understanding the workflow. The main aim of the LPS is to produce a more efficient schedule for the construction activities as it synchronizes the activities according to the resources availability and the capacity of the workforce and enhances the communication process during the planning process (Ballard, 2000). LPS consists of two units the workflow unit and the production unit. The look-ahead meeting controls typically the workflow, and the weekly work planning manages the production. The weekly work plan identifies the variation in the workflow by integrating the “Foreman” in the decision process for achieving the flow of work at the highest efficiency (Remon Fayek Aziz *, Sherif Mohamed Hafez, 2013).

Several integrated components that are usually used in the LPS are a master plan, phase planning, look-ahead planning, weekly work planning, and **P**ercent **P**lan **C**ompleted (PPC), which is the key to find the success of LPS. PPC only measures the effectiveness of the planning and not productivity or production directly, but indirectly, it affects production and productivity. The reason is efficient planning reduces the variation in the process and also reducing the waste owing to the matching of required resources according to the demand for the production. Percent Plan Completed is calculated when the weekly work plan is executed by dividing the quantity of work completed by the amount of work that is planned. The calculation of PPC shows what work has been executed and what is remaining in the plan, so a new program is immediately scheduled with new finishing dates (Remon Fayek Aziz *, Sherif Mohamed Hafez, 2013).

The most interesting factor for the success of LPS is the integration of “Forman” in the decision and planning process because the Forman implements the sequence of SHOULD-CAN-WILL-DID on the site. Generally, a schedule for the activity is chosen (SHOULD) be done and after reviewing the condition on site (CAN), i.e., what is possible on site with resources and workforce and (WILL) which gets done at the required time. The last planner system is responsible for selecting those activities which are possible to be done with available resources and materials so that assignment can be done, which is the DID. LPS is graphically represented below:

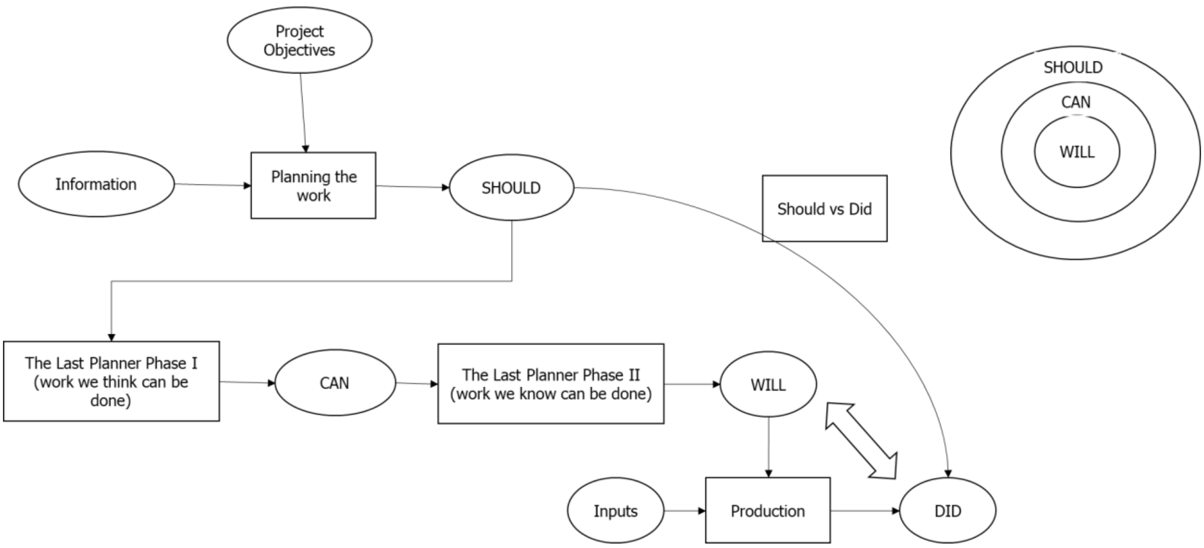


*Figure 12: Last Planner System(Remon Fayek Aziz *, Sherif Mohamed Hafez, 2013).*

Some of the main advantages and benefits of LPS are summarized below:

- The flow of activities or works are constant, i.e., without any variation
- Reduce the wastes, duration of time, and also the cost.

- Increase productivity by integrating the field personnel in the planning process.

2.2.2.3. Just-in-Time

One of the vital tools of lean construction is using a pull approach as a production method. Pull approach is considered the most basic and important way to improve the flow of work (Swefie, 2013). Just in time is one of the associated techniques to pull approach, and in simple words, just-in-time (JIT) means to produce what is needed, when it is required, and in how much quantity it is necessary. It is a pull system that responds to the actual demand of the customers that leads to reduce inventories and wastes of material and also the storage problem (Swefie, 2013). It is also classified as the most developed and mostly used lean construction tool designed to eliminate the non-value adding activities. It is based on the concept that stock on the site, which does not bring value to the customers, is considered as a source of waste. It means the material and equipment must be provided for the production when it is required or necessary (Vidhate, 2018).

2.2.2.4. Continuous Improvement

It is the process of reducing the variability and improving the workflow, which begins right from the start of the project until the completion of the project (Sacks et al., 2010). According to Salem, all the techniques of lean construction are supporting the aspect of continuous improvement (Salem et al., 2005). The continuous improvement process in construction projects is divided into two types: Process improvement, and operation improvement (Swefie, 2013).

Process Improvement

It simply means to develop an efficient method to deliver the project to improve the overall process by reducing the lead time. The main objective of process improvement to reduce the lead time, minimize the wastes, enhance productivity, and make the process more clear and transparent. The main methods related to the processing improvement tool are 1) Current State Mapping (CSM), which shows the current scenario of the project process, including delays, disruption, and any other wastes. CSM is the first step for Future State Mapping (FSM). 2) Future State Mapping is the process to apply required lean techniques on the process to make it efficient, so the workflows become more efficient and eliminate wastes and avoid delays in the process and also define the roles and responsibilities (Swefie, 2013).

Operation Improvement

It is about to improve the execution method of activity. The main objective of the operational improvement is to reduce the cycle time by eliminating the steps that are not adding value to the activity. Also, enhancing productivity, eliminating defects through fixing the problem at once, monitoring and controlling the performance, and optimizing the resources (Swefie, 2013).

2.2.2.5. Visual Management

Visual management is the primary tool to enhance and increase the transparency on the construction site. VM is one of the essential tools associated with the transparency principle of Lean construction. It is the visualization of the information on the site. The increase visualization aspect of the lean tool is to communicate the key information more efficiently and effectively to the workforce by posting various kinds of signs, symbols, and labels on the construction site. It is human nature that what one sees that remains for a long time in his mind, and when various processes and activities on the site are visualized to the workforce, they remember it, i.e., the workflow, performance, required actions, safety, schedules and quality (El-Kourd, 2009). Visualization is also essential in the construction process to avoid any uncertainty in the information. If the visualization is adopted more rigorously for supporting the Lean approach in construction, it tends to enhance the project performance. The technique includes specifying the status of the previous activities, readiness of materials, any changes in the layout of the site, and also the location of the resources. Mobile signs, notice boards, electric wiring, safety signs, project milestones, PPC charts, and increase transparency on site are some of the forms that can be used on construction projects (Swefie, 2013). Nowadays, some computer-aided visualizations are used to support the Lean requirements on the site (Sacks et al., 2010).

Some of the most commonly used VM tools on the construction site are:

- Site Layout and Fencing
- 5´s Technique

- Visual Performance Boards
- Standardization of the Workplace Elements
- Pull Production through Kanban
- Production Levelling through Heijunka Box
- Prototyping and Sampling
- Visual Signs
- Visual Work Facilitator
- Visualization of the VSM and Work Schedule

Figure 13: Example of Digital Communication and information screen on site

2.2.2.6. 5´S Technique

5´S is also a lean construction tool mainly associated with the transparency of the process. It comes from the Japanese word Seiri, Seiso, seiton, Seiketsu, and Shitsuke (meaning Sort, Straighten, Shine, Standardize, and Sustain). The 5´s was initially applied in the manufacturing industry to identify any resources that do not contribute to the performance are considered waste, which should be eliminated from the process (Swefie, 2013). As the name of the techniques demonstrates, it consists of five steps, and each step can affect the process or the workflow. The first and foremost important step is Sort, which means to separate the important items or resources, that are frequently used and are important for the workflow, from the non-important items to save time for searching them. The second step is to straighten, which means specify the location of each item at a single place and in an accessible location. The third step is to Shine, which means to keep the work area or site clean and organized. The fourth step is Standardize, which means to keep the workplace at a good working order to reduce the wastage of time in transporting the items or material. The fifth and last step of this technique is Sustain, to maintain this standard and organization of the workplace or site to achieve the required productivity by sustaining it through repeated training, inspections, and workshops (Koladiya, 2017).

2.2.2.7. Takt time Planning

The word “Takt” is German for the word “beat.” Takt-time “is the unit of time within which a product must be produced (Supply rate) to match the rate at which it is required (Demand rate). The main objective of takt-time planning is to create a more stable flow of activities (Frandson et al., 2014). Takt-time planning is a work structuring method, and it is mainly based on the location-based management system (LBMS) to make the flow of activities or work more continuous. Takt-time in construction projects is the production rate at which the construction work will be carried out. If the rate of production in a construction project is higher than the takt-time, then the buffer time is increased in such a manner that it does not become waste. If the rate of production in construction projects is less or slower than the required takt-time and the activities are taking longer to complete, which ultimately delays the successive activities and thus reducing the production rate, which is demanded by the customers (Koladiya, 2017).

Before the implementation of the takt-time planning technique, some iterative steps are carried out, which are listed below (Frandson et al., 2014):

- Gather data.
- Zone definition (for LBMS).
- Generation of the trade sequence.
- Individual trade duration identification.
- Balancing of the workflow.
- Generating of the production plan.

2.2.2.8. Heijunka

Heijunka is a Japanese term that means leveling. It is a lean method to reduce the variation or unevenness in the production process and minimizing the chances of overburden. It helps in managing the changes in the demand of the customers and utilizing the resources and workforce in the best possible way. Implementing *heijunka* helps to stop producing in batches and start producing according to the demand of the customers, which reduces the inventory cost of keeping or holding the resources and products while the order is low. Heijunka is to carry out the process or flow of work with at a takt-time even when the demand is high (Heijunka, 2019).

Heijunka boxes are used as VM tool and it is used for scheduling. A Heijunka box is a wall schedule that consists of a grid of boxes, and each box represents the same amount of time, which is generally called the takt time. Some colored card is used, which are called Kanban cards; these cards represent the products that are planned to be produced in that time (Koladiya, 2017).

2.2.2.9. Kanban

Kanban is a Japanese word for “visual cards” it is a JIT tool and was used in the automotive company. Kanban is a pull approach and it functions as a work order to start and it is mainly used for the smooth flow of materials. In the construction industry, Kanban is used for the procurement process by organizing orders, also act as a visual management tool to improve the communication among all the stakeholders, and ensuring that the right material or items are delivered in the right amount and the right time (Jang and Kim, 2007).

Kanban system is based on the cards that contain information about either of the job type, quantity, material and labors, safety information, and the conditions for the successive work or activity. All this information on the cards is a weekly work plan based, and these are issued daily, not weekly except for some additional work. The information on the cards becomes more tangible and easily understandable because of the cards. At each phase of the construction process, the information about the work ordered, the volume of work, start date and finish date of the activity, reasons for non-completion, and many more can be easily obtained from the Kanban card or with Kanban system. The construction process on the site consists of three groups, management, construction, and construction support (logistics and workforce). The management group consists of office work controller (Main project Planners), the construction group consists of site or field engineer, and the construction support group consists of all the field workers on the site (Supervisor, Forman, and workers). All of these three departments planned together, but the work ordered by the project controller in the construction support group (The Last Planner, i.e., Forman), so the last planner is not the same person as the field engineer. Some of the simple steps for the application of Kanban of the construction site can be easily understood from the figure below (Jang and Kim, 2007):

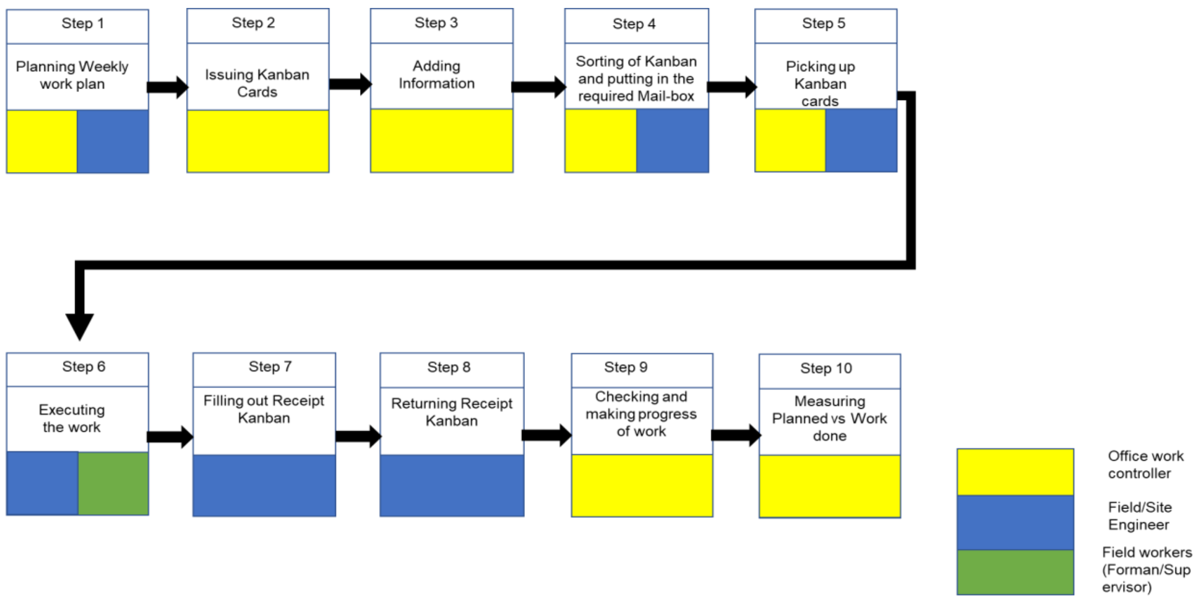


Figure 14: Circulation of work order information via the Kanban and participant Information

Some of the benefits of Kanban system implementation are:

- It increases visualization on the site

- It is the best tool to monitor the performance of construction.
- Communication among the projects member increases.
- Transparency of the process and information increases.
- Performance of work is increased owing to defect less (performance improvement) production of work, and also a reduction in waste of time cost caused by inventories.
- It is more effective on the construction site for the supply of materials

2.2.2.10. Genchi Genbutsu / Go and See

Genchi Genbutsu is another Japanese term like “Kanban, Kaizen, and Muda,” and it is also linked with Toyota Production System (TPS). The Japanese word “ Genchi” means “actual place” while the Genbutsu” means “actual thing.” In the TPS, it means “to go and see” or even better going into the source. It is a tool that is linked with the lean tool of process improvement. For the application Genchi Genbutsu, it is necessary that first, you find out the Genchi, a place of Genbutsu, or a place of problem. It means that they do not believe in what the people of the reports say or give information, but some skilled people will go and check the place of the problem. Once the source of the problem is identified, then various there are various ways of getting involved in the process like (Kanban Zone, 2019):

- ***Hands-on experience:*** To get involved personally as actors and experience have to value is created, and waste is generated in the process.
- ***Observations:*** An outside analysis of how the work is carried can give a different perspective. Problems and inconsistencies in the process can be easily identified as compared to people who are working or used to it, fail to find the issues.
- ***Interviews and Surveys:*** It can help you find how people think of how they carry out the work. This can also help to find the problems or gaps in the process caused due to human misunderstanding or bias.
- ***Reports:*** Consider all the past reports and data that are generated about the process.

2.2.3. Barriers to the Implementation of Lean Construction Principles

LC implementation in the construction industry is still in the initial stages. Even the concept is developed in the early '90s, but the application of lean principles in the construction industry is minimal. From the literature review, various kinds of barriers are identified, depend on the country of application. After a detail literature review, it is found out the most common obstacles which are mentioned in the majority of the papers are seven main challenges in implementing LC shown in figure #15. These are: managerial, technical, human attitude, the process of lean (how it works), educational. Government, and financial, and some others are the main barriers in implementing lean in construction projects. The most prominent barrier which is identified is the lack of commitment from the top management of the company or organization to implement lean on construction projects. Lack of involvement of senior management is also related to other aspects of the organization. For instance, the lack of communication of the senior management with stakeholders is also an aspect that makes it difficult for the stakeholders to adapt to the LC concept (Marhani et al., 2013).

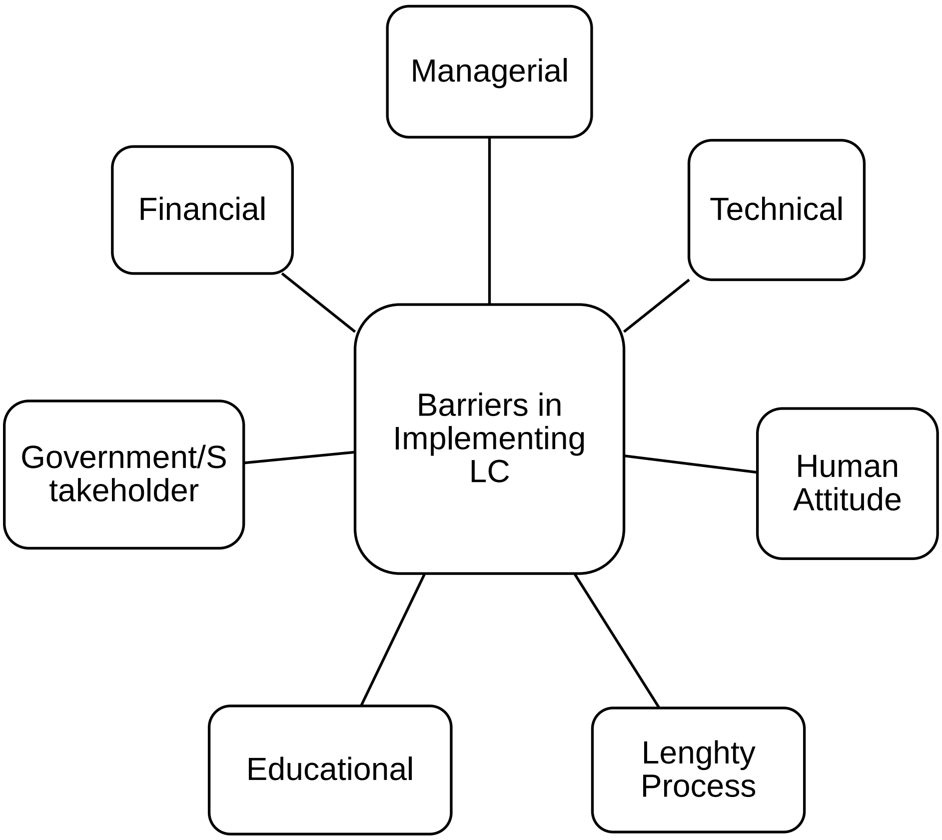


Figure 15: Barriers in Implementing LC in the Construction Industry

Under the technical barriers in the implementation of the LC concept is the constructability aspect of the project. Besides, the uncertainty in the production process is also contributed as one of the barriers. The lack of involvement of all the stakeholders right from the pre-construction stage causes the constructability of design vaguer, which later on in the construction stage causes a variety of design changes that reduce productivity. It is also significant that human attitude toward the adoption of new techniques and skills slows down the productivity of the construction process and even the implementation of LC in the industry (Marhani et al., 2013). Abdullah et al. (2009) explain that attitude means the tendency regarding the intent, commitment, and co-operation that need to be present in the stakeholders if they want to implement LC in construction. Such a kind of attitude toward the adoption of LC will affect the productivity of the construction industry.

Proper training is necessary for the stakeholders who are involved in the construction related to the LC to develop some expertise related to the implementation of LC in the industry. Lack of proper training and knowledge related to the application of LC makes it challenging to adopt the LC in industry. Although training and educating the employees may take time and effort, the top management has to play there role to expand the training and education to implement the LC concept (Abdullah et al., 2009).

Finally, financial barriers are also significant, owing to the unstable market condition for construction and the higher cost of construction, but lower Return on Investment (ROI) makes the implementation of the LC concept in the industry riskier. Also, lack of a reward or incentive system in the construction project makes the employees more resistant to adopt new techniques, which makes the implementation of LC more difficult in the industry (Marhani et al., 2013).

Sarhan et al. (Sarhan et al., 2017) 2017 divide the barriers in the implementation of LC in the construction industry into two categories based on developed countries and developing countries. Developed countries include UK, Germany, and Singapore, while the developing countries include Malaysia, India, China, Libya, Ghana, and Uganda. This suggests that barriers to the implementation of LC in construction are more apparent in developing countries rather than in developed countries. In the study, he identifies that unwillingness to adopt innovation was one of the significant barriers in Singapore to implement LC in the industry.

Further, in developed countries like the UK, it is found out that barriers to the implementation of LC in the construction industry are lack of adequate awareness and understanding, lack of commitment of top management, and human attitude. The human attitude was the most critical barrier in the implementation of LC in construction. In developing countries, the focus on the obstacles to implementing LC in construction is more similar to the developed countries. The most common barriers identified in the developing countries are lack of management commitment, limited understanding of the concept of lean construction, and unwillingness to adopting new ideas. Some of the significant barriers identified to implement LC in the construction industry are (Sarhan et al., 2017):

- Managerial: Lack of willingness of top management.
- Technical: Problems with the constructability of the design.
- Human Attitude: unwillingness to change.
- Lack of education.
- Absence of communication among the construction team.
- Unavailability of benchmark performance.
- Traditional management practices.
- Unfavorable organization culture.
- Lack of uncertainty in the production process.
- Absence of standardization.
- Absence of adherence to time commitment.
- Absence of Government or Client involvement.
- Corruption.
- Absence of financial resources.
- Absence of workforce.
- Lack of participation of contractors and experts in the design process.
- Extensive used of sub-contractors.
- Unclear project definition and outcomes.
- Long-time required to implement the LC process.
- Uncertainty in the supply chain.

2.2.4. Lean in Joint Venture (JV) Project

A joint venture is defined as “it is an agreement between two or more legally independent companies or enterprises, who combine their resources and capabilities to a shared business or venture. Or project-based JV in construction is a mechanism that brings two or more organizations to work together to deliver the clients or the customer's expectation. The main aim of the JV is to share the risk, utilize the resources, skills, knowledge, and experience of each partner in the JV projects. JV is a form of contract in which the two or more companies work together to accomplish a project. Owing to the risk involved in the construction project, the use of JV has increased significantly and especially in infrastructure projects in the UK. The reason behind the increase in JV in infrastructure projects is the risk and the skills required to execute the project (Daniel et al., 2016). The venture becomes international when there is at least one foreign partner is involved. Some of the characteristics of JV is (Mo, 2012):

- Independent legal unit involving two or more parties.
- May be established as a corporation, partnership, or other legal business or association selected by parties.
- Parties own all the ownership, responsibilities, risks, and rewards combinedly.
- Each party of the venture keeps his corporate identity and independence.
- Parties in the venture contribute capital, skills, experience, and knowledge for a specific purpose.
- The venture will always be for a limited duration.

Owing to the globalization trend and also due to the crises related to the lack of availability of skilled workforce, material, and various kind of economic-related risks companies develop a partnership or agreement to share the resources, knowledge, skills, and risk to deliver a product and this agreement or partnership is called Joint Venture (JV). It is a type of contract in which the partners share the risk, resources, skills, experience, and knowledge to accomplish a project is called the joint venture (JV) (Daniel et al., 2016). According to the global construction dispute report, 1 out of 3 (33.3%) JV projects failed due to the dispute among the parent companies (Allen, 2015).

Disputes or conflicts are common in any organization, but its worst effects appear when the management team is composed of a mixture of people from different entities. The significant challenge in managing JV projects is the collection of individuals or persons with differences in culture, geographical locations, and organizational politics (Abd-Karim et al., 2014). Some of the factors that create problems in implementing the JV successfully are the difference in the size of the parent companies, difficulties in establishing inter-partner trust, mutual understanding, and inconsistencies in management practices (Adnan, 2008).

The most common kind of conflicts identified in JV projects is inter-personal and intra-personal conflicts, which affect the success rate of the JV projects. The inter-personal conflicts that usually occurs between the employees of the parenting companies or partners. Intra-Personal conflicts are the conflicts that generally develop within the organization. Various reasons are found out for the inter-personal disputes, which are: Differences in the management style, Lack of clear information, Lack of discipline of the employees, and the lack of inter-partner trust. Some other conflicts causing factors within the JV projects are intra-personal, which usually develops within the employees of one of the parent company and ultimately affect the productivity of the project. Some of the frequent intra-personal conflicts are Differences in opinion, self-centered behavior, poor communication, and un-cooperativeness (Abd-Karim et al., 2014).

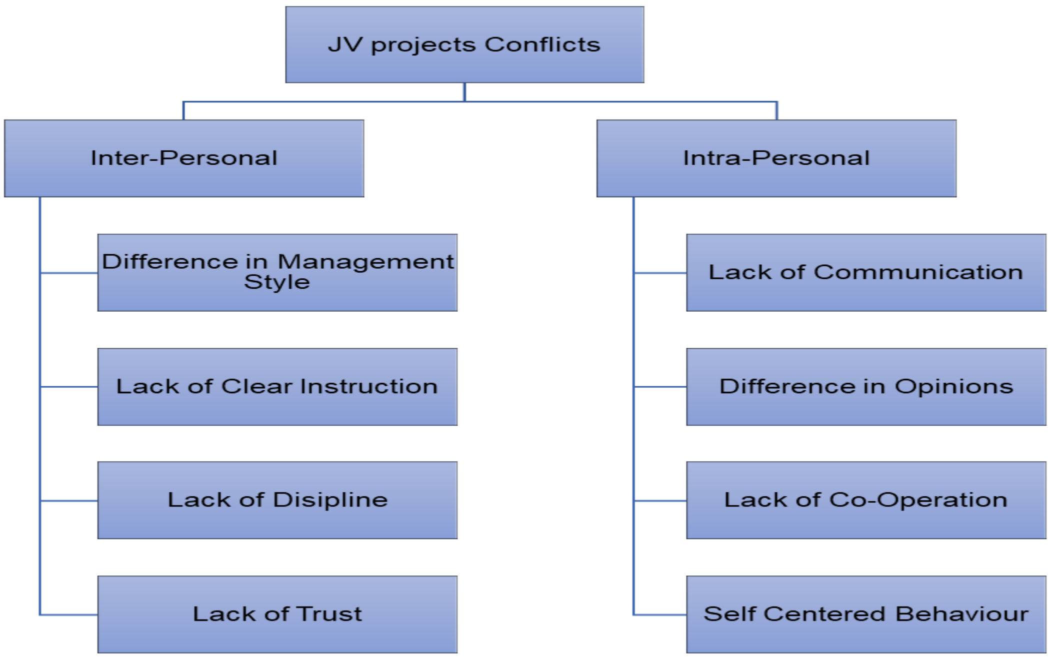


Figure 16: Common Conflicts in Joint Venture (JV) Projects

Studies had reported a high failure rate of between 45-50% of JV projects due to a lack of clear communication and a lack of clarity of delivery. But, the Last Planner System has the potential to reduce such risk because of its capacity to produce collaboration and enhance the certainty of project delivery. LPS is a production planning and control method that concentrates on reducing the uncertainty in the workflow, which is generally not found in the conventional or traditional project management. Studies have identified LPS implementation under various kinds of contracting structures such as Integrated Project Delivery, Integrated Form of Contract, and Lean Project Delivery System. However, no studies are conducted and carried to find out the factors that affect the application of LPS on the construction projects under the growing practice of the JV contracting structure (Daniel et al., 2016).

JV is the alliance of the two companies to share all the resources to accomplish a project and deliver it to the client. But, JV itself does not bring the team into collaboration at the project level. To develop a collaborative atmosphere between the parent companies, a system is needed to develop cooperation among them. This collaboration between the parent companies can only be developed with LPS, to manage the production system in such kind of contracting structures. It is only the LPS tool of the LC to develop a collaborative relationship at the project level (Daniel et al., 2016).

Daniel et al. (2016) carried out a study on the application of LPS on infrastructure JV projects in the UK. In the study, he finds out various factors for the productive use of LPS on infrastructure projects.

- Reduce the batch size.
- Addition of LPS practice in the contract. (Develop collaboration among the stakeholders)
- Use of Collaborative Form of Contract and Long Term Relationship Focus.
- Training and Creation of Awareness.
- Selection of Facilitators and Lean Champions.
- Team Combination and Less parent Company Identity.
- Delivery of Physical Space and Locate the teams together.

The review identified various kinds of factors that are considered liable for the failure or the conflicts in the JV projects in the construction industry. Some of the factors which are causing conflicts are in line with LC construction principles implementation and can be eliminated if the LC principles are implemented in the JV construction projects. The detailed study will be carried out to find possible LC principles that can improve the performance of JV projects.

3. Research Concept

For a long time, Architecture, Engineering, and Construction (AEC) industry has and is facing the problem of low performance in production or execution management. The main reason behind the weak performance of the sector is linked with the quantity of wastes. It is necessary to change the thinking of the stakeholders who are involved in the AEC industry and identify the benefits of Lean Thinking. VSM is a systematic way of implementing lean as it derives improvements throughout the process flow of the project. Previously studies have been carried out on the application of VSM in the AEC industry on various processes such as house construction, concrete block, ceramic, and drywall applications. All the studies were carried out to find the non-adding value activities and the resources in the process to reduce the waste in the construction process (Melo et al., 2017).

In order to identify and understand the actual benefits of the LC, It is vital to assess efficiency by applying the principles to real projects. Construction waste is one of the significant factors that reduce the productivity and performance of construction projects in the form of cost and duration (Shahidullah, 2013).

In order to identify the benefits of VSM on the construction project, Rother and shook proposed five steps to apply Lean Thinking through VSM: Select a group of products, map the current state, examine the current map, map the future state, and explain the work and execution plan (Rother and Shook, 1999). In this research, the author selected the family of the product of the production process of construction projects to identify the possible waste of the workforce.

The study aims to implement the VSM on the construction of a house building project in Pakistan and Dubai. To find out the impact of VSM application on the total cash-flow of the project. The application of VSM on the home building projects will be carried out only to find out the waste in the form of waiting time and reduce these waste but will also change the sequence of the task that produces the value and find its impact on total cash-flow.

A method of developing the current state map and future state map will be adopted to find out the waste of waiting time, and other duration related waste, to carry out the activities. Waiting time is the time during which no other task or activity is carried out and that waiting time costs money to the contractor or the company. During the study, a current state map of the whole project is developed by using a VICO Control Software to find out the waiting time between the tasks and calculate the amount of money or capital that is costing.

Also, the production rate of each task will be calculated manually from the quantity and duration of the task from the current value stream. Additionally, the number of labors required to complete the task will also be calculated manually from the total cost of labor for the task, the per-hour labor cost, and the duration of the task by using the formula below mentioned formula:

$$\text{No of labors Required} = \frac{Labour\ cost\ of\ Task}{Duration\ of\ Task * Cost\ of\ labour\ per\ Hour}$$

Equation 1: Number of Labor Required to carry out a Task

To calculate the production rate (Hours/Unit) of each task, the calculation will be carried out manually by using the below-mentioned formula.

$$\text{Consumption Rate (Hours/Unit)} = \frac{No\ of\ Labours\ required * Duration\ of\ the\ Task}{Total\ Quantity\ of\ the\ task}$$

Equation 2: Production Rate of the Task

A detailed analysis of the current value stream will be carried out to find all the non-adding value time, which is mainly the waiting time in the current state map. After analysing the current state map for the waiting time in the value stream and its cost, future state map of the project will be developed by eliminating the waiting time and changing the sequence of the tasks to get maximum value and also try to reduce the duration of project by keeping the production rate (Hr/Unit) constant as in the current state map. Also, the duration of the project will try to be reduced with an early start and early finish of the task, and through speeding up the process through using more resources by keeping the production rate the same as in the current value stream of the project.

After identification of all possible waste in the process, a cash-flow of the current state map is developed to find out the performance of the total cash-flow of the current state of the project. After generating the cash-flow of the current state, the percentage of the negative cash-flow will be calculated. A similar process will be carried out to find out the cash-flow of future state maps, which will be developed after eliminating the waiting time and reduction of the duration of the task to find out the impact of the VSM on the total cash-flow of the projects. The required percentage of negative cash-flow of future state maps will be developed and compared with the total cash-flow of the current state. The impact of VSM will be assessed by comparing the total cash-flow of the current state map with the future state for the possible improvements in the total cash-flow after the elimination of the waste in the stream. All the steps that were carried out in both the case studies to assess the impact of VSM on the total cash-flow can be seen in figure # 17.

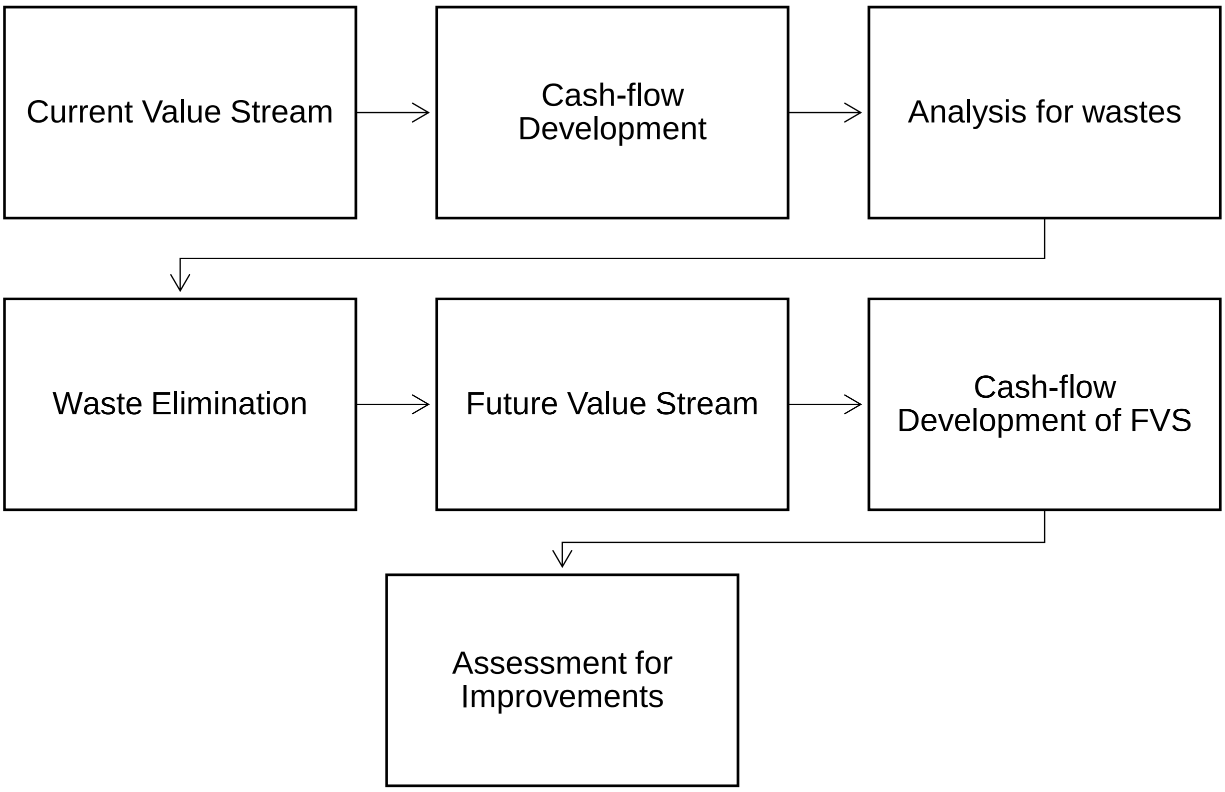


Figure 17: Steps of Value Stream Mapping to find the impact on the cash-flow of the project

Visual management

The aim of the research work to find out the quantitative result related to the implementation of visual management techniques that are usually employed on the construction site. The study is conducted to find out the effects of visual management, Visual Signboards, 5´s, Standardization of site, Prototyping, Health and Safety Management, Visualisation of the workflow, and Other Visual Communication on the site and its effects on the performance of the project.

Response Scale	1	2	3	4	5	6
Factors/Variables	V. Low 0%	Low 1-15%	Medium 15-30%	High 30-45%	V. High >45%	No Answer

Table 2: Variables for VM Questionnaire and their required Scale

After gathering the data, the data is analyzed by using the software "Statistical Package for the Social Sciences" (SPSS) to find out the significance of the VM and correlation between visual management implementation and the performance improvement of construction projects. The impact of VM on the performance of the project will be predicted from the data received, using the regression model.

To analyse the data regression model will be applied to the received data to find out the amount of performance improvement predicated with the implementation of VM on the construction project.

Barriers in Implementing LC in Pakistan and Dubai

To enhance the productivity of the construction industry in Pakistan and UAE, it is vital to implement the LC principles. But, due to various problems faced by the industry, the implementation of LC principles is minimal. To find the barriers to the application of LC in the sector, a questionnaire survey is carried out in both countries. To find out the main obstacles to the implementation of LC and find out the possible solution to handle the barriers to enhance the productivity of the industry. The questionnaire is sent to the respondents who are directly or indirectly connected with the construction industry in the mentioned countries. The concept of the survey is to find out the barriers that are creating impediments in the performance improvement of the construction projects.

The questionnaire survey is based on the Likert-scale from 1 to 5. Scale 1 represents “strongly disagree,” and scale 5 represents the “ Strongly Agree.”

Response Scale	1	2	3	4	5
Factors/Variables	Strongly disagree	Disagree	Neutral/ Partially agree	Agree	Strongly agree

Table 3: Variables for questionnaires and their scale

The level of agreement of the respondents on the barriers to the implementation of LC in the construction industry in both countries will find out. Data analysis will be carried out using the statistical package for social sciences (SPSS) software. The frequency distribution and percentage will be used to summarise the background information of respondents, while the Relative Importance Index (RII) will be used to the main responses (Sarhan et al., 2017). The RII is based on equation # 3, which is the sum of items scores for each identified barrier to lean construction divided by the highest weightage and the total number of respondents contributing to it. Therefore, RII represents the average of agreement among the respondents about barriers to LC in Pakistan and the UAE construction industry (Sarhan et al., 2017). The five-point Likert-scale will be used, and the barriers which have RII value higher will be considered the most significant barrier, and also the RII value will also show which barriers are most common. RII is the sum of the score for each barrier to lean construction divided by the multiplication of the highest weightage and the total number of respondents (*AN*).

$$RII \quad = \frac{5n5 + 4n4 + 3n3 + 2n2 + n1}{AN} * 100$$

Equation 3: Relative Importance Index (RII) equation

Where, n1= No. Of respondents who answered 1

n2= No. Of respondents who answered 2

n3= No. Of respondents who answered 3

n4= No. Of respondents who answered 4

n5= No. Of respondents who answered 5

where N = Total number of respondents.

A = the highest weightage, which is 5 in this case.

After finding the main barriers to the implementation of LC in industry, possible solutions will be recommended to solve the problem of barriers.

Lean in Joint Venture Projects

A detail literature review was carried out to find the main reason for conflicts that caused the JV project failures and reduce performance. From the literature, various factors of low performance of JV projects were identified, but the most significant factor that reduces the performance of the JV projects is lack of communication, lack of clear instruction, and lack of trust among the parent companies.

A detailed study will be carried out to find the possible solution from the lean principles family for the conflicts in JV projects that are affecting the performance of the JV projects. The problems identified in the literature and mentioned in chapter 2 of the study will be focused mainly on the perspective of the LC principles. The study will recommend principles and techniques that can eliminate those problems in the JV project, which affect the performance of JV projects.

4. Case Studies Related to Cash-flow

This chapter is dedicated to analyse two existing building projects which are conventionally or traditionally planned. The objective of the study is to find out the impact of LC tools application on the project and its performance improvement in the form of wastes reduction and its impact on the total cash-flow of the project. The cases were chosen based on data availability, and to find a better solution for the negative total cash-flow factor that causes many project failures.

Also, the inclusion of case studies' aim is to find out the non-adding value activities, duration (time waste), and resources that cost capital to the project. But, had no direct impact on the enhancement of the product. Also, to find out how possibly the LC tool can improve the total cash-flow of the projects.

4.1. Dubai, United Arab Emirates

The study is conducted on a recently constructed Villa in the Ras Al Khaimah, the region in the United Arab Emirates (UAE), which is famous for Villas projects. The contractor of the project was a small construction company with a license for the G+1 building, Golden Gem Contracting Company (GGC). The building is owned by a private owner and is responsible for all the costs of the project.

4.1.1. Case Description

The building is located in the area of Ras Al-Khaimah, UAE. It is a luxury house with two floors and a roof, with a covered area of 400sqm. The building frame structure mainly of prefabricated concrete elements and the partition walls with blockwork. The project was started in October 2018 and completed in June 2019. The total duration of the project was about nine months, and the construction cost of the project was about 1,558,003.00 Dirham.

The project was planned conventionally without considering the concepts of LC. In order to reduce all kinds of wastes in the project, a plan was developed using the Vico Control software to visualize the value stream of the project. Now the concept of LC will be implemented on the project to find out its effect on the total cash-flow of the project. The aim of the study to find out those waste and eliminate the wastes and find out how much the total cash-flow of the project can be improved with implementation LC principle of VSM on the real-life project.

4.1.2. Case Analysis

To understand the actual benefits of LC, it is important to evaluate the efficiency of LC by implementing its principles on a real project. Wastes in the construction execution process are the major problems that affect the overall progress of the project in terms of time and cost. The paper's aim is to keep the production rate of the project constant and reduce the waste in the execution phase by implementing lean principles.

A method of value streaming will be used to identify all kinds of non-value adding activities, duration, and resources, and its effects on the total cash-flow of the project will be measured in the form of a performance improvement after eliminating those wastes.

Data Collection

At this stage, all data about the project, for instance, overall description, Bill of Quantities (BOQ), location of the project, and the work schedule or the activity report, are collected from the required contracting company with the help of a friend. The table below gives all the detail of the project, like the category of the building type and location of the project. Also, the table gives detail about the total built area and the area of each floor of the project. Also, the table gives the start date of the project and the end date of the project and also the total duration of the project to complete, i.e., the duration of the construction phase of the project and the total cost of the project.

No	Subject	Data
1	Project name	Confidential
2	Project Category	Single Family House
3	Project Location	Dubai, UAE
4	Total Built Area	816 sqm
5	Area of Ground Floor	383 sqm
6	Area of First Floor	405 sqm
7	Terrace Floor Area	27 sqm
8	Start Date	10/10/2018
9	Finish Date	31/07/2019
10	Total Project Duration	9 Months
11	Duration of Contract	12 Months
12	Total Project Cost	1,558,000.00 Dirham
13	Project Owner	Confidential
1.	Project Contractor	Confidential

Table 4: Project detail of Dubai Villa

The part of the chapter is limited to analyse the existing project and the work schedule of the project. The work plan of the project was conventionally planned by using the primavera P6 software, which can be seen in Appendix A. The majority of the activities of the project are planned to finish to start and start to start. All the project activities combined according to the milestones, as mentioned in the conventionally planned schedule. The number of milestones with the required percentage of money fixed in the Bill of Quantities (BOQ) can be seen below in table 5.

No	Milestones	Percentage of Money	Construction Cost
1	Preliminaries	5%	75000.00
2	Sub-Structure	12%	178530.00
3	Super-Structure	16%	250250.00
4	Block Work	7%	105050.00
5	Plastering Work	5%	82650.00
6	Finishing Work	20%	306920.00
7	Woodwork	9%	140000.00
8	Electrical Work	13%	198000.00
9	Boundary Wall	9%	143600.00
10	External Work	4%	70000.00
	Total	**100%**	**DEM 1,558,000.00**

Table 5: Milestones of the project and Construction Cost of each Milestone

Table #5 show the total construction cost of the project, and the cost fixed for each milestone was found out from the BOQ of the construction project. Each milestone of the project has a specified percentage of the total construction cost, which was calculated from BOQ. The BOQ and the schedule of the project can be seen in Appendix A.

As the total cost of the project includes hard cost (materials) and soft cost. In the UAE, the hard cost of the project is about 50-60% of the total construction cost and the soft cost (machinery and labor), which is 30-40% of the total construction cost. Also, there is a 10% overhead cost, also included in the total construction cost of the project (Shahidullah, 2013).

No	Task	Construction Cost (Dirham)	Labor Cost (40%)
1	Preliminaries	75000.00	30000.00
2	Sub-Structure	178533.00	71412.00
3	Super-Structure	250250.00	100100.00
4	Block Work	105050.00	42020.00
5	Plastering Work	82650.00	33060.00
6	Finishing Work	306920.00	122768.00
7	Woodwork	140000.00	56000.00
8	Electrical Work	198000.00	79200.00
9	Boundary Wall	143600.00	57440.00
10	External Work	70000.00	28000.00
	Total Cost	**1,558,000.00 DEM**	**620,000.00 DEM**

Table 6: Percentage of the Labor cost of the project for each task.

Analysis

From the received information related to the project, it is difficult to identify the waste in the value stream of the project. As the project duration is within the contract period, and the project is predicted to be within the project cost specified in the BOQ of the project. The study aims to find out the cash-flow of the project and find out the cash-flow curve whether the curve is negative or positive.

To develop the cash-flow of the original project, a value stream of the existing schedule was developed in the schedule planner with the same milestones as identified in the original schedule received. The start date and finish date of each milestone were kept the same as in the original schedule.

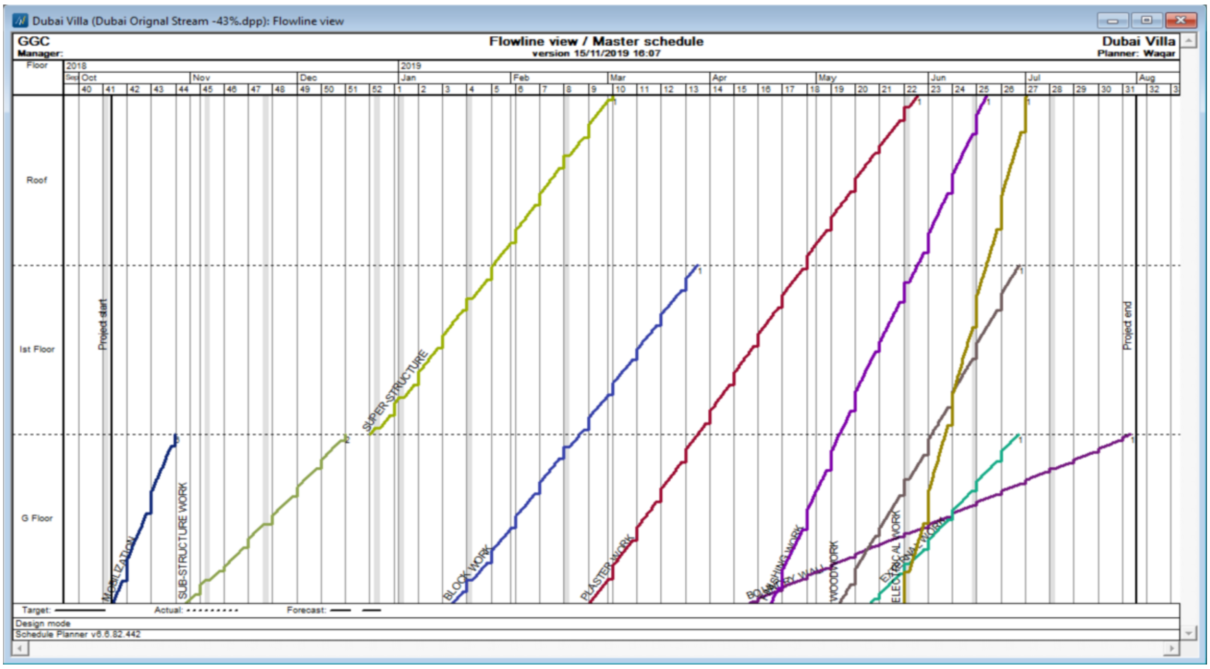


Figure 18: Current Value Stream of Dubai Project.

Figure # 18 shows the current value stream of the project developed in the Vico Control Software. The development of the stream in Vico control is to identify all the non-adding value durations, and activites in the stream of the original schedule.

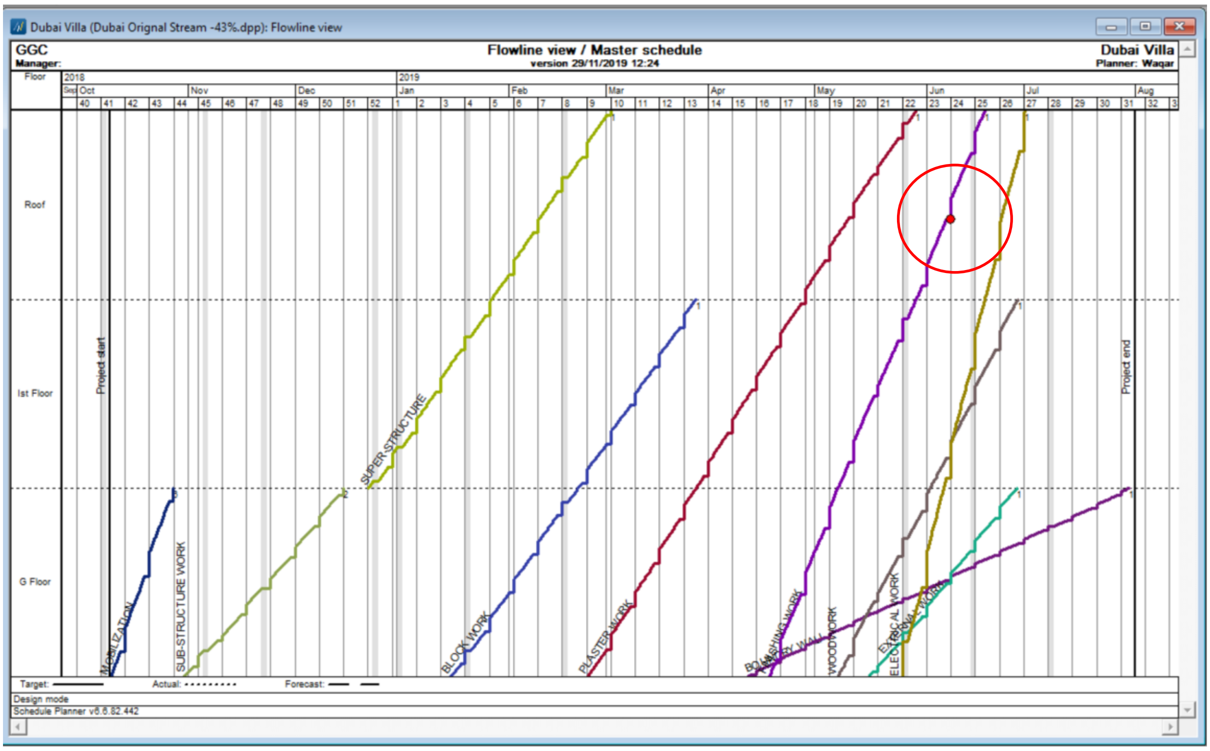


Figure 19: Current Value Stream after Simulation

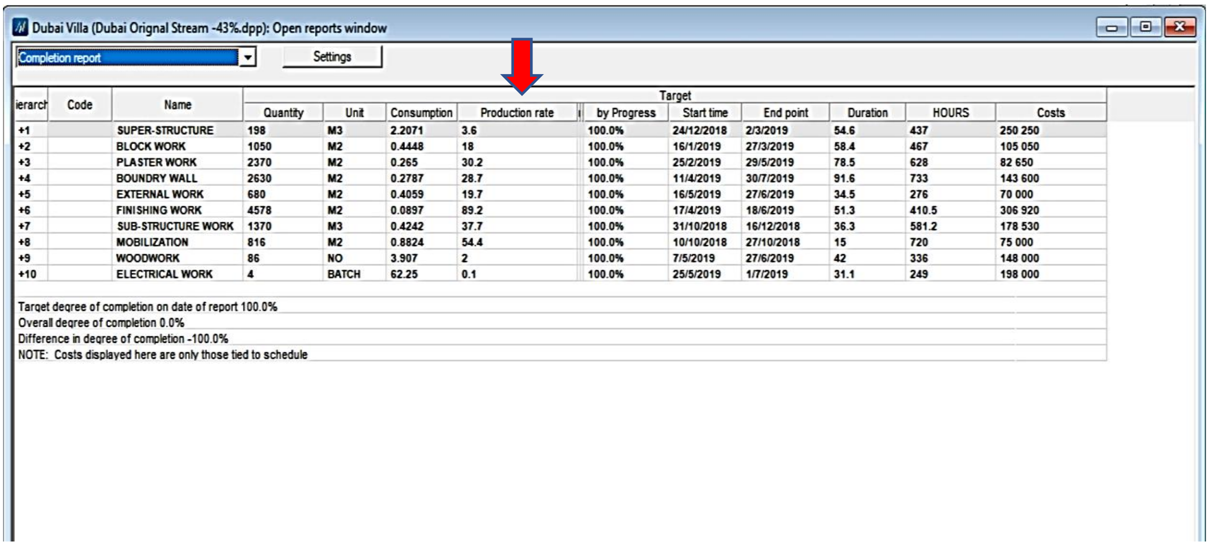
Figure # 19 shows the possible clashes between the tasks in the current value stream of the project. The figure shows that the finishing work is 100% clashing with plasterwork. This simulation helps to identify the possible clashes between the tasks which can possibly delay the project.

After developing the current value stream of the project in the Vico Control software, the next step was to analyse the current value stream for the non-adding value activities, resources, and the waste of time in the stream, which are possibly affecting the cash-flow of the project. The waste of time is the time or duration at which labors are idle, but the contractor claims the cost of labor, which is normally waiting time to start another activity. The waiting time is the duration between the two activities at which labors do nothing, just waiting for the next task to start.

Tasks	**Lbr Cost (40%)**	**S.Date**	**F.Date**	**Duration (days)**	**Qt**
Mobilization	30000.00	10/10/2018	27/10/2018	15	816 m^2
Sub-Structure	71412.00	31/10/2018	16/12/2018	37	1370 m^3
Superstructure	100100.00	24/12/2018	2/3/2019	55	198 m^3
Blockwork	42020.00	16/1/2019	27/3/2019	48	1050 m^2
Plastering work	33060.00	25/2/2019	29/5/2019	79	2370 m^2
Finishing work	122768.00	17/4/2019	18/6/2019	44	4578 m^2
Woodwork	56000.00	7/5/2019	27/6/2019	28	86 No
Electrical work	79200.00	25/5/2019	1/7/2019	31	4 Batch
Boundary wall	57440.00	11/4/2019	30/7/2019	92	2630 m^2
External Works	28000.00	16/5/2019	27/6/2019	35	680 m^2

Table 7: The Details of the current Value stream of the Dubai Villa Project

Table #7 above shows the detail of the current value stream of the project. The labor cost of each activity was to find out from the total construction cost of the task. The labor cost was calculated as 40% of the construction cost of each task. According to "Shahidullah," the labor cost of the project in UAE is 30-40% of the total project cost, 50-60% is considered as material cost, and 10% overhead cost. On the bases of 40%, the labor cost of each activity was calculated. The labor cost per hour in UAE was found out to be 8$/hour which is equal to 20 Dirham per hour on average (Shahidullah, 2013).


Dubai Villa (Dubai Orignal Stream -43%.dpp): Open reports window

Completion report | Settings

ierarch	Code	Name	Target									
			Quantity	Unit	Consumption	Production rate	by Progress	Start time	End point	Duration	HOURS	Costs
+1		SUPER-STRUCTURE	198	M3	2.2071	3.6	100.0%	24/12/2018	2/3/2019	54.6	437	250 250
+2		BLOCK WORK	1050	M2	0.4448	18	100.0%	16/1/2019	27/3/2019	58.4	467	105 050
+3		PLASTER WORK	2370	M2	0.265	30.2	100.0%	25/2/2019	29/5/2019	78.5	628	82 650
+4		BOUNDRY WALL	2630	M2	0.2787	28.7	100.0%	11/4/2019	30/7/2019	91.6	733	143 600
+5		EXTERNAL WORK	680	M2	0.4059	19.7	100.0%	16/5/2019	27/6/2019	34.5	276	70 000
+6		FINISHING WORK	4578	M2	0.0897	89.2	100.0%	17/4/2019	18/6/2019	51.3	410.5	306 920
+7		SUB-STRUCTURE WORK	1370	M3	0.4242	37.7	100.0%	31/10/2018	16/12/2018	36.3	581.2	178 530
+8		MOBILIZATION	816	M2	0.8824	54.4	100.0%	10/10/2018	27/10/2018	15	720	75 000
+9		WOODWORK	86	NO	3.907	2	100.0%	7/5/2019	27/6/2019	42	336	148 000
+10		ELECTRICAL WORK	4	BATCH	62.25	0.1	100.0%	25/5/2019	1/7/2019	31.1	249	198 000

Target degree of completion on date of report 100.0%
Overall degree of completion 0.0%
Difference in degree of completion -100.0%
NOTE: Costs displayed here are only those tied to schedule

Figure 20: Detail of Current Value Stream with Production Rate.

Figure# 20 represents the whole detail of the current value stream of the project developed in the Vico Control Software, containing the task start date and end date, consumption, and the production rate of each task. The analysis aims to keep the same production rate as in the original value stream and develop the future value stream of the project.

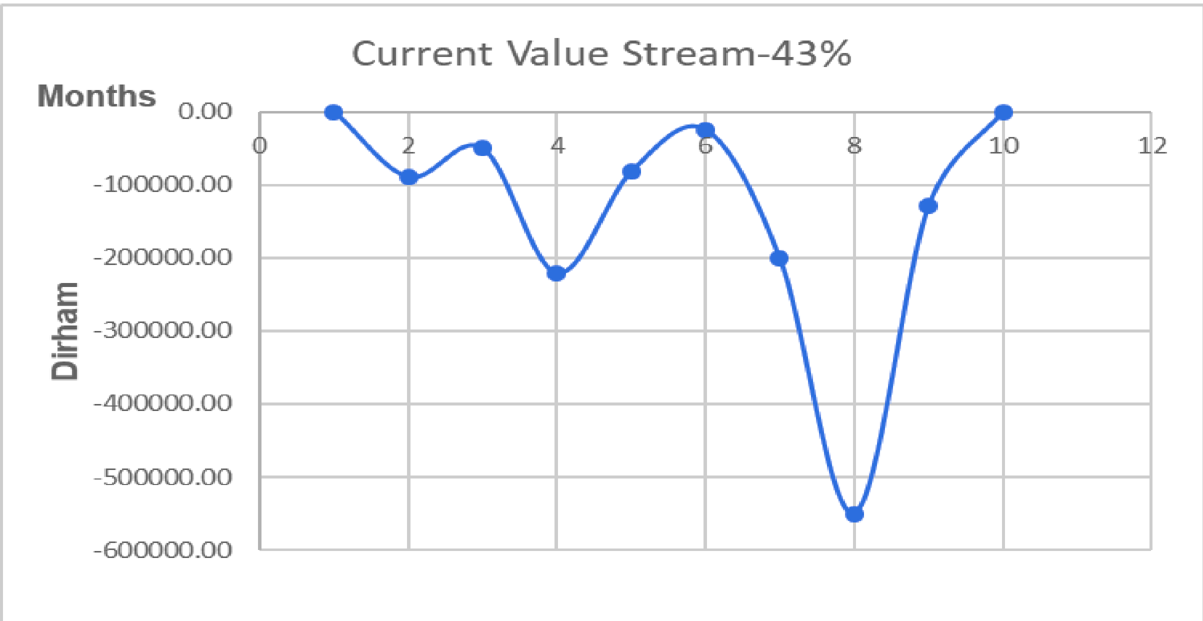


Figure 21: Cash-flow of Current Value Stream of Project

After generating the value stream in Vico Control Schedule Planner, the total cash-flow curve of the project was developed to find out the nature of the cash-flow of the project. Figure # 21 represents the total cash-flow curve of the project, which was planned traditionally without considering the wastes of waiting time in the schedule. The total cash-flow of the project was found out to be 43% negative.

Lean Application Process

The Lean application process starts with the estimation of the number of labors required to carry out each task and the consumption rate of each task (Hours/unit). The estimate of the number of labors required and the consumption rate was carried out manually from the given details shown in table# 07. The number of labors and the rate of consumption hours/unite for the activities was calculated using the following equations.

No of labors Required = $\frac{Labour\ cost\ of\ Task}{Duration\ of\ Task*Cost\ of\ labour\ per\ Hour}$

Here,

- No labors required to complete the task.
- The labor cost of the task is a 40% cost of total activity construction cost.
- -The duration of the task is the number of hours required to complete the task.
- Cost of labor per hour

Consumption Rate (Hours/Unit) = $\frac{No\ of\ Labours\ required*Duration\ of\ the\ Task}{Total\ Quantity\ of\ the\ task}$

Here,

- Consumption rate is the number of hours required to complete each unit of the task.
- The total quantity of the task is the quantity, which will be either in meter (M), square meter (SQM), cubic meter (CM), Numbers (No), or Batches, which depends on the quantity given in the BOQ of the project.

Tasks	Lbr Cost (40%) Total Cost $	Qty	Duration (Hrs)	Cost/H	Lab Req	Hours/Unit
Mobilization	30000.00	816 m^2	120	20 DEM	12.5	1.8
Sub-Structure	71412.00	2495 m^3	296	20 DEM	12.1	2.6
Superstructure	100100.00	198 m^3	440	20 DEM	11.4	25.3
Blockwork	42020.00	1050 m^2	384	20 DEM	5.5	2.0
Plastering work	33060.00	2370 m^2	632	20 DEM	2.6	0.7
Finishing work	122768.00	3732 m^2	352	20 DEM	17.4	1.3
Woodwork	56000.00	17 No	224	20 DEM	12.5	32.6
Electrical work	79200.00	4(Batch)	248	20 DEM	16.0	990.0
Boundary wall	57440.00	2531 m^2	736	20 DEM	3.9	1.1
External Works	28000.00	550 m^2	280	20 DEM	5.0	2.1

Table 8: Consumption rate and No of labors required calculated

Table # 8 shows the cost of labor per hour, the number of labors required to complete each task, and the required consumption rate of each task, which was calculated manually using the above mentioned equations. The next step is putting the calculated consumption hour/unit in the Vico control schedule planner for each task. As shown in figure #22 below,

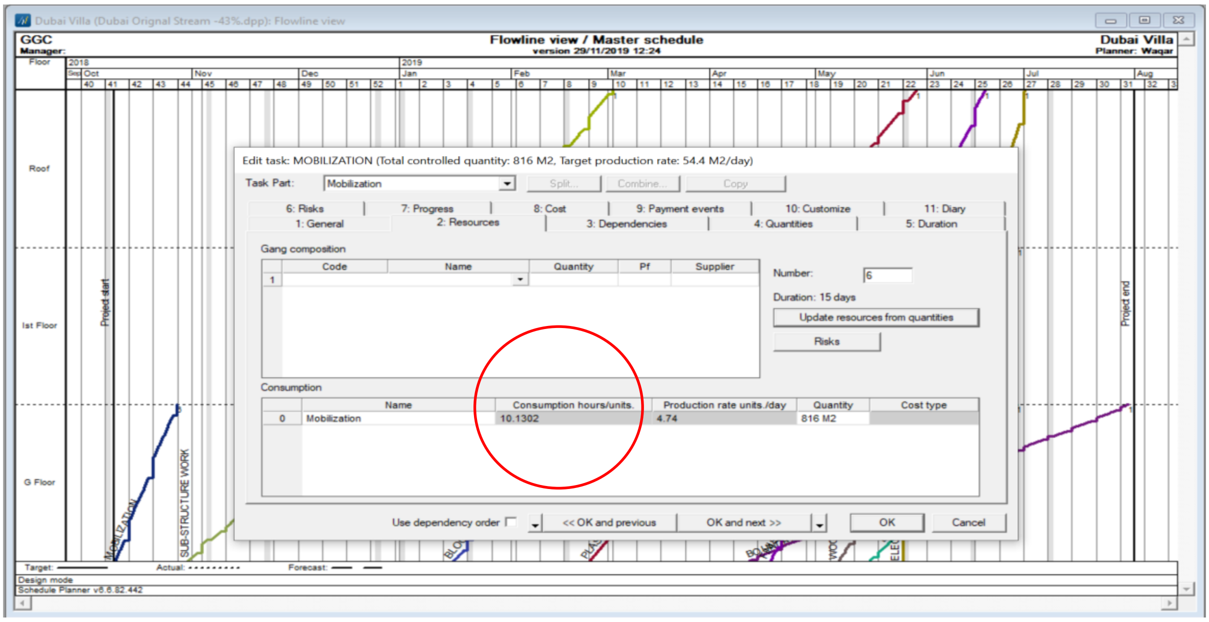


Figure 22: Insertion process of consumption hours/Unit

The specified process was repeated and change the consumption hours/unit for all the tasks with consumption hours/units calculated manually for the tasks. After changing the consumption hours/unit of the task, the production rate of the tasks either increase or decrease. But the aim is to keep the production rate constant as in the original stream.

But to reduce or increase the production rate, the number of resources or the production factor of labor, are required to change to keep the production rate according to the original stream. Whenever changes to the duration of the task are carried out following menu appears on the software, as shown in the figure below.

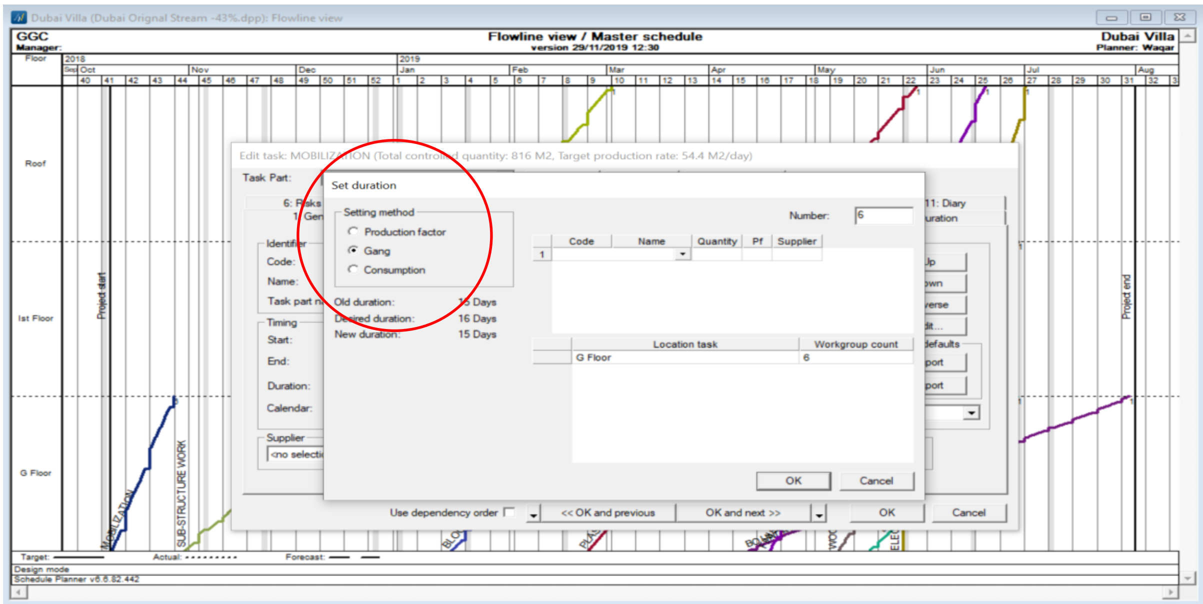
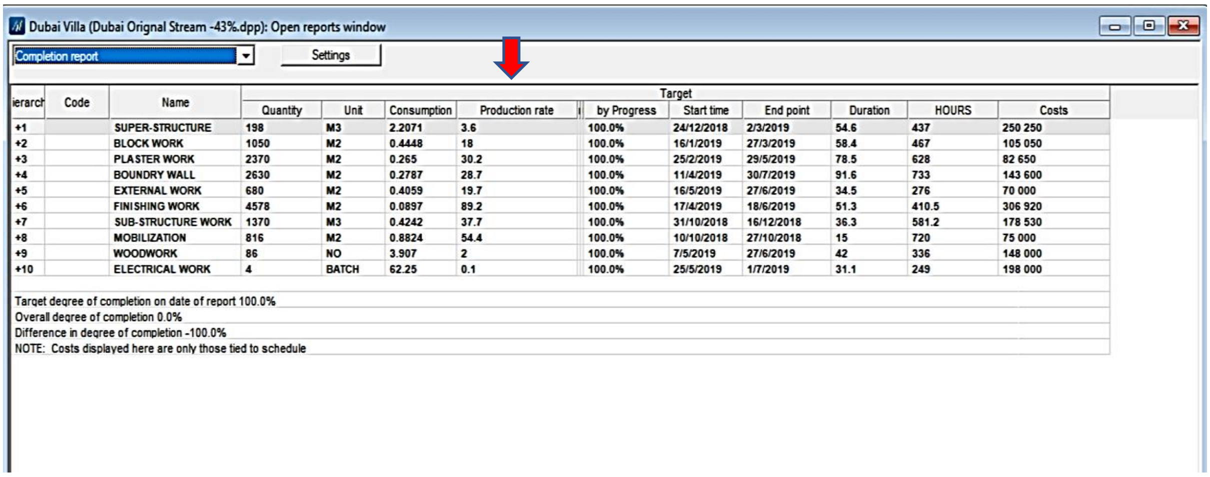


Figure 23: Changing menu in Vico Control Software

The software automatically gives the options when we try to make changes in the task; for instance, to finish an activity early, then the options appear how we want to change task duration, as we have to keep the consumption unit the same as calculated earlier. So we have to either change the production factor or the number of resources to speed up or to make activity slower by changing the resources or the production factor.

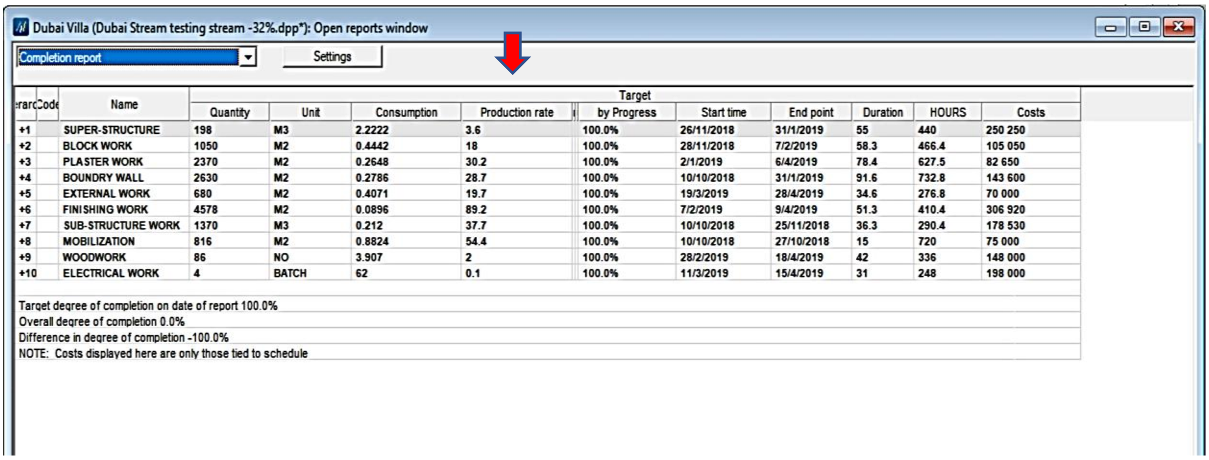
So, the only option to change the value stream is to change the resources or the production factor, which will automatically change the duration of the task. But, that will also change the production rate of the task, which we have to keep according to the production rate of the current value stream, as shown in figure # 20. The other option is to start the task earlier by eliminating the waiting time by dragging the activity to start early. In such a case, the production rate of the task will remain the same, and also the duration and resources will be the same as in the current value stream.


Dubai Villa (Dubai Orignal Stream -43%.dpp): Open reports window

Completion report | Settings

ierarch	Code	Name	Target									
			Quantity	Unit	Consumption	Production rate	by Progress	Start time	End point	Duration	HOURS	Costs
+1		SUPER-STRUCTURE	198	M3	2.2071	3.6	100.0%	24/12/2018	2/3/2019	54.6	437	250 250
+2		BLOCK WORK	1050	M2	0.4448	18	100.0%	16/1/2019	27/3/2019	58.4	467	105 050
+3		PLASTER WORK	2370	M2	0.265	30.2	100.0%	25/2/2019	29/5/2019	78.5	628	82 650
+4		BOUNDRY WALL	2630	M2	0.2787	28.7	100.0%	11/4/2019	30/7/2019	91.6	733	143 600
+5		EXTERNAL WORK	680	M2	0.4059	19.7	100.0%	16/5/2019	27/6/2019	34.5	276	70 000
+6		FINISHING WORK	4578	M2	0.0897	89.2	100.0%	17/4/2019	18/6/2019	51.3	410.5	306 920
+7		SUB-STRUCTURE WORK	1370	M3	0.4242	37.7	100.0%	31/10/2018	16/12/2018	36.3	581.2	178 530
+8		MOBILIZATION	816	M2	0.8824	54.4	100.0%	10/10/2018	27/10/2018	15	720	75 000
+9		WOODWORK	86	NO	3.907	2	100.0%	7/5/2019	27/6/2019	42	336	148 000
+10		ELECTRICAL WORK	4	BATCH	62.25	0.1	100.0%	25/5/2019	1/7/2019	31.1	249	198 000

Target degree of completion on date of report 100.0%
Overall degree of completion 0.0%
Difference in degree of completion -100.0%
NOTE: Costs displayed here are only those tied to schedule


Dubai Villa (Dubai Stream testing stream -32%.dpp*): Open reports window

Completion report | Settings

erarc	Code	Name	Target									
			Quantity	Unit	Consumption	Production rate	by Progress	Start time	End point	Duration	HOURS	Costs
+1		SUPER-STRUCTURE	198	M3	2.2222	3.6	100.0%	26/11/2018	31/1/2019	55	440	250 250
+2		BLOCK WORK	1050	M2	0.4442	18	100.0%	28/11/2018	7/2/2019	58.3	466.4	105 050
+3		PLASTER WORK	2370	M2	0.2648	30.2	100.0%	2/1/2019	6/4/2019	78.4	627.5	82 650
+4		BOUNDRY WALL	2630	M2	0.2786	28.7	100.0%	10/10/2018	31/1/2019	91.6	732.8	143 600
+5		EXTERNAL WORK	680	M2	0.4071	19.7	100.0%	19/3/2019	28/4/2019	34.6	276.8	70 000
+6		FINISHING WORK	4578	M2	0.0896	89.2	100.0%	7/2/2019	9/4/2019	51.3	410.4	306 920
+7		SUB-STRUCTURE WORK	1370	M3	0.212	37.7	100.0%	10/10/2018	25/11/2018	36.3	290.4	178 530
+8		MOBILIZATION	816	M2	0.8824	54.4	100.0%	10/10/2018	27/10/2018	15	720	75 000
+9		WOODWORK	86	NO	3.907	2	100.0%	28/2/2019	18/4/2019	42	336	148 000
+10		ELECTRICAL WORK	4	BATCH	62	0.1	100.0%	11/3/2019	15/4/2019	31	248	198 000

Target degree of completion on date of report 100.0%
Overall degree of completion 0.0%
Difference in degree of completion -100.0%
NOTE: Costs displayed here are only those tied to schedule

Figure 24: Production rate of Current & Future Value Stream

Figure# 24 shows the production rate of the current value stream and future value stream, which are kept constant in both the streams.

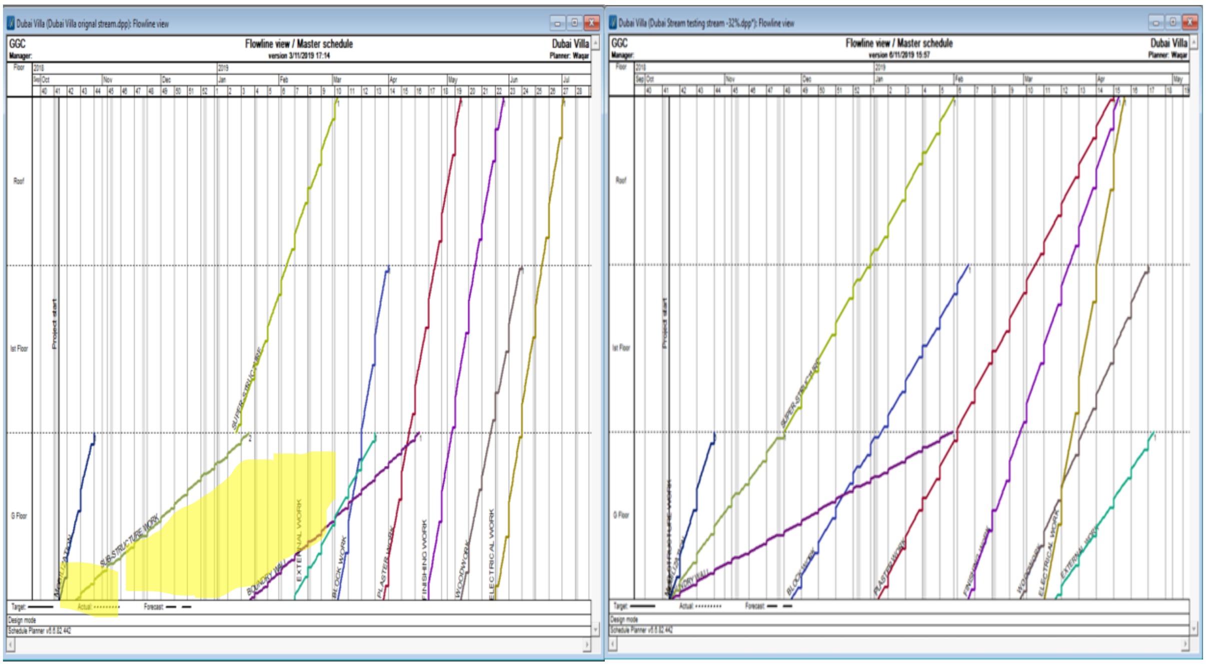


Figure 25: Current value stream waiting time and Future Value Stream Waiting time

Figure # 25 represent the current value stream of the project and the future value stream of the project by reducing or eliminating the waiting time to start another task. The waiting time in the future value stream is eliminated by arranging the activities to start earlier than the scheduled date. In this case, the production rate of the task remains the same as in the current stream, for instance, the sub-structure activity which starts after eight days of mobilization can be started the same date of mobilization to eliminate the waiting time, which cost money and time.

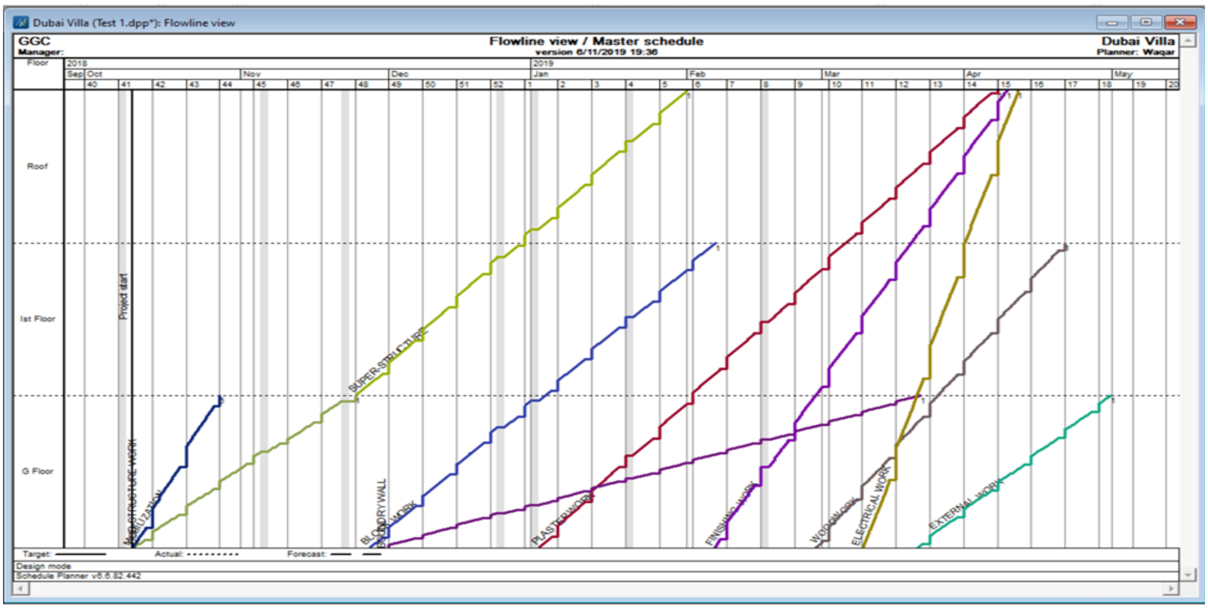


Figure 26: Future Value Stream test 1

Figure # 26 shows the test value stream developed after keeping the production rate constant as in the original schedule. The next step was to find out the clashes among the tasks and also an impact on the total cash-flow of the project after reducing eliminating the waste. The cash-flow developed for the future value stream shown in figure #26 was 63% in negative, which much more than the current value stream of the project.

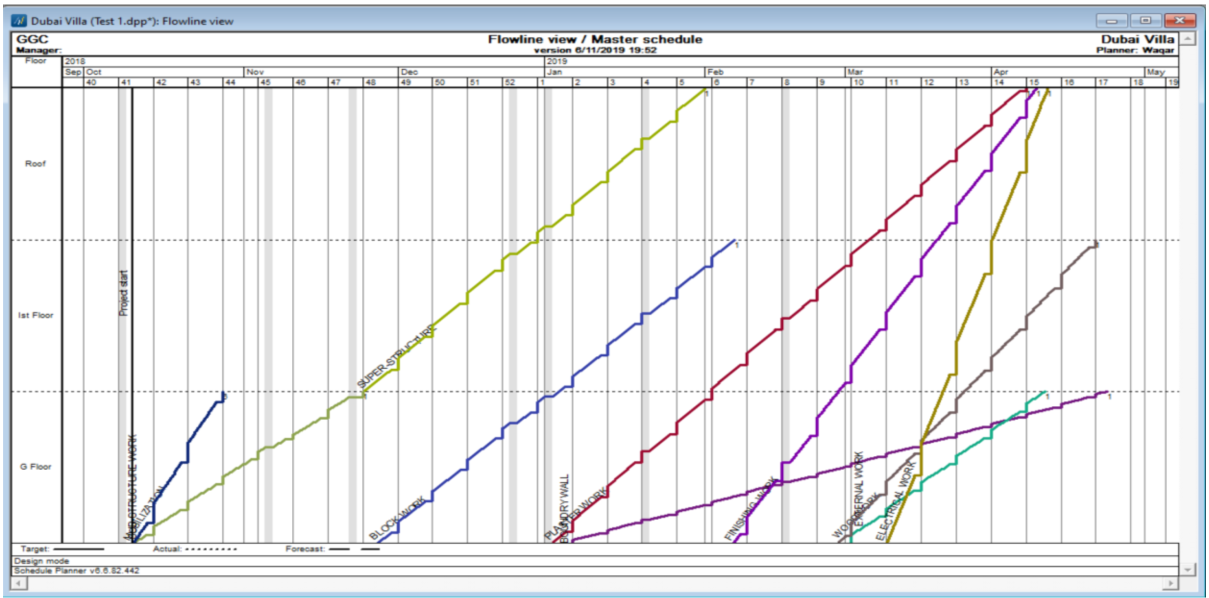


Figure 27: Future Value Stream test # 2

Similarly, another test future value stream of the project was developed to find the impact of the streaming on the total cash-flow of the project. Although the duration and the waiting time between the tasks were reduced, the impact on the cash-flow of the project was not very promising. Instead of improving the total cash-flow of the project, the performance of the cash-flow was still more negative than the total cash-flow of the current value stream. The cash-flow of the stream showed in figure # 27 was found out to be about 53% negative, which is 10% higher than the current stream although there are no clashes among the tasks.

Similarly, various test value stream was developed to find out the stream, which has a positive impact on the cash-flow of the project. After various tests on the value stream to find a positive impact on the cash-flow of the project, a stream was developed with a positive impact on cash-flow. Also, a positive impact on the elimination of waste in the form of waiting time and also reduced the duration of the project and no clashes among the tasks.

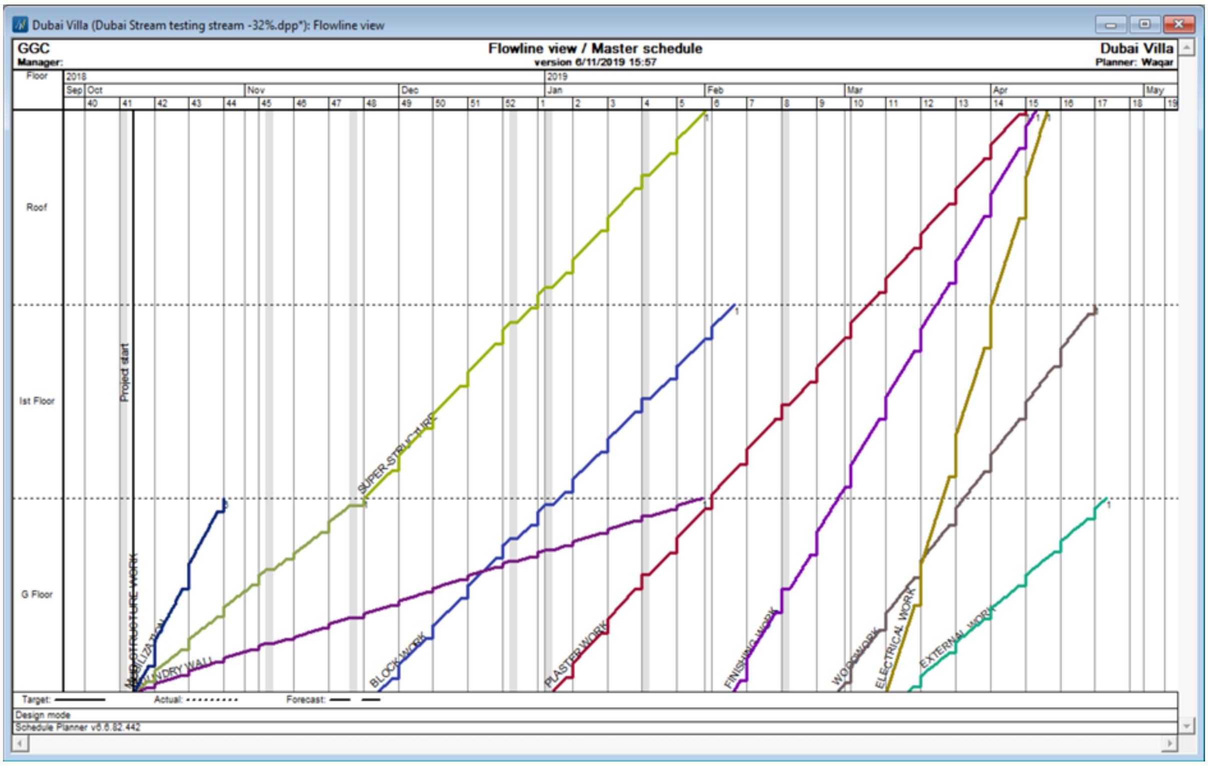


Figure 28: Final Future Value Stream of project

After a various test run of different value streams, a value stream with a positive impact on the cash-flow, wastes, and the duration of the project was developed, as shown in figure # 28. The total cash-flow of the project was found to be 32% in negative, which is about 11% less than the current value stream of the project.

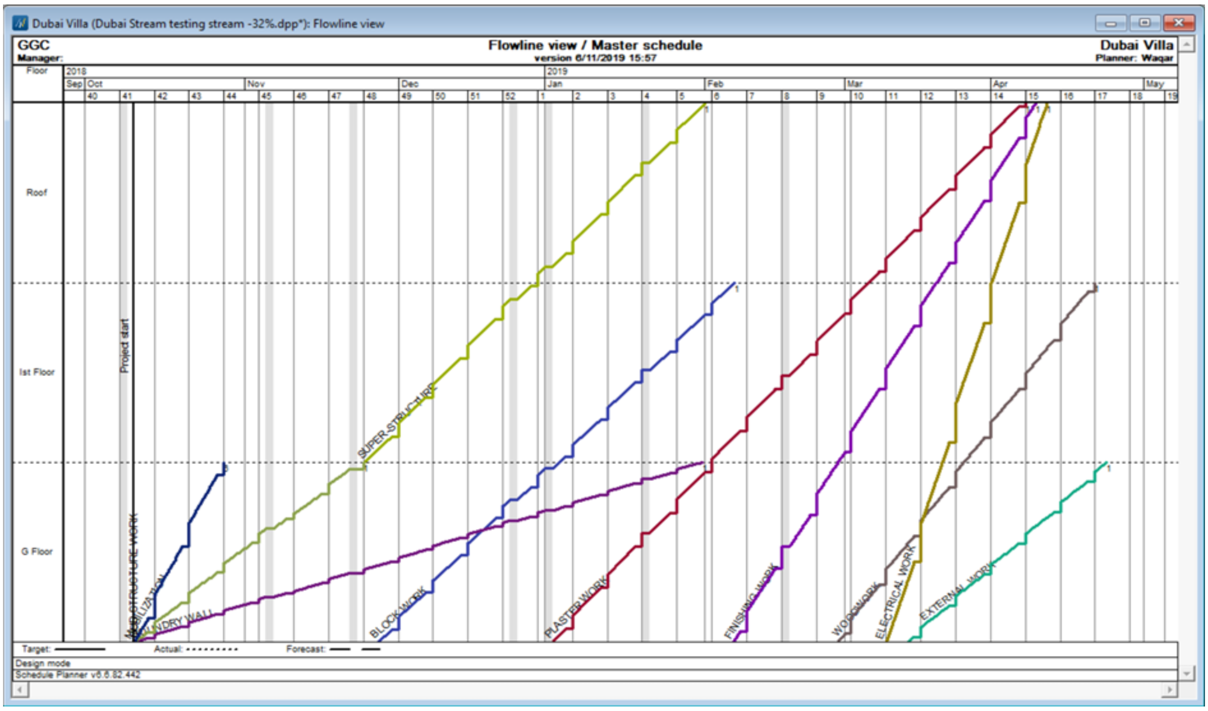


Figure 29: After Simulation of the FVS of Project

Later on, the simulation of the value stream was carried to find any possible clashes among the tasks. Figure # 29 above shows the simulation result; from the simulation, it is found out that there are no clashes among the task, although the waiting time between the task was reduced. Also, the duration of the project was significantly reduced.

	Current Stream			**Future Stream**		
Task	**Start**	**End**	**Waiting Time(Hr)**	**Start**	**End**	**Waiting Time**
Mobilization	10.10.2018	27.10.18	0	10.10.18	27.10	0
Substructure work	31.10.2018	16.12.18	168	10.10.18	25.11	0
Super-Structure Work	24.12.2018	2.03.19	48	26.11.18	31.01.19	0
Block Work	16.01.2019	27.03.19	600	28.11.19	7.02.19	376
Plaster Work	25.02.2019	29.05.19	320	2.01.109	6.04.19	32
Finishing Work	23.04.2019	16.06.19	448	7.02.19	9.04.19	40
Wood & Aluminium Work	11.05.2019	15.06.19	152	28.02.19	20.04.19	168
Electrical Work	21.05.2019	27.06.19	80	11.03.19	10.04.19	80
Boundary wall	11.04.2019	30.07.19	808	10.10.18	31.01.19	0
External works	16.05.2019	27.06.19	176	21.03.19	30.04.19	80
Waste (Hrs)	2800*20= 56,000.00 DEM			776*20= 15,520.00 DEM		

Table 9: The cost of waiting time in the current value stream

Table # 9 shows the total waste of waiting time between the tasks and their respective labor costs because, during this waiting time, the labors are doing nothing, but they cost money. The cost of waiting time was reduced by 27% in the future value stream of the project. Also, the waiting time within the value stream cause to increase the duration of the project.

The Future value stream was developed with the same production rate as the current value stream. All the waiting time between the task were eliminated or reduced to maximum level through a change in the sequence and dependencies from finish to start (FS) to start to start (SS) and arranged the sequence of the task in such a manner that tasks do not have any clashes with other tasks. This process reduces the duration of the project and makes it possible to finish the project earlier than the expected duration of the project.

Task	CVSM waiting time (Hrs)	FVSM waiting time (Hrs)
Mobilization	0	0
Substructure work	168	0
Super-Structure Work	48	0
Block Work	600	376
Plaster Work	320	32
Finishing Work	448	40
Wood & Aluminium Work	152	168
Electrical Work	80	80
Boundary wall	808	0
External works	176	80
Total Hours	**2800**	**776**
Cost of Waste	**56,000.00 DEM**	**15,520.00 DEM**

Table 10: Waiting Time in CVS & FVS and Their Cost

Table # 10 shows the waste of waiting time between the tasks and their respective costs. As earlier mentioned in UAE the per hour labor cost is between 15-25 Dirham/ Hour which is about 8$/Hr (Shahidullah, 2013). This waiting time is the time during which only one task is under observation. This waiting time between the task cost money because the labors and other resources costing capital, and they have nothing to carry out. The waste of waiting time in the future value stream was reduced by 27% as compared to the current value stream of the project.

The future value stream of the project was developed after removing the above-mentioned extra waiting time between the task, which costing capital and also time.

Value streaming has shown a significant impact on reducing the waste of waiting and the duration of the project. The value streaming has reduced the duration of the project by three months, which is about 90 days. The duration of the project was reduced to seven months (7 months), which was earlier about ten months (10).

Tasks	**Current Value Stream Duration**		**Future Value Stream Duration**	
Mobilization	15 days	120 Hours	15 days	120 Hours
Substructure work	36.3 days	296 Hours	36.3 days	290.4 Hours
Super-Structure Work	54.6 days	440 Hours	55 days	440 Hours
Block Work	58.4 days	464 Hours	58.3 days	464 Hours
Plaster Work	78.5 days	632 Hours	78.4 days	624 Hours
Finishing Work	51.3 days	352 Hours	51.3 days	408 Hours
Wood & Aluminium Work	42 days	224 Hours	42 days	352 Hours
Electrical Work	31.1 days	248 Hours	31 days	216 Hours
Boundary wall	91.6 days	736 Hours	91.6 days	736 Hours
External works	34.5 days	280 Hours	35.5 days	280 Hours
Total Duration of Project	**290 days**		**198 days**	

Table 11: Duration of Tasks Before and After Value Streaming

Table # 11 shows the reduction in the reduction in the total duration of the project. Although the change in the duration of the tasks, after the change in the consumption hours/Unit, was not very significant, the duration of the project was reduced by 68% owing to the early start of the activities and change in the sequence of tasks. The future value stream was developed after eliminating all the non-vale adding durations. The next step was to check the total cashflow curve, whether the value stream has a positive impact or a negative impact on the total cashflow of the project

After developing the future state map of the project, the total cash-flow of the project was calculated to find out the impact of value streaming on the cash-flow of the project.

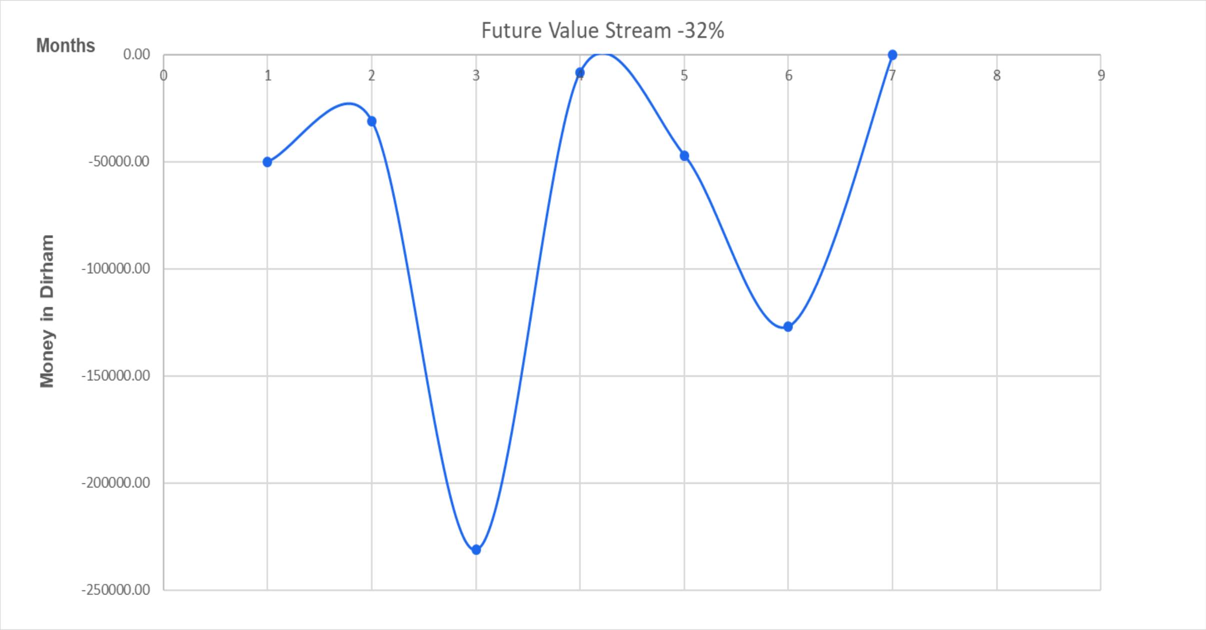


Figure 30: Future Value Stream Cash-flow Pattern

Figure # 30 shows the total cash-flow of the future value stream; although the cash-flow is negative, the value stream has shown a positive impact on the cash-flow with at least some improvement. The cash-flow of the project improved by 11%, which means the cash-flow of the project in the future value stream is 32% negative, which is 11% less than the current value stream having 43% negative cash-flow.

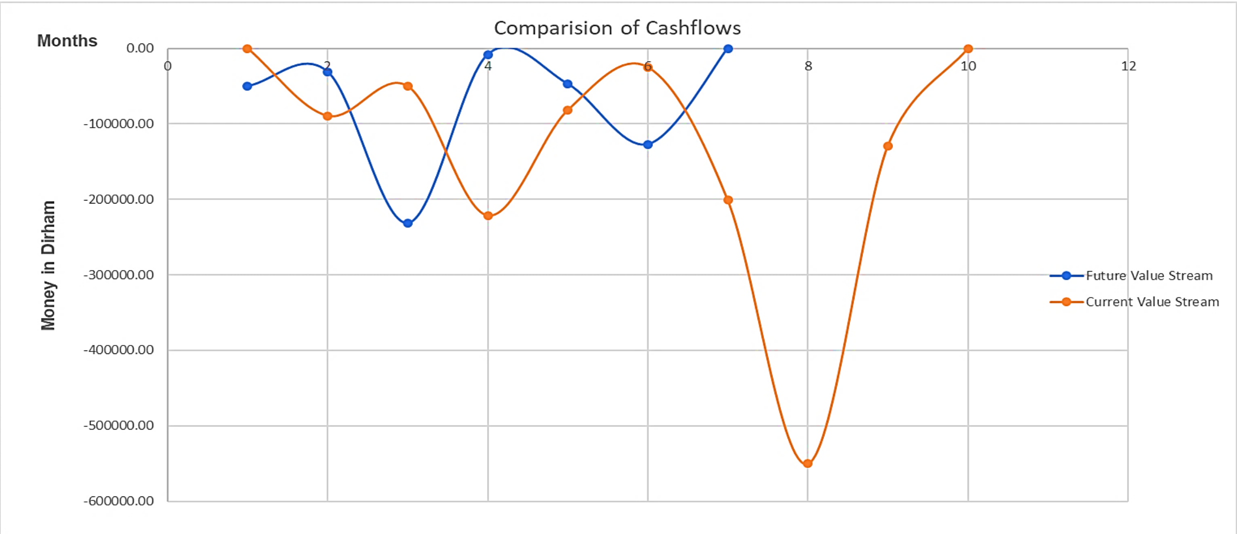


Figure 31: Cash-flow Comparison of Current and Future Value Stream

Figure # 31 show the pattern of total cash-flow of the current value stream with 43% negative and the future value stream with 32% negative. Additionally, the value stream also showed a positive impact on the duration of the project by reducing the duration of the whole project from 10 months to 7 months.

4.2. Pakistan

The study is carried out on the already constructed single-family houses in DHA Phase II, Islamabad, Pakistan. The project is financed by the UAE's most renowned company, Emaar, a Dubai based real estate development company. Habib Rafiq. Pvt. Ltd. (HRL) was the main contractor responsible for the construction of the buildings and relevant infrastructure.

4.2.1. Case Description

The project for the case study is located in Islamabad, Pakistan. The building is a single-family house with two floors, with a covered area of 285 sqm. The building is a frame structure with partition walls constructed off solid cement blockwork. The project was completed and was built in 2015-16, with a construction cost of about 15 million Pakistani Rupees (PKR). The project is a G+1 building, having a ground floor and first floor. The building is majorly an RCC building and with partition walls of solid concrete block. The total expected construction period of the building project was 11 months.

The project was selected based on the availability of data, and also the project was conventionally planned without considering the factors of wastes that can have possibly affected the project cost, duration, and, ultimately, the total cash-flow of the project.

4.2.2. Case Analysis

To understand the impact of lean on the construction project, it is important and significant to implement the LC principles on a real construction project. For analysis of the impact of value streaming on the construction project, data of the project is required. So the first step of analyzing the case study is the collection of data of the project under observation.

Data Collection

All the required data for analyzing the project like BOQ, work schedule, and other related detail of the project were collected. All the data related to the project was acquired with the help of a friend working in a company. The table shows the general detail of the project.

No	Subject	Data
1.	Project name	Mirador Villa
2.	Project Category	Single Family House
3.	Project Location	Islamabad, Pakistan
4.	Total Project Built Area	285 sqm
5.	Area of Ground Floor	120 sqm
6.	Area of First Floor	105 sqm
7.	Area of Roof	61 sqm
8.	Start Date	3-08-2015
9.	Finish Date	30-06-2016
10.	Total Project Duration	11 months
11.	Duration of Contract	12 months
12.	Total Project Cost	15,172,775.00 PKR
13.	Project Owner	Emmar, Pakistan
14.	Project Contractor	HRL

Table 12: General Detail of Pakistani Villa Project

Table #12 shows the general detail of the project, including the total built area and the floor area of the project. Also, the table shows the total cost of the project and also the duration of the project and year of construction. The schedule of this project is developed conventionally by using the MS Project software. The schedule was developed without considering the waiting time waste in the value stream. The majority of the activities are planned finished to start, and some are scheduled as a start to start. The project was developed in the Vico control schedule planner with the same milestone tasks and with the same dependencies and same dates to see the waste of waiting time between the tasks, which is normally not possible to see in the MS Project schedule. The original schedule of the project is attached in Appendix B.

No	Milestones	Percentage Cost (PKR)	Construction Cost
1.	MOBILIZATION	9%	1 422 525
2.	SUBSTRUCTURE WORK	14%	2 162 500
3.	SUPERSTRUCTURE WORK	18%	2 390 000
4.	BLOCK WORK	3%	507 000
5.	PLASTER WORK	7%	1 038 000
6.	WATERPROOFING WORK	2%	330 000
7.	PAINT WORK	6%	944 000
8.	WOOD & ALUMINUM WORK	2%	285 650
9.	MEP WORK	12%	1 901 000
10.	FINISHING WORK	13%	2 073 100
11.	EXTERNAL WORKS	14%	2 119 000
	Total	**100%**	**15,172,775.00PKR**

Table 13: Milestones of Pakistani Villa and Construction cost of each Milestone

Table #13 show the total construction cost of the project, and the cost fixed for each milestone was found out from the BOQ of the construction project. Each milestone of the project has a specified percentage of the total construction cost which was calculated from BOQ. The BOQ and the schedule of the project can be seen in Appendix B.

No	Task	Construction Cost (PKR)	Labor Cost (40%)
1.	MOBILIZATION	1 422 525	569,010.00
2.	SUBSTRUCTURE WORK	2 162 500	865,000.00
3.	SUPER STRUCTURE WORK	2 390 000	956,000.00
4.	BLOCK WORK	507 000	202,800.00
5.	PLASTER WORK	1 038 000	415,200.00
6.	WATER PROOFING WORK	330 000	132,000.00
7.	PAINT WORK	944 000	377,600.00
8.	WOOD & ALUMINUM WORK	285 650	114,260.00
9.	MEP WORK	1 901 000	760,400.00
10.	FINISHING WORK	2 073 100	829,240.00
11.	EXTERNAL WORKS	2 119 000	847,600.00
	Total Cost	**15,172,775.00 PKR**	**6,069,110.00 PKR**

Table 14: Total Construction cost and the Labor Cost

Table # 14 shows the total construction cost of each task and the labor cost of each task. The hard cost of the project in Pakistan is considered to be between 60-70%, and the labor cost is about 30-40%, and 10% is considered overhead. Compare to other developed countries, the less percentage of labor cost in Pakistan is considered due to a high population in the country (Muzamil and Khurshid, 2014). To find the percentage of labor cost, an assumption was made to keep the labor cost for the project at 40% to calculate the total labor cost for each task.

Analysis of Case Study

The analysis of the case study was started with the development of the construction schedule of the project in Vico Control Schedule Planner software, which is called the current value stream of the project. A similar process was adopted in the case study as the process was carried out in the case study of the Dubai project.

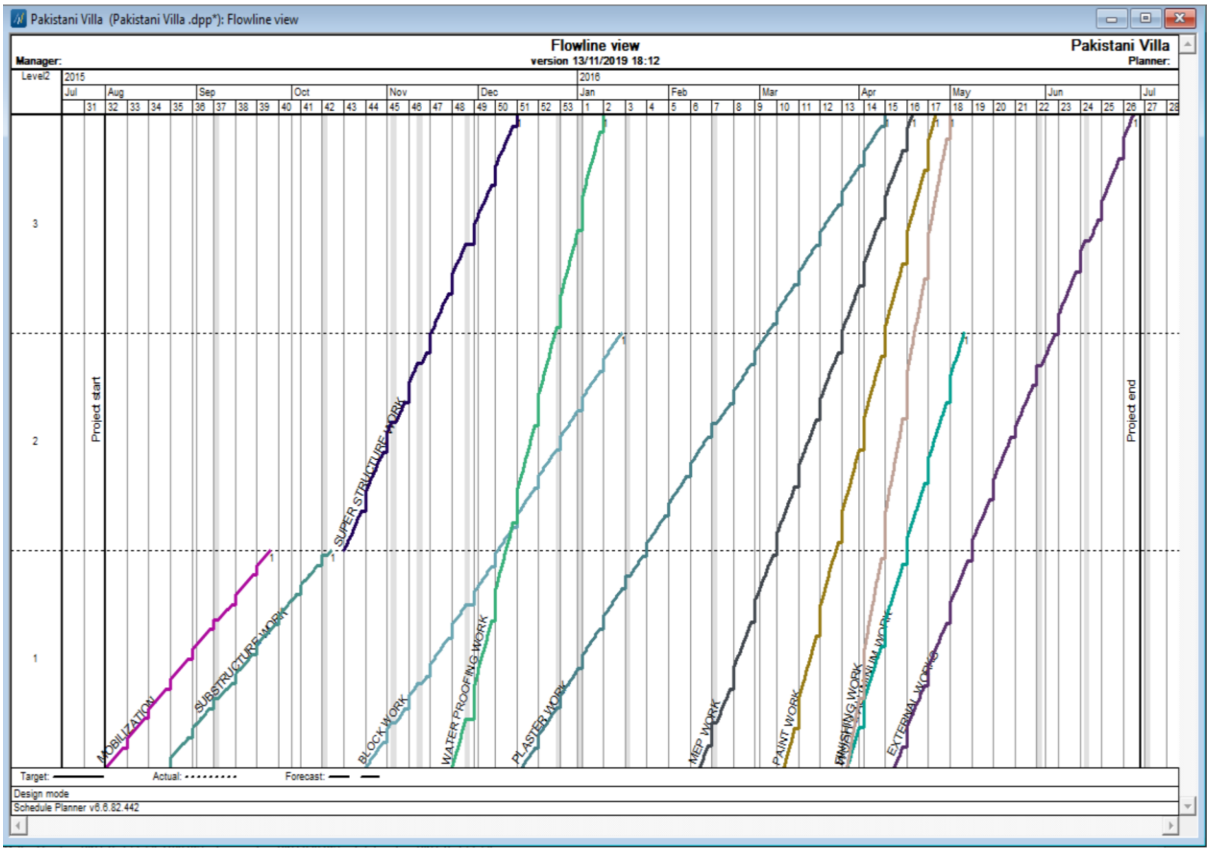


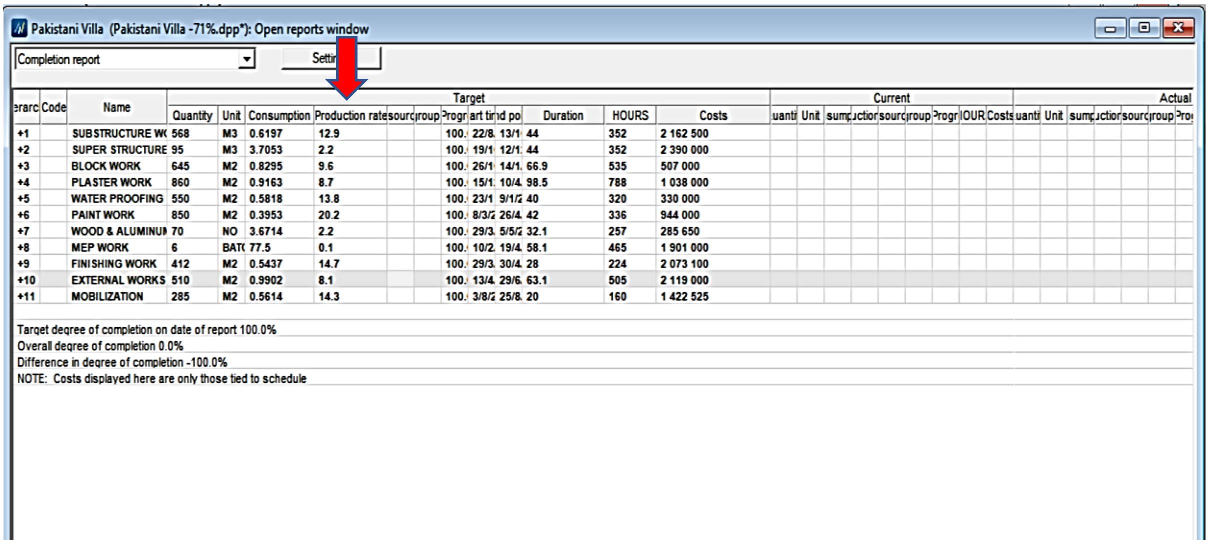
Figure 32: Current Value Stream of Pakistani Villa (Own Work)

Figure # 32 represents the Current Value Stream of the project in Pakistan, which was developed with a conventional method without considering the aspect of waste of waiting time between the tasks. The simulation of the CVS was carried out to find any possible clashes among the tasks, but due to a huge amount of waste of waiting time among the tasks, no clashes were found between the tasks.

Tasks	Lbr Cost (40%)	St.Date	F.Date	Duration (days)	Qt
MOBILIZATION	569,010.00	3/8/2015	25/8/2015	20	285m^2
SUBSTRUCTURE WORK	865,000.00	22/8/2015	13/10/2015	44	568 m^3
SUPER STRUCTURE WORK	956,000.00	19/10/2015	12/12/2015	44	95 m^3
BLOCK WORK	02,800.00	26/10/2015	14/1/2016	67	645 m^2
PLASTER WORK	415,200.00	15/12/2015	10/4/2016	99	860 m^2
WATERPROOFING WORK	32,000.00	23/11/2015	9/1/2016	40	550 m^2
PAINT WORK	377,600.00	8/3/2016	26/4/2016	42	850 m^2
WOOD & ALUMINUM WORK	114,260.00	29/3/2016	5/5/2016	32	70 NO
MEP WORK	760,400.00	10/2/2016	19/4/2016	58	6 batch
FINISHING WORK	829,240.00	29/3/2016	30/4/2016	28	412 m^2
EXTERNAL WORKS	847,600.00	13/4/2016	29/6/2016	63	510 m^2

Table 15: Detail of the Current Value Stream of the Pakistani Project

Table # 15 shows the 40% labor cost of each task, the duration of the tasks, and their required start date and finish date. The table also shows the quantities of each task and the number of days required to complete each task. All the detail were obtained after developing the current value stream in Vico Schedule Planner software to visualize the clashes between the tasks and the waste of waiting time between the tasks.



Pakistani Villa (Pakistani Villa -71%.dpp*): Open reports window

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erarc	Code	Name	Quantity	Unit	Consumption	Production rate	sourc	roup	Progr	art tir	nd po	Duration	HOURS	Costs
+1		SUBSTRUCTURE W(	568	M3	0.6197	12.9			100.(	22/8.	13/1(	44	352	2 162 500
+2		SUPER STRUCTURE	95	M3	3.7053	2.2			100.(	19/1(	12/1.	44	352	2 390 000
+3		BLOCK WORK	645	M2	0.8295	9.6			100.(	26/1(	14/1.	66.9	535	507 000
+4		PLASTER WORK	860	M2	0.9163	8.7			100.(	15/1.	10/4.	98.5	788	1 038 000
+5		WATER PROOFING	550	M2	0.5818	13.8			100.(	23/1	9/1/2	40	320	330 000
+6		PAINT WORK	850	M2	0.3953	20.2			100.(	8/3/2	26/4.	42	336	944 000
+7		WOOD & ALUMINUI	70	NO	3.6714	2.2			100.(	29/3.	5/5/2	32.1	257	285 650
+8		MEP WORK	6	BAT(	77.5	0.1			100.(	10/2.	19/4.	58.1	465	1 901 000
+9		FINISHING WORK	412	M2	0.5437	14.7			100.(	29/3.	30/4.	28	224	2 073 100
+10		EXTERNAL WORKS	510	M2	0.9902	8.1			100.(	13/4.	29/6.	63.1	505	2 119 000
+11		MOBILIZATION	285	M2	0.5614	14.3			100.(	3/8/2	25/8.	20	160	1 422 525

Target degree of completion on date of report 100.0%
Overall degree of completion 0.0%
Difference in degree of completion -100.0%
NOTE: Costs displayed here are only those tied to schedule

Figure 33: The Production Rate of the CVS (Own Work)

Figure #33 shows the entire detail of the project along with the production rate of the current value stream (CVS) of each task, which would be used as a cornerstone for developing the future value stream of the project.

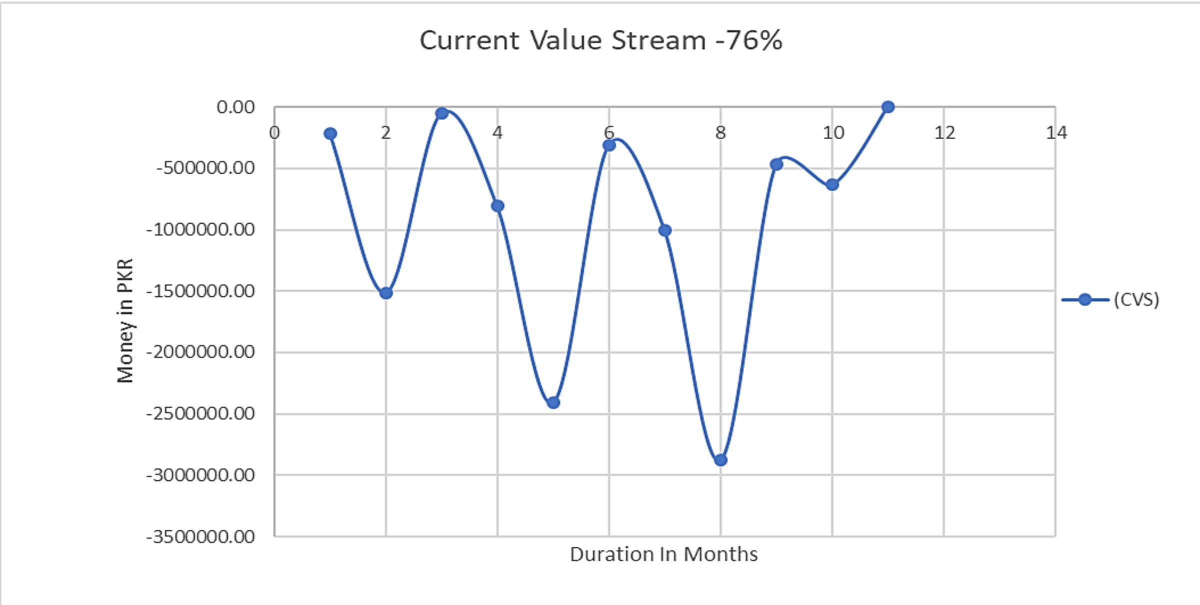


Figure 34: The Total Cash-flow Curve of the CVS of the Project

Figure # 34 shows the total cash-flow curve of the project, which is about 76% negative. The cash-flow was developed from the Current Value Stream (CVS) of the project, which was developed in the Vico Control Schedule Planner.

Tasks	Lbr Cost	Qty	Hours	Cost/Hr	Lab Req	Hr/Unit
MOBILIZATION	569,010.00	285m^2	160	75PKR	47	26.6
SUBSTRUCTURE WORK	865,000.00	568m^3	352	75PKR	33	20.3
SUPER STRUCTURE WORK	956,000.00	95m^3	352	75PKR	36	134.2
BLOCK WORK	202,800.00	645m^2	536	75PKR	5	4.2
PLASTER WORK	415,200.00	860m^2	788	75PKR	7	6.4
WATER PROOFING WORK	132,000.00	550 m^2	320	75PKR	6	3.2
PAINT WORK	377,600.00	850 m^2	336	75PKR	15	5.9
WOOD & ALUMINUM WORK	114,260.00	70 No	257	75PKR	6	21.8
MEP WORK	760,400.00	6 Batch	465	75PKR	22	1689.8
FINISHING WORK	829,240.00	412 m^2	224	75PKR	49	26.8
EXTERNAL WORKS	847,600.00	510 m^2	505	75PKR	22	22.2

Table 16: Consumption Hours/ Unit and No of Labor Calculation

Table # 16 shows the number of labors required to carry out each task and the consumption hours required per unit of the task. All these calculations are carried out exactly as carried for the last case study of UAE through using equation #1 and #2. In Pakistan, labor cost per hour is about 60-80 PKR/Hour; this cost is for unskilled labor (Muzamil and Khurshid, 2014). The rest of the calculation was carried using the same procedure used for the Dubai case study.

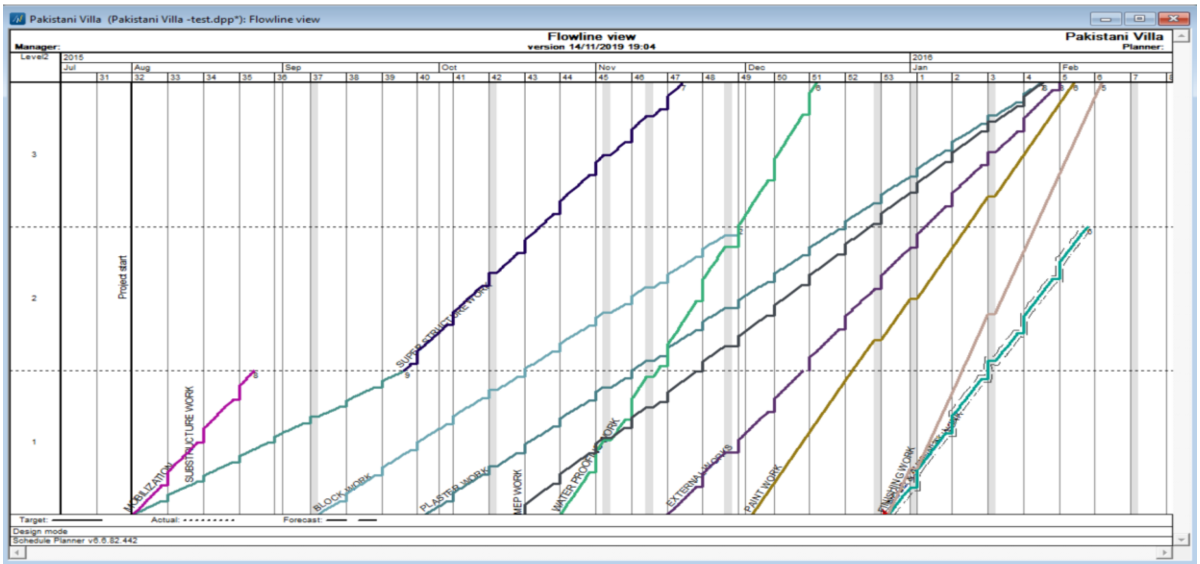


Figure 35: Future Value Stream (FVS) of Pakistani Villa

Figure # 35 shows the FVS of the villa project in Pakistan, which was developed after changing the consumption hours/unit in the same way as explained in the previous case study. Also, the sequences of the activities and the dependencies of some tasks are changed to eliminate the waiting time between the tasks and also reduce the duration of the project. Later on, simulation of the future value stream (FVS) was carried out to find possible clashes among the tasks; the simulation showed that no clashes were expected among the task.

Pakistani Villa (Pakistani Villa -71%.dpp*): Open reports window

Completion report — Settings

erarc	Code	Name	Quantity	Unit	Consumption	Production rate	sourc	roup	by Progress	Start time	End point	Duration	HOURS	Costs
+1		SUBSTRUCTURE W(	568	M3	0.6197	12.9			100.0%	22/8/2015	13/10/2015	44	352	2 162 500
+2		SUPER STRUCTURE	95	M3	3.7053	2.2			100.0%	19/10/2015	12/12/2015	44	352	2 390 000
+3		BLOCK WORK	645	M2	0.8295	9.6			100.0%	26/10/2015	14/1/2016	66.9	535	507 000
+4		PLASTER WORK	860	M2	0.9163	8.7			100.0%	15/12/2015	10/4/2016	98.5	788	1 038 000
+5		WATER PROOFING	550	M2	0.5818	13.8			100.0%	23/11/2015	9/1/2016	40	320	330 000
+6		PAINT WORK	850	M2	0.3953	20.2			100.0%	8/3/2016	26/4/2016	42	336	944 000
+7		WOOD & ALUMINUI	70	NO	3.6714	2.2			100.0%	29/3/2016	5/5/2016	32.1	257	285 650
+8		MEP WORK	6	BAT(	77.5	0.1			100.0%	10/2/2016	19/4/2016	58.1	465	1 901 000
+9		FINISHING WORK	412	M2	0.5437	14.7			100.0%	29/3/2016	30/4/2016	28	224	2 073 100
+10		EXTERNAL WORKS	510	M2	0.9902	8.1			100.0%	13/4/2016	29/6/2016	63.1	505	2 119 000
+11		MOBILIZATION	285	M2	0.5614	14.3			100.0%	3/8/2015	25/8/2015	20	160	1 422 525

Target degree of completion on date of report 100.0%
Overall degree of completion 0.0%
Difference in degree of completion -100.0%
NOTE: Costs displayed here are only those tied to schedule

Pakistani Villa (Pakistani Villa -test.dpp*): Open reports window

Completion report — Settings

erarc	Code	Name	Quantity	Unit	Consumption	Production rate	sourc	roup	by Progress	Start time	End point	Duration	HOURS	Costs
+1		SUBSTRUCTURE W(	568	M3	22.355	12.9	G. L:	9	100.0%	3/8/2015	24/9/2015	44.1	12697.7	2 162 500
+2		SUPER STRUCTURE	95	M3	103.7473	2.2	Skill	7	100.0%	24/9/2015	17/11/2015	44	9856	2 390 000
+3		BLOCK WORK	645	M2	3.324	9.6	Skill	2	100.0%	8/9/2015	29/11/2015	67	2144	507 000
+4		PLASTER WORK	860	M2	6.4025	8.7	G. L:	7	100.0%	29/9/2015	27/1/2016	98.3	5506.1	1 038 000
+5		WATER PROOFING	550	M2	3.4739	13.8	Skill	6	100.0%	26/10/2015	14/12/2015	39.8	1910.6	330 000
+6		PAINT WORK	850	M2	11.8588	20.2	Pain	6	100.0%	2/12/2015	2/2/2016	42	10080	944 000
+7		WOOD & ALUMINUI	70	NO	21.8	2.2			100.0%	29/12/2015	4/2/2016	31.8	1526	285 650
+8		MEP WORK	6	BAT(	4506.1333	0.1	Skill	8	100.0%	17/10/2015	27/1/2016	84.5	27036.8	1 901 000
+9		FINISHING WORK	412	M2	18.9838	14.7	G. L:	5	100.0%	29/12/2015	8/2/2016	27.9	7821.3	2 073 100
+10		EXTERNAL WORKS	510	M2	11.8588	8.1	Skill	3	100.0%	16/11/2015	30/1/2016	63	6048	2 119 000
+11		MOBILIZATION	285	M2	17.9649	14.3	G. L:	8	100.0%	3/8/2015	25/8/2015	20	5120	1 422 525

Target degree of completion on date of report 100.0%
Overall degree of completion 0.0%
Difference in degree of completion -100.0%
NOTE: Costs displayed here are only those tied to schedule

Figure 36: Production Rate of CVS & FVS of Project

Figure # 36 shows the production rate of the project before and after the value streaming. The production rate was kept constant by only make changes in the sequence, resources, production factor of labor, and also by changing the start and finish date of the task by moving the task to start early, compared to the current value stream. This early start and early finish process had ultimately reduced the duration of the project.

	Current Stream			**Future Stream**		
Task	**Start**	**End**	**Waiting Time (Hr)**	**Start**	**End**	**Waiting Time**
Mobilization	3.08.2015	25.08.15	0	3.08.2015	25.08.15	0
Substructure Work	22.08.2015	13.1.15	120	03.08.2015	24.09.15	0
Super-Structure Work	19.10.2015	12.12.15	400	24.09.2015	17.11.15	0
Block Work	26.10.2015	14.01.16	440	08.09.15	29.11.15	240
Plaster Work	15.12.2015	10.04.16	352	29.09.15	27.01.16	136
Water Proofing Work	23.11.2015	09.01.16	192	26.10.15	14.12.15	200
Paint Work	8.03.2016	24.04.16	568	2.12.15	2.02.16	432
Wood & Aluminium Work	29.03.2016	5.05.16	736	29.12.15	4.02.16	624
MEP Work	10.02.2016	19.04.16	400	17.10.15	27.01.16	136
Finishing Work	29.03.2016	30.04.16	736	29.12.15	8.02.16	648
External Works	13.04.2016	29.06.16	800	16.11.15	25.08.15	160
Waiting Cost	**4744*75= 355,800 PKR**			**2576*75= 193,200 PKR**		

Table 17: Waiting Time in CVS & FVS of the project

Table # 17 shows the quantity of the waiting time between the tasks in the current value stream and the future value stream of the project. Also, it shows the start dates and finishes dates of the task in CVS and in FVS and total cost of the waiting time before value streaming and the cost after value streaming, which is significantly reduced in FVS compared to CVS. The waiting time in the FVS was reduced by about 54% compare to CVS of the project.

Task	CVS waiting time (Hrs)	FVS waiting time (Hrs)
Mobilization	0	0
Substructure Work	120	0
Super-Structure Work	400	0
Block Work	440	240
Plaster Work	352	136
Water Proofing Work	192	200
Paint Work	568	432
Wood & Aluminium Work	736	624
MEP Work	400	136
Finishing Work	736	648
External Works	800	160
Total Hours	**4744**	**2576**
Cost of Waste	**355,800 PKR**	**193,200 PKR**

Table 18: The Waste of Waiting Time in CVS & FVS and Respective Cost

Table #18 shows the total cost of the waiting time between the tasks before value streaming and after value streaming.

Tasks	Current Value Stream Duration		Future Value Stream Duration	
Mobilization	20	160 Hours	20 days	120 Hours
Substructure Work	44	352 Hours	44.1	352.8 Hours
Super-Structure Work	44	352 Hours	44	352 Hours
Block Work	67	536 Hours	67	536 Hours
Plaster Work	99	792 Hours	98.3	786.4 Hours
Water Proofing Work	40	320 Hours	39.8	318.4 Hours
Paint Work	42	336 Hours	42	336 Hours
Wood & Aluminium Work	32	256 Hours	31.8	254.4 Hours
MEP Work	58	464 Hours	84.5	676 Hours
Finishing Work	28	224 Hours	27.9	223.2 Hours
External Works	63	504 Hours	63	504 Hours
Total Duration of Project	**285 days**		**190 days**	

Table 19: Duration of the Project in CVS and FVS of the Project

Table # 19 shows the duration of the task before and after the lean application principle. Although there is a small change in the hours of some of the tasks, the duration of the project was reduced significantly due to the early start and early finish of the tasks. Also, the table shows how much the duration of the project is reduced after the elimination of the waiting time between the tasks. The duration of the project was reduced by 66% in the future value stream, after elimination or reduction of waiting time between the tasks, through the early start of tasks and early finish of tasks in the stream.

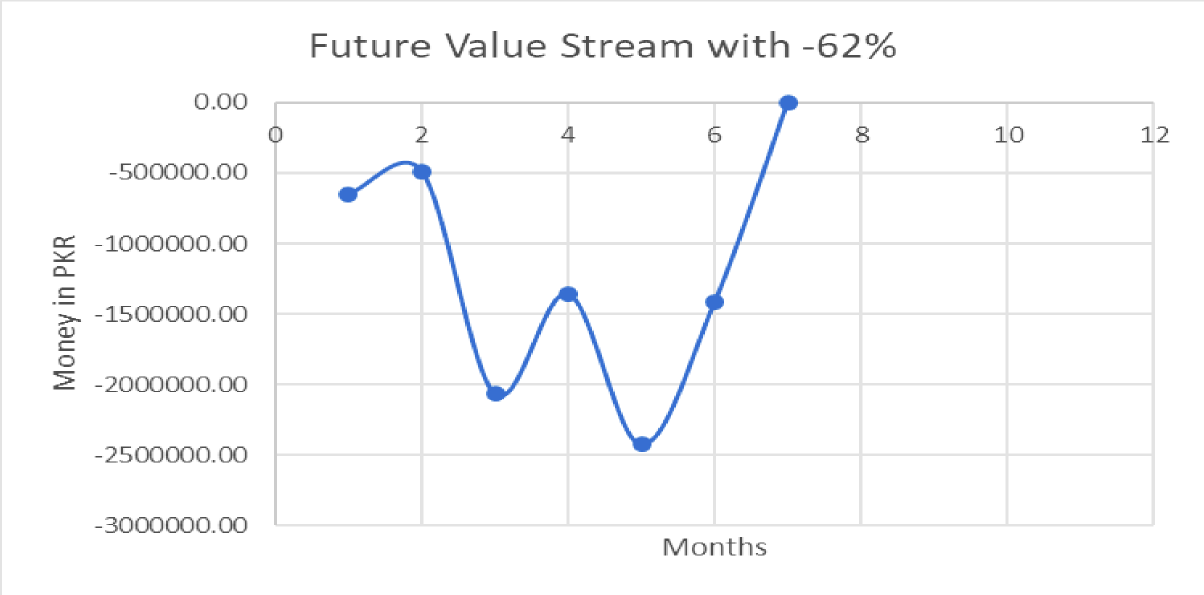


Figure 37: The Total Cash-flow Curve of the Future Value Stream. (Own Work)

Figure # 37 represent the total cash-flow curve of the future value stream after removing the majority of the waste and change of the sequence of the tasks. The figure shows that the total cash-flow of the FVS is 62% negative, which has improved by 14% after removing the waste of waiting time and the early start of activities compared to the current value stream of the project.

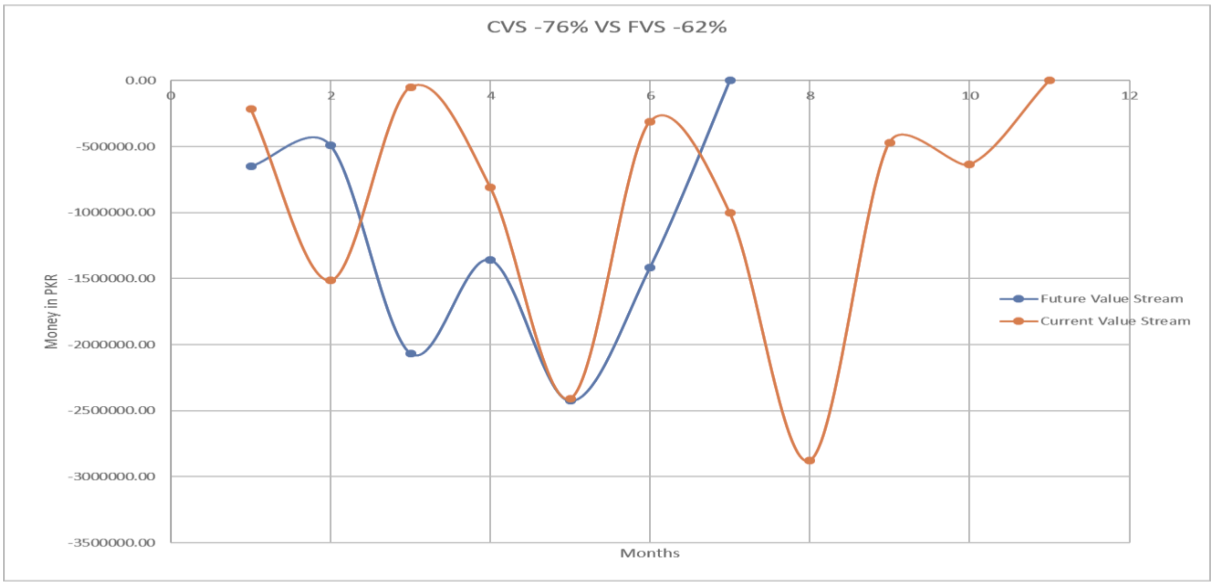


Figure 38: Cash-Flow Comparison of CVS and FVS of the Project

Figure # 38 shows the total cash-flow of the project before value streaming and after value streaming. The value stream has shown a positive impact on the total cash-flow of the project. The total cash-flow of the project improved by 14% in the future value stream after the elimination of a significant portion of the waste of waiting time. The total cash-flow of the current value stream was about 76% negative, while the future value stream had cash-flow of about 62% negative.

4.3. Case Studies Conclusion

The value streaming of construction projects had shown positive results in the form of waiting time waste reduction and also a positive impact on the total cash-flow of the projects. Also, the development of the value stream in Vico Control software has the character to practically visualize the waiting time between the task, which is normally not possible to access with conventional project planning with Primavera or the MS project.

The visualization of the value stream of the UAE project has helped to identify the waste of waiting time between the tasks, which was reduced by 27% in the future value stream of the project. Additionally, the reduction of waste of waiting time has reduced the cost of labor by 27%. The reduction or elimination of the waiting time and the early start of activities has positively reduced the duration of the project by 68%. The reduction in the duration of the project has also improved the total cash-flow of the project by 11%, improving the cash-flow from negative 43% to negative 32%.

Similarly, the Pakistani project also showed positive results with the implementation of the VSM lean principle on the project. The waste of waiting time is reduced by 54%, and also the cost of waiting time was reduced by 54%. The duration of the project was reduced by 66% due to the early start and early finish of the tasks. The total cash-flow of the project was improved by 14% from negative 76% to negative 62% in the FVS of the project.

From the studies, it is found out that Value Stream Mapping (VSM) has a positive impact on the duration, waste of waiting time, and the total cash-flow of the project. It is significant to implement the VSM on the construction project to enhance the performance of the project in the form of waste reduction of waiting time, duration of the project, and the cash-flow improvement of the projects.

5. Survey

5.1. Questionnaire Survey for Barriers to LC

The questionnaire survey commenced in October 2019, with ten questions. The survey was conducted in Pakistan and UAE. The questionnaire survey was carried through “Google Form” by sending the link to all the respondents. The questionnaire was divided into two sections. The first section was about to get the information of the respondents, which is mainly the profession and the Country (Civil Engineers, Architects, Construction Managers, Project Managers, Pakistan, and UAE). The second section was related to the factors that are considered to be the barriers to the implementation of LC in other developing countries, which are found out from the literature. The questionnaire was distributed among the respondents who have work experience and have knowledge about the concept of lean construction.

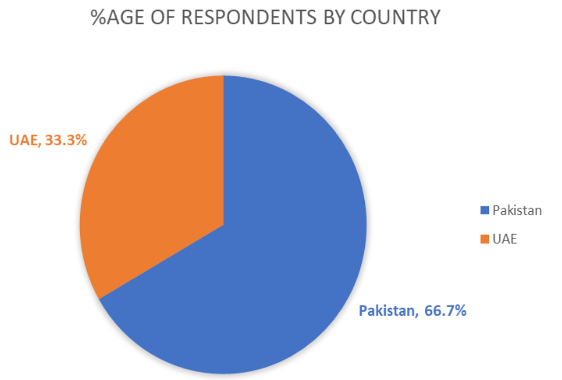
The questionnaire was distributed among 100 respondents by using E-mail, LinkedIn, and Social Media to get the maximum responses from the professionals who are related to the construction industry in the mentioned countries. The respondents were asked to rank each barrier by a weightage which are scaled, ranging from 1 to 5.

5.1.1. Data Analysis

The questionnaire was distributed with the help of the internet using various platforms to get a maximum number of responses from the respondents. Almost 100 questionnaires were distributed in both countries to get a maximum number of responses. The total number of responses received after waiting for almost one month was 78. Before analyzing the data reliability test of the questionnaire was conducted. For the data to be reliable a reliability test is required to be carried for which the Cronbach´s value is required to greater than the minimum value of 0.7. The reliability test value of the data was found out to be 0.829, which is higher than the minimum required value for the data to be reliable.

From the data, it was found out that the majority of the respondents are from Pakistan which is about 66.7%, and 33.3% are from UAE. The respondents belong to the construction industry with different positions in the field. The major number of respondents are Civil Engineers who are directly connected with the construction sites.

Out of all the respondents, 44.9% are Civil Engineers, 20.5% are Architects, 23.1% Construction Managers, 7.7% are Project Managers, and only 3.3% are at Senior Management positions.



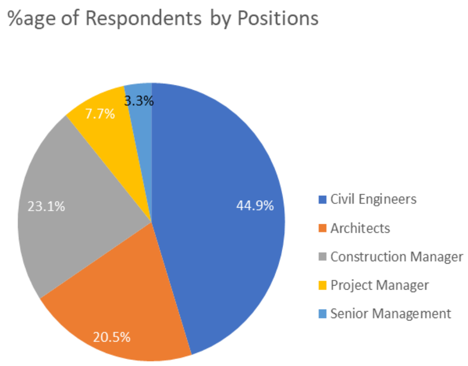


Figure 39: Respondents detail from Pakistan and UAE (Own Work)

The date was analyzed to find out the relative importance index (RII) by using the SPSS software. After analysis, the RII of the barriers were identified, which the respondents think are more prominent barriers to the implementation of LC in the construction industry of Pakistan and UAE.

	Lack of Commitment	Human Attitude	Lack of Knowledge	Lack of Lean Expert	Application Time	Stakeholder Interest	Benefits are not Known	High Competition	Lack literate labor
Strongly Agree	66	4	14	19	7	12	46	18	24
Agree	12	54	54	37	64	47	8	43	41
Partially Agree	0	20	4	8	7	5	13	6	11
Disagree	0	0	6	1	0	3	1	1	2
Strongly Disagree	0	0	0	13	0	11	10	10	0

Table 20: The Responses Detail

Table # 20 shows the number of respondents who selected the required factor for the barriers.

Statistics

	N		Mean	Std. Deviation
	Valid	Missing		
Lack of Commitment of top management is the cause of not implementing LC in the industry	78	0	4.8462	.36314
Lack of understand and knowledge of lean principles are the causes of not implementing LC in the industry.	78	0	3.9744	.73810
Lack of Skilled professional of LC is the cause of not implementing LC in construction projects	78	0	3.6154	1.33125
Application time of LC is lengthy due to which companies are hesitant to implement LC in projects	78	0	4.0000	.42640
Lack of Interest from the Government or the stakeholders is the cause of not implementing LC in the industry.	78	0	3.5897	1.22141
Benefits of LC in the industry are not well known is the cause of not implementing LC in the industry	78	0	4.0128	1.40956
Due to high competition among the construction companies, companies do not want to share information with other companies to implement LC in the projects	78	0	3.7436	1.21073
Lack of literate labors and skilled workers in the industry is the reason of not implementing LC in Industry.	78	0	4.1154	.73821
Human attitude to adopt new techniques is a factor of not applying Lean Construction (LC) in industry.	78	0	3.7949	.51871

Table 21: Mean & Standard Deviation of the Responses for each Barrier

Table # 21 shows the mean and standard deviation of the responses. The value of the mean, which is higher or equal to 2.5, is considered a significant barrier. The data shows that according to the responses of the respondents, these are all significant barriers to the implementation of LC in the industry.

5.1.2. Results

The most significant and common barriers identified by the respondents in Pakistan and UAE are these top nine barriers, as shown in the table.

Barriers to Implementation	**RII**	**Mean**	**St. Dev**	**Rank**
Lack of Commitment	0.969	4.8462	0.36314	1
Lack of Literate Workforce	0.823	4.1154	0.73821	2
Unawareness to Benefits of LC	0.803	4.0128	1.40956	3
Lengthy Application Time	0.800	4.0000	0.42640	4
Lack of Knowledge	0.795	3.9744	0.73810	5
Human Attitude to Adopt	0.759	3.7949	0.51871	6
High Competition Among Companies	0.749	3.7436	1.21073	7
Lack of Skilled Professionals	0.723	3.6154	1.33125	8
Lack of interest from Stakeholders	0.718	3.5897	1.22141	9

Table 22: Relative Importance Index (RII) of Barriers to LC in Pakistan & UAE

Table # 22 shows the Relative Importance Index of the barriers to LC in the construction industry of Pakistan and UAE. To find the RII values, equation # 03 was used. The table shows that the value of RII, mean, standard deviation, and the rank of the barrier according to its RII value. Higher the value of RII means a higher percentage of respondents think the factor is the barrier to implementation of LC in industry. The table shows that the most common barrier to implementation of LC is the “Lack of Commitment from the top Management” with RII value 0.969, which means 96% of respondents consider this as a barrier. At rank 2 is the “ Lack of Literate Workforce” with RII value 0.823, at rank 3 is the “Unawareness to the Benefits of LC” with RII value 0.803, “ Lengthy Application Time” with 0.800, “ Lack of Knowledge” with 0.795, “ Human Attitude” with 0.759, “ High Competition Among Companies” with 0.749, “ Lack of Skilled Professional” with 0.723, and the last one in list which has the RII value the smallest one of 0.718. The ranking system shows the barriers which are in the priorities of the respondents.

The barriers identified are the same, which identified in other developing countries (Sarhan et al., 2017). The barriers to implementation of LC are the same, but the ranking is changed, although the factor of lack of commitment is the same rank in all the developing countries and also in Pakistan and UAE.

5.1.3. Conclusion

The study shows that the identified barriers to the implementation of LC in the industry are highly significant for the respondents. Based on the RII values, the top-ranking barriers are of the greatest concern to construction industry in the specified countries are the lack of commitment from the top management, the workforce on the construction site are majorly not literate which is also considered as barrier, unawareness of the benefits of LC, the respondents consider the application time of LC is lengthy, lack of knowledge about LC, human attitude to adopt new techniques and method, high competition among the companies because companies don’t share information and experiences, also, lack of skilled lean professional, and the last one lack of interest of stakeholders or Government to implement the LC are significant barriers according to respondents.

As all the barriers mentioned, have a mean value greater than >2.5 shows that all of the identified barriers are significant. So the construction industry in both countries should focus on the above mentioned main barriers to implement the LC in the industry. But, the most important and with the greater concern of the respondents are with lack of commitment from the top management, which means top management should take clear steps and must show clear inclination in the implementation of LC to enhance the performance of the industry.

5.2. Visual Management Questionnaire Survey

A quantitative questionnaire method was adopted for Visual Management (VM) implementation in the construction industry and its effects on construction project performance. All the questions in the survey were closed-ended. The questionnaire was designed with the Likert Scale variables from very low to very high, and the Likert Scale of percentages for some questions. According to the Likert Scale, " Very Low" was represented by scale 1 and "very high" by scale 5 of the Likert scale. Also, an additional option of " No Answer/ No Improvement " was provided with Likert Scale 6. The same condition was adopted for the questions with percentages, i.e., 0% on the scale was represented by 1 and the highest percentage by scale 5 on the scale, while 6 represents the option of "No Answer."

5.2.1. Data Analysis

The questionnaire was distributed to the respondents by using the channel of the internet using various platforms like LinkedIn, personal E-Mails, and Social Media Networks to get a maximum number of responses. Almost more than 100 questionnaires were administered to the respondents from all parts of the world, who have the information of LC, and have work experience on the construction sites. The respondents include majorly Civil Engineers, Architects, Construction Managers, Project Managers, and other Senior Management position holders.

Almost 89 responses were received from the respondents. Out of these 89 responses, 28 responses were incomplete which were majorly the responses for questions that have percentages as factors for scale. After the data is received, a reliability test of the data was carried out to find how much is the data reliable. To find out whether that data is reliable, the reliability test value needs to be higher than $\alpha > 0.7$. The reliability test was carried out using the SPSS Software, from the test, it was found out the value of reliability test (α) is 0.874, which is higher than the required minimum value of reliability test. The reliability test results can be seen in Appendix C.

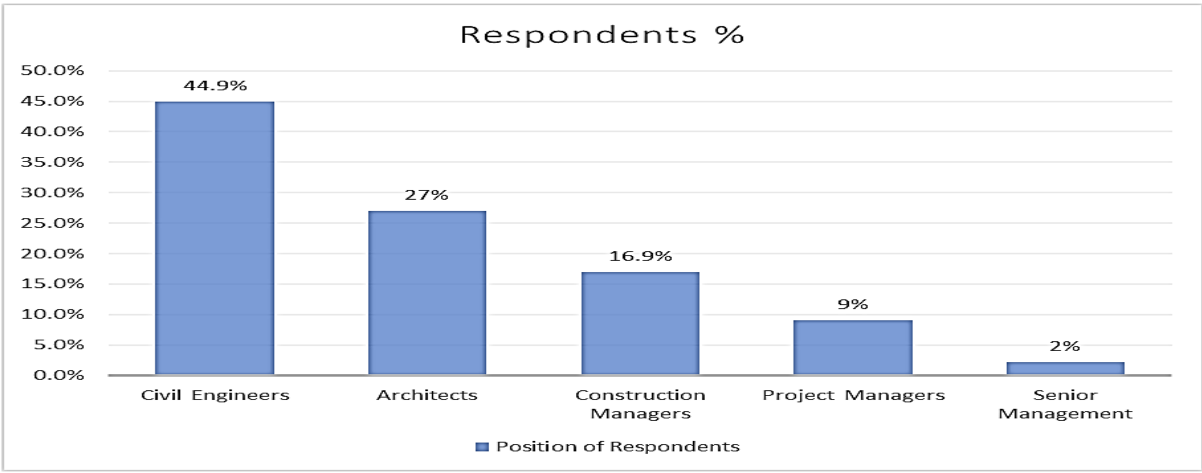


Figure 40: The Visual Management Questionnaire Respondents

From the data, it was found out that the majority of the respondents are Civil Engineers with the highest percentage of 44.9%, followed by Architects with a percentage of 27%, Construction Managers 16.9%, Project Managers 9%, and the least one Senior Management position holders with only 2.2%. The questionnaire can be found in the Appendix “c” of the report.

Statistics

	N	
	Valid	Missing
1. Position	89	0
2. How significantly the VM techniques can reduce the waste of time on site?	89	0
3. Does the VM technique is significant for reducing or eliminating the waste of materials and resources?	89	0
4. To what extent VM techniques are important to enhance the communication on the construction site?	89	0
5. To what extent it is important to implement VM technique on the construction site?	89	0
6. How much 5´s technique of VM can reduce the duration of the activity on-site?	81	8
7. How much the Health and Safety boards on-site can enhance project performance?	89	0
8. How much prototyping of the construction activity can enhance the performance of the project?	80	9
9. To what proportion VM helps in communicating the information on the construction site in a more easy and simple way without the help of other entities?	89	0
10. To what extent VM can enhance the transparency on the construction site?	78	11

Table 23: Total Number of Respondents and Missing Respondents

Table # 23 shows the total number of respondents and the number of responses missing for the questions. The frequency of the responses can be seen in Appendix C of the report.

Furthermore, the data was analysed to find out the significance of VM and its possible effects on the construction projects in the form of performance improvement from the respondent's opinions. To find out the impact of VM on construction projects the regression model was applied on the date through the identification of a correlation between the dependent variable (Performance) and the independent variable (Effects) which can be seen in the table below

Correlations

		Effect	MeanPerfor
Effect	Pearson Correlation	1	.550**
	Sig. (2-tailed)		.000
	N	78	78
MeanPerfor	Pearson Correlation	.550**	1
	Sig. (2-tailed)	.000	
	N	78	89

**. Correlation is significant at the 0.01 level (2-tailed).

Table 24: Correlation table Between Performance and Effects on Projects

Table # 24 shows the correlation of data between the mean performance and the effects of VM on the construction projects. The table shows that the data is 55% correlated and is also significant, so the hypothesis is developed to further check and predict the impact of VM on the performance of the project.

(H_0) = VM improve the performance

(H_1) = VM management can improve performance by 30%

the null hypothesis is rejected and try further to check the new hypothesis related to VM implementation.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.550[a]	.303	.294	.83471

a. Predictors: (Constant), Effect

Table 25: Regression Model Summary of the Variables

In table # 25 the value of "R" shows the relationship among the dependent variable and independent variable. The value of R shows the impact of the effects of VM on the performance of the project. The table shows predicted from the received data that VM has the capability to impact the performance of the project by 55%.

Additionally, the R-square value tells about how much the data point fits the regression line. The R-square value shows how far the actual values of the data are far from the predicted values. Higher the value of R-square more reliable the data is lower the value of R-square less reliable and the predicted values are far from actual points. For more reliable results it is required that the value of R-square should be greater than 0.30, but the value for the model is exactly 0.30, which means the results of the data are not very much reliable to be used in the future research by the researcher.

After all from this regression model it is found out that the null hypothesis (H_0) will be rejected and the alternative hypothesis (H_1) will be kept, because the data are correlated and significant have ƒ-value smaller than 0.05. The results show that the data can be used for further analysis.

H_0 ≠ VM improve Performance

H_1 = VM can Improve performance by 30%

5.2.2. Results

The results of the preliminary analysis show that the data is significant at 99% confidence interval and is correlated by 55% (R-value) and the effects of the VM predicted from the analysis are 55% on the performance of the project.

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	.921	.524		1.757	.083
	Effect	.801	.139	.550	5.747	.000

a. Dependent Variable: MeanPerfor

Table 26: Coefficient Table of the VM data

Table # 26 shows the regression line that will be formed based on the data that has been analysed. The significance value for the effects of VM on construction projects is less than 0.05 and it means we reject the null hypothesis and accept the alternative hypothesis. The information in the table shows that VM has an impact of 0.550. It means that a change of 1 value in the effects will change the value of performance by 0.550, which means a change of 1% in effects of VM will change the performance by 55%.

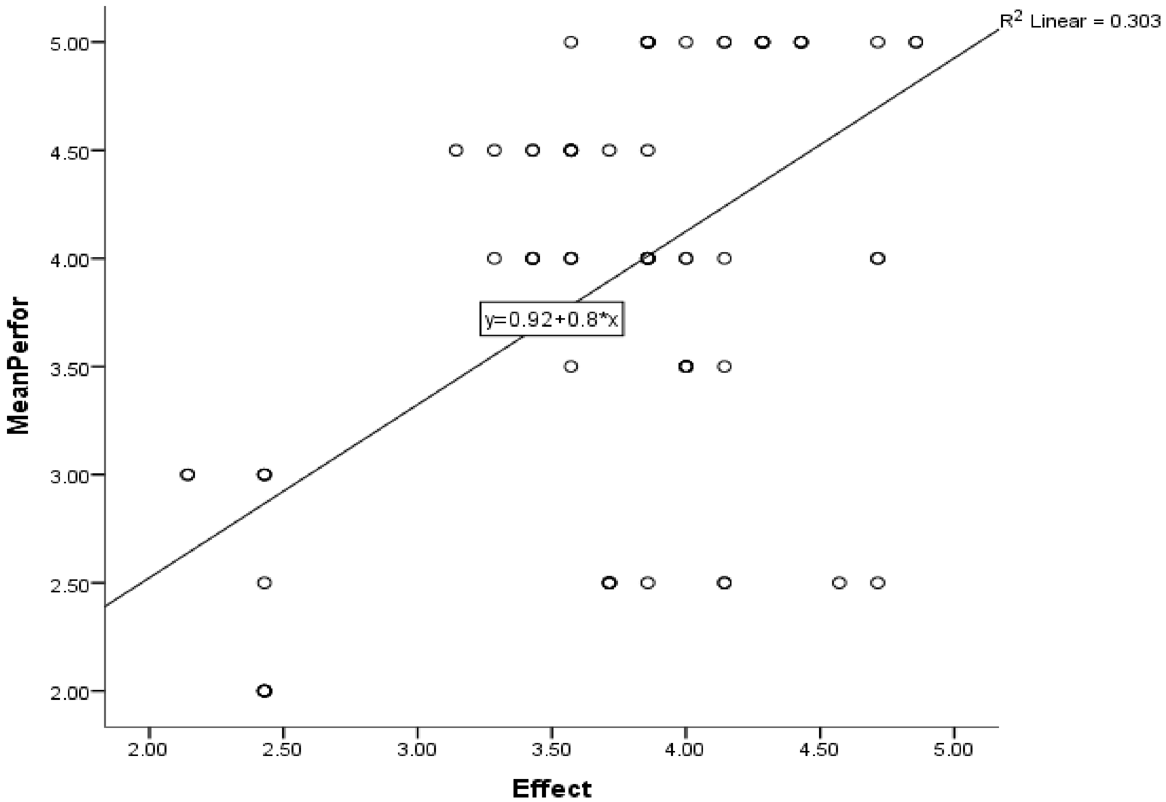


Figure 41: Regression graph the Relationship Between Mean Performance and Effects of VM on Projects

Figure # 41 shows the relationship between mean performance, the dependent variable, and the effect, independent variable when VM is implemented on the construction projects from the respondents' perspective. Further detail related to the R-square value can be seen in Appendix c.

The H_1 hypothesis was found out to be correct, and the implementation of the VM of the construction project can enhance the performance of the construction project by more than 55%, which was assumed for the analysis. So, the author rejected the null hypothesis (H_0) VM can enhance the performance of construction projects and keep the new hypothesis (H_1) of increasing the performance by 55%.

But, due to the smaller value of R-square, which is the variation in the actual data and the predicted data, the results are not reliable to be used by the researcher for further research. The main reason for having an R-Square value less than the minimum required value is a smaller number of respondents and a large number of missing responses related to the effects of VM on construction projects.

5.2.3. Conclusion

The hypothesis assumed for the application of VM on construction projects related to the performance improvement was found to be greater than the assumed value of performance improvement. The study shows that VM has the capacity to enhance the performance of the construction projects if it is applied in proper manners. VM has the capacity to effects the performance of the construction projects by 55%, through reducing waste of time, resources, enhancing the transparency on the construction site, increasing the safety on-site, standardizing the construction site, prototyping the activity, and by communicating the information to the workforce in a simple way. But, due to a higher number of missing responses, the results are not very much reliable to be used in future research. So more research is required to find more reliable results related to the implementation of VM on construction projects and its impacts on the performance of projects.

6. Research Questions Answers

This chapter of the study is dedicated to explaining the research questions. These answers are found out and suggested after the case studies analysis and also the literature review related to the questions.

1) How the Value Streaming principle can affect the cash-flow of a conventionally planned project?

Value stream mapping is a principle of LC presented by Howell and Koskela in the form of enhancing the value of the product according to the customer requirements (Howell, 1999) (L.koskela, 1992). The value streaming principle is based on the elimination of all the non-adding value activities, duration, resources, and processes that cost money but do not add value to the end product.

Although, value streaming had shown positive results in the form of elimination of non-adding value activities, resources, and duration. But, how the VSM can impact the cash-flow of the construction projects was not implemented.

The study was carried out to find the impact of VSM on the cash-flow of the project by implementing the VSM on two cases of building construction from Pakistan and UAE. The study had shown significant results in the form of reduction of waiting time between the tasks, reduction of the duration of the projects, and also showed a positive impact on the total cash-flow of the projects.

In both cases, the VSM principle was applied on the schedule of work, which was developed without considering the waste of waiting time between the task and the corresponding cost of the waiting time and the impact of this waiting time on the duration of the project and the total cash-flow of projects. In both cases, the total cash-flow of the project was improved by 11% and by 14% with the help of VSM principle applications.

2) What are the significance of Visual Management (VM) and its effect on the project?

Visual Management is the technique of lean construction principle of “*Increasing the Transparency of the process.”* Enhancing transparency of the process was presented by Koskela in his 11 principles of lean construction (L.koskela, 1992). VM is a lean technique to communicate the information on the construction site more naturally and easily without the help of another entity.

The study was carried out to find out the importance of the VM implementation on the construction site and its impact on the performance of the project. A quantitative questionnaire survey was carried to find out from the respondent's opinion about the VM and its effects on the reduction of waste of time, materials, energies, communication of information, health and safety, and increase of the transparency on the construction site.

From the study, it is found out that VM has the capacity to enhance the performance of the construction project by 55% if appropriately applied to the construction site. But, the result of the study is not very reliable due to a higher number of missing responses from the respondents. The higher number of missing answers due to lack of proper implementation of VM for the performance improvement on-site, which lead to the smaller R-square value making the results undependable for future researchers to use the data of the study.

3) What are the possible reasons and factors that hinder the application Lean concept in the United Arab Emirates and Pakistan?

The performance of the construction industry all over the world and especially in developing countries is not very promising due to the high amount of waste in the construction industry. The only possible solution to enhance the productivity and performance of the industry is to implement LC principles. But due to various factors, the implementation of LC in the industry is not possible to implement.

A qualitative questionnaire survey was carried out in Pakistan and UAE to find out the main barriers to the application of LC in the construction industry of the mentioned countries. Various elements were identified in the literature and shared with respondents from both countries, and their opinion was recorded to find out the most concerning factors that hinder the implementation of LC in the construction industry of both countries.

All the factors that were shared with respondents found out to be the main barriers to LC implementation, and they were ranked according to their relative importance index (RII). All the barriers were significant because, from the analysis, it was found out that all the factors have a mean value higher than 2.50. So all the specified barriers are a matter of concern for the respondents, which needs to be addressed to implement LC in the construction industry of the mentioned countries.

4) What are the possible ways or options of Lean Principles application on Joint Venture projects?

A detail literature review was carried out to find out the main factors that cause the failure of Joint Venture (JV) projects and find out the possible option of LC principles on JV projects that can be implemented. From the literature, it was found out that 1 out of 3 JV projects failed due to conflicts among the parent companies (Daniel et al., 2016). Also, 40-45% of the disputes among the parent companies develop due to lack of communication and lack of clarity of the end product among the employees of the parent companies.

For this purpose of enhancing the communication among the companies and employees, the techniques of the Last Planner System were successfully implemented on a JV project in the UK. From the study, it was found out that LPS is the primary LC technique that can be applied to JV projects to enhance their performance. But, also from the literature review, it is found out that the significant problem of lack of communication can also be handled with the implementation of Visual Management techniques to enhance transparency on the construction project and efficiently communicate the complete information.

It is found out that only the Last Planner System (LPS) and Visual Management (VM) are the two most effective LC techniques that can solve the problem of lack of communication, that usually the cause of failure and conflicts in JV projects.

7. Conclusion and Recommendation

7.1. Conclusion

The study aimed to find out how LC principles can enhance the performance of construction projects with the application of various lean tools. Detail research was conducted to confirm the following objectives of the study. (1) Determination of VSM principle effects on the total cash-flow of the project. (2) Determination of VM significance and its effects on construction projects. (3) Finding the main barriers to LC implementation in the construction industry of Pakistan and the UAE. (4) Determination of possible lean tool applications on JV projects.

To achieve the specified objectives detail literature review was carried out, two case studies were carried out, and also two survey questionnaires was conducted to find a solution to accomplish the mentioned objectives.

As the concept of the VSM tool is to identify the waste in the stream and eliminate the wastes to optimize the process. The study was carried out to find out the impact of VSM on the total cash-flow of the project. A case study from the UAE and Pakistan were selected to implement the VSM tool. Both the case studies the project schedule is developed with the conventional techniques, in which it is difficult to find the waste in the stream. To find the waste in the stream, the Vico Control software was utilized to visualize the stream and find the waste in a stream in a more simple and easy manner. The visualization of the stream has significantly helped in the elimination of waste of waiting time. The elimination of waste from the stream has shown a positive impact on the total cash-flow of the projects and also on the reduction of project duration.

In both the case studies, the VSM has shown positive results in the form of total cash-flow improvement, waste of waiting time reduction, and the reduction of project duration. In the case study of UAE, reduced the waste of waiting time between the task by 27%, which has ultimately reduced labor costs by 27%. The removal of waste of waiting time and the arrangements of the tasks with an early start and early finish technique the total duration of the project was reduced by 68%, which in turn improved the cash-flow of the project by 11%.

Similarly, the process of VSM on the Pakistani project has reduced the waste of waiting time by 54% and the cost of waste by 54%. The removal of waste of waiting time has significantly affected the total duration of the project and reduced the duration of the project by 66% due to waste removal and the early start and finish of tasks. The reduction of waste and reduction of project duration has ultimately effected the total cash-flow of the project and improved the total cash-flow by 14%. The study showed that VSM has a significant impact on the total cash-flow of the projects if it is implemented properly for the development of the value stream of the construction projects.

Similarly, Visual Management (VM) has an impact on the performance of the construction projects, which is entirely a subjective concept due to the lack of objective data related to VM and performance improvement. The researcher aimed to find the actual results associated with VM implementation and its impact on project performance. A quantitative survey questionnaire helped to find out from the respondent's opinion how much VM can improve the performance. The study predicted that VM could enhance the performance by 55%. But, the results are not reliable due to a high degree of variance among the actual data points and the predicted regression line points i.e. R-square value is minimal. Also, due to a large number of missing responses from the respondents related to the performance improvement of VM. The study showed that VM has the capacity to improve the performance of the construction projects and further research is recommended to find out more reliable data related to VM implementation and performance improvement.

LC, which is the only solution to increase the productivity and performance of the construction industry, but due to several barriers to its implementation, the industry is still not as productive as other industries. A questionnaire survey was carried out to find out the barriers to the implementation of LC in the construction industry of Pakistan and the UAE. The study showed that all the barriers identified in the study are significant for the application of LC in the industry. All the barriers have RII and mean higher than 2.5, which shows that all the identified barriers are substantial concerns of respondents to implement LC. Based on the RII values, the top-ranking barriers are of the most significant concern to construction industry in the specified countries are the lack of commitment from the top management, the workforce on the construction site are majorly not literate which is also considered as barrier, unawareness of the benefits of LC, the respondents believe the application time of LC is lengthy, lack of knowledge about LC, human attitude to adopt new techniques and method, high competition among the companies because companies don’t share information and experiences, also lack skilled lean professional, and the last one lack of interest of stakeholders or Government to implement the LC are significant barriers according to respondents.

Additionally, the literature review has shown that JV projects are facing a higher failure rate due to lack of communication among the stakeholders and parent companies. LC tools can eliminate the problem of lack of communication and enhance the performance of the JV project. Only two LC tools were identified from the detail literature review that is: The Last Planner System (LPS) and Visual Management (VM). Both the tools are highly significant to eliminate the communication problem in construction projects.

The study showed that significant factors of the poor performance of the construction projects are lack of transparency, lack of communication, too much waste in the process, and the various kind of barriers to LC implementation to enhance the performance of projects. The research study showed that with the application of LC tools in construction projects, the performance of projects could be improved. Also, the study will help the construction industry to identify the waste of waiting between the tasks and how it affects the total cash-flow and the duration of the projects. The study also helps the stakeholders of the construction industry to implement the VM for performance improvement. Also, the study develops the foundation for the implementation of VM on the JV projects to reduce the conflicts in JV projects and how it can reduce the failure rate of JV projects. Furthermore, the study helped in the identification of main barriers to the implementation of LC tools in the construction industry of Pakistan and the UAE. Further research is required to tackle the specified barriers and implement the LC tools in the construction industry to enhance the productivity of the sector in the mentioned countries.

7.2. Recommendation

It has been more than two decades that the concept of LC has been introduced in the construction industry. But, still, the idea of LC implementation is very limited in the construction industry, although LC has shown positive results in reducing wastes in the construction process through the application of various LC tools. Considering the benefits of LC tools implementation related to the elimination of waste in the process, enhancing transparency, and barriers to implementation of LC in the industry, some of the recommendations are suggested. These recommendations according to the author, will not only reduce wastes in the process but will enhance transparency and show objective results on construction projects and also helps in the implementation of LC in the industry.

1. Measurable indicators of the performance improvement with visual management technique.
2. Visualization of the stream is required to identify the wastes in the process.
3. Increase transparency on the construction site by visualizing the responsibilities and the information.
4. Senior management needs to more inclined toward the implementation of LC tools on projects.
5. Proper training and skills development of the workforce on site about LC.
6. 5's technique needs to practice on site.
7. Prototyping of the task or activity should be done to quickly understand the whole process.
8. The standardization technique needs to implement on-site to avoid the unnecessary movements of the workforce and to enhance safety.
9. Last Planner System (LPS) need to be implemented to visualize the progress of the projects.
10. "5 Why" tools should be implemented to identify the root causes of waste and problems on the construction site.
11. Further research is required for the implementation of VM on construction and finds the measurable benefits and more reliable results of VM implementation.
12. Lean Project Delivery System (LPDS) should be implemented on construction projects to identify the benefits of LC from the early phase of the projects.
13. The national culture of LC implementation is required to adopt for LC implementation in the specified countries.
14. Further research work and LC development institutes are required to establish for the implementation of LC in the construction industry.
15. Implementation of the LC principle should be included in the contracts to make it necessary to implement LC.

Declaration of Authorship

I hereby declare that the attached Master's thesis was completed independently and without the prohibited assistance of third parties, and that no sources or help were used other than those listed. All passages whose content or wording originates from another publication have been marked as such. Neither this thesis nor any variant of it has previously been submitted to an examining authority or published.

Date

Signature of the student

Appendices

Appendix A: Details of UAE Project

BILL OF QUANTITIES (BOQ) of Dubai Villa.

No	Description of work	Unite	QTY	Rate	Amount
1	**Preliminaries**				
1.1	Mobilization	LS			**DEM 75,000.00**
2	**Sub-Structure work**				
2.1	Exc for Foundation	m3	500	20	DEM 10,000.00
2.2	Backfilling around fdn & plinth	m3	750	20	DEM 15,000.00
2.3	PCC below Fdn and Tie beam	m3	20	600	DEM 12,000.00
2.4	RCC isolated footing	m3	40	1200	DEM 48,000.00
2.5	RCC tie beam	m3	28	1250	DEM 35,000.00
2.6	RCC neck Column	m3	5	1250	DEM 6,250.00
2.7	RCC stair	m3	7	1100	DEM 7,700.00
2.8	RCC GF slab 100mm thick	m3	20	700	DEM 14,000.00
2.9	1000 gauge plastic sheet	m2	300	5	DEM 1,500.00
2.10	DPC	RM	64	20	DEM 1,280.00
2.11	Blockwork below tie beam	m2	100	120	DEM 12,000.00
2.12	Ant termite treatment	m2	459	10.9	DEM 5,003.10
2.13	Bitumen Paints	m2	600	15	DEM 9,000.00
2.14	50mm thick floor insulation	m2	60	30	DEM 1,800.00
					DEM 178,533.10
3	**Super-Structure**				
3.1	RCC Colum	m3	20	1300	DEM 26,000.00
3.2	First floor slab	m3	72	1250	DEM 90,000.00
3.3	Roof Slab	m3	71	1250	DEM 88,750.00

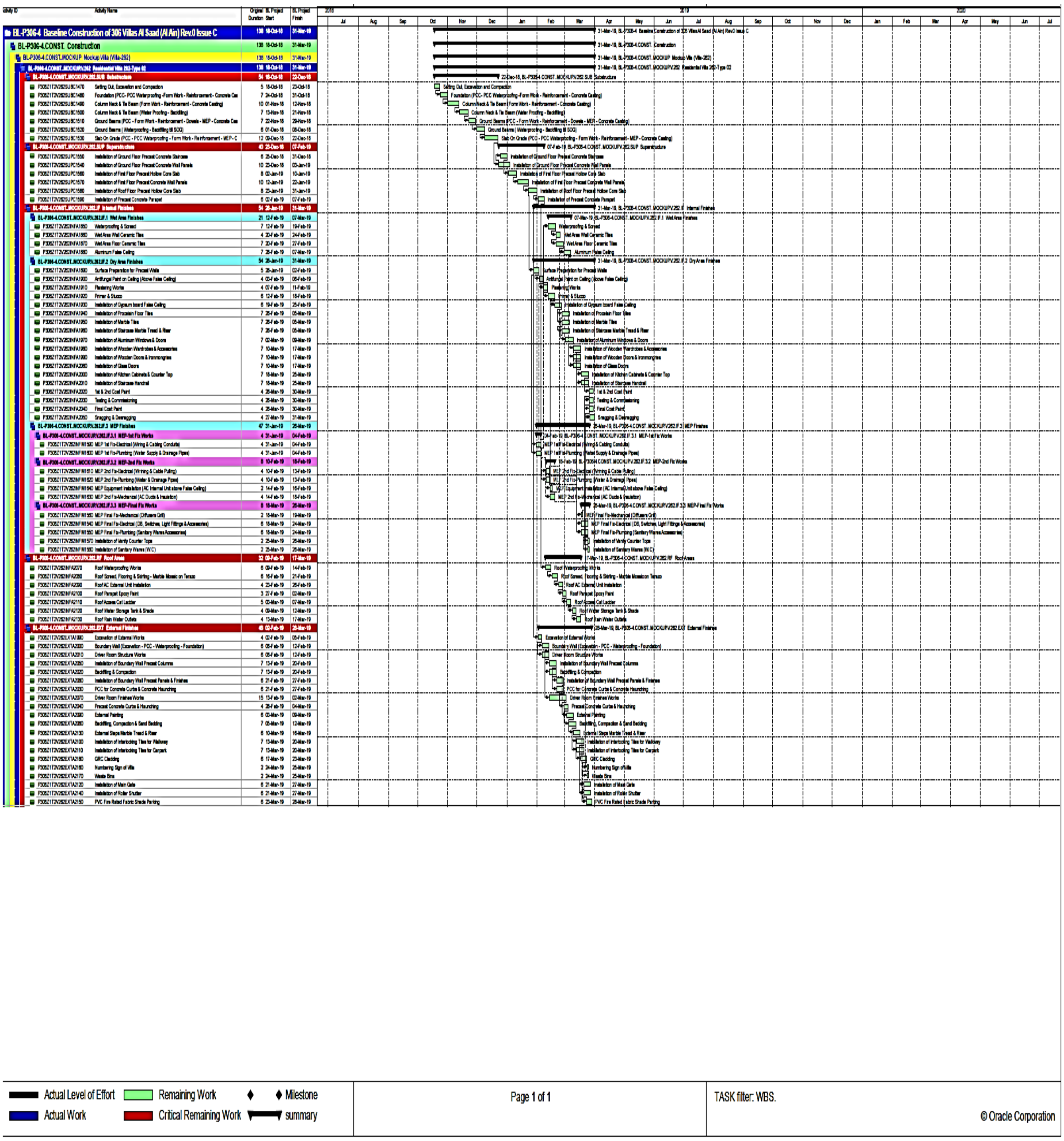
3.4	RCC staircase	m3	5	1300	DEM 6,500.00
3.5	RCC Lintels & Arches	m3	5	1300	DEM 6,500.00
3.6	RCC Parapet	m3	25	1300	DEM 32,500.00
4	**Block Work**				**DEM 250,250.00**
4.1	250mm thk insulated B wall	m2	480	120	DEM 57,600.00
4.2	200mm thk Hollow B wall	m2	370	85	DEM 31,450.00
4.3	100mm thk Hollow B wall	m2	200	80	DEM 16,000.00
					DEM 105,050.00
5	**Plaster Internal & External**				
5.1	Internal plaster	m2	1600	30	DEM 48,000.00
5.2	External Plaster	m2	770	45	DEM 34,650.00
					DEM 82,650.00
6	**internal floor, wall, ceiling finishes**				
6.1	Ceramic tiles flooring DHS 40/m2	m2	360	95	DEM 34,200.00
6.2	Ceramic tiles flooring DHS 30/m2	m2	360	60	DEM 21,600.00
6.3	Marble Landing & Flooring @ DHS 120/m2	m2	3	210	DEM 630.00
6.4	Marble Steps @ DHS 120/m2	m2	33	210	DEM 6,930.00
6.5	Marble Threshold DHS 100/m2	m2	30	120	DEM 3,600.00
6.6	Internal Fenomastic Paint	m2	1800	12	DEM 21,600.00
					DEM 88,560.00
7	**Roofing & Water Proofing**				
7.1	Compound roof System	m2	200	140	DEM 28,000.00
7.2	Wet Area water proofing	m2	60	50	DEM 3,000.00
					DEM 31,000.00
8	**External Finishes**				
8.1	Granite Flooring @ DHS 120/m2	m2	10	210	DEM 2,100.00

8.2	Granite steps @ DHS 120/rm	m2	30	210	DEM 6,300.00
8.3	Epoxy paints	m2	770	30	DEM 23,100.00
					DEM 31,500.00
9	**Woodwork**				
9.1	Main wooden door	NO	2	2000	DEM 4,000.00
9.2	Room Wooden Doors	NO	8	2000	DEM 16,000.00
9.3	Bathroom Wooden Doors	NO	12	1500	DEM 18,000.00
9.4	Kitchen Cabinet	NO	7	2857	DEM 20,000.00
9.5	Wardrobes	NO	16	1875	DEM 30,000.00
					DEM 88,000.00
10	**Vanity Counter & Sanitary Wares**				
10.1	Marble Counters	M2	38	120	DEM 4,580.00
					DEM 4,580.00
11	**False Ceiling Work**				
11.1	Gypsum work	m2	345	130	DEM 45,000.00
11.2	False Ceiling 60*60	m2	69	120	DEM 8,280.00
					DEM 53,280.00
12	**Plumbing**				
12.1	Internal Drainage & Water supply	m2	120	291	DEM 35,000.00
12.2	Water Tanks	NO	1	5000	DEM 5,000.00
12.3	Solar Water Heater	NO	1	15000	DEM 15,000.00
12.4	water transfer pump	No	1	3000	DEM 3,000.00
12.5	Booster water pump	NO	1	2000	DEM 2,000.00
12.6	Sanitary wares	M2	200	100	DEM 20,000.00
					DEM 80,000.00
13	**Drainage**				
13.1	External Drainage & Manholes	m2	150	120	DEM 18,000.00

					DEM 18,000.00
14	**Electrical work**				
14.1	Electrical work	LS		92000	DEM 92,000.00
14.2	light Fittings	LS		8000	DEM 8,000.00
14.3	intercom system	LS		3000	DEM 3,000.00
					DEM 103,000.00
15	**Metal Aluminium Work**				
15.1	Aluminium Windows	No	35	1285	DEM 45,000.00
15.2	Internal railing	No	4	2500	DEM 10,000.00
15.3	Spiral Stair	No	2	2500	DEM 5,000.00
					DEM 60,000.00
16	**Boundary Wall**				
16.1	Excavation	m3	300	20	DEM 6,000.00
16.2	Backfilling around fdn & plinth	m3	250	20	DEM 5,000.00
16.3	PCC work	m3	15	600	DEM 9,000.00
16.4	RCC work	m3	25	1200	DEM 30,000.00
16.5	Bitumen Paints	m2	400	10	DEM 4,000.00
16.6	8" Thick Solid Block work	m2	150	116	DEM 17,400.00
16.7	8" Thick Solid Hollow work	m2	380	80	DEM 30,400.00
16.8	Plastering work	m2	800	29	DEM 23,200.00
16.9	Epoxy paints	m2	800	22	DEM 17,600.00
16.10	"20mm thick flexcel Sheet	m2	100	10	DEM 1,000.00
					DEM 143,600.00
17	**External Work**				
17.1	Interlock	m2	550	80	DEM 44,000.00
17.2	Heel kerb supply	RM	100	40	DEM 4,000.00
17.3	Cast aluminium gates	m2	30	400	DEM 12,000.00
17.4	Car Parking	m2	100	100	DEM 10,000.00
18	**Airconditioning**				**DEM 70,000.00**

18.1	AC work	LS			DEM 95,000.00
					DEM 95,000.00
	Total				**DEM 1,558,000**

Work Schedule of Dubai Project



Appendix B: Detail of Pakistani Project

BILL OF QUANTITIES (BOQ) of Pakistani Villa.

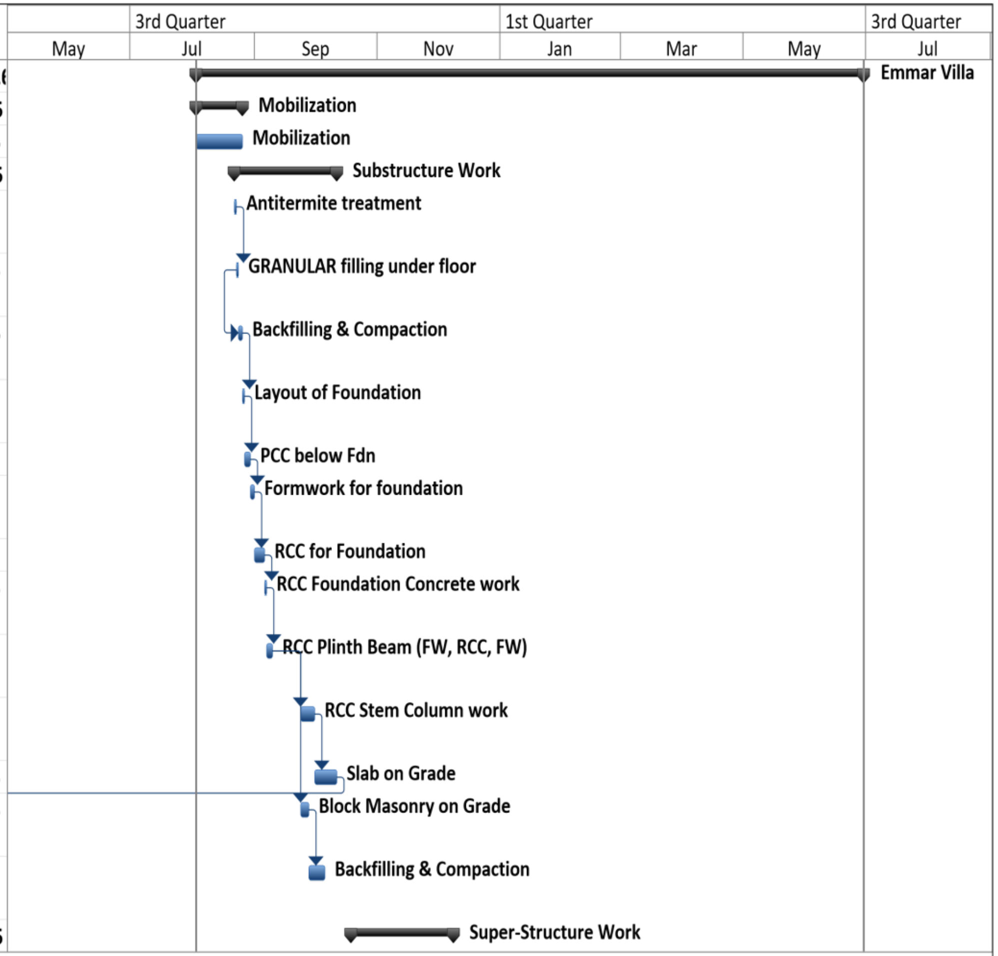
No	Description of work	Unite	QTY	Rate	Amount
1	**Preliminaries**				
	Mobilization	LS			PKR 1,422,525.00
2	**Earthwork**				
	Excavation	m3	450	150	PKR 67,500.00
	Backfilling of Soil	m3	500	90	PKR 45,000.00
	Anti-termite work	LS			PKR 30,000.00
3	**Sub-Structure work**				
	Polythene Sheet	LS			PKR 12,000.00
	PCC	m3	22	7000	PKR 154,000.00
	Footing	m3	38	15000	PKR 570,000.00
	Neck Column	m3	5	15000	PKR 75,000.00
	Tie Beam	m3	30	15000	PKR 450,000.00
	Grade Slab	m3	23	25000	PKR 575,000.00
	Solid Block	m2	180	800	PKR 144,000.00
	Bitumen Paint	LS			PKR 40,000.00
4	**Super-Structure**				
	RCC Column	m3	24	25000	PKR 600,000.00
	Beams (first & Roof)	m3	26	15000	PKR 390,000.00
	Slab (first & roof)	m3	33	25000	PKR 825,000.00
	Slab (Sloping)	m3	11	25000	PKR 275,000.00
	Staircase	m3	8	15000	PKR 120,000.00
	RCC for lintels & arches	m3	5	15000	PKR 75,000.00

	RCC Parapet	m3	7	15000	PKR 105,000.00
5	**Block Work**				
	200mm thk solid B wall	m2	600	800	PKR 480,000.00
	100mm thk Solid B wall	m2	45	600	PKR 27,000.00
6	**Plaster Internal & External**				
	Internal plaster	m2	460	1300	PKR 598,000.00
	External Plaster	m2	400	1100	PKR 440,000.00
7	**Flooring**				
	Granite + Skirting	m2	65	4000	PKR 260,000.00
	ceramic Skirting	m2	320	2300	PKR 736,000.00
	Threshold	m2	27	2000	PKR 54,000.00
	Staircase Steps internal	NO	30	550	PKR 16,500.00
	Villa Flooring, Bath, & Kitchen Tiles	LS			PKR 800,000.00
	Staircase External	NO	12	550	PKR 6,600.00
8	**Roofing & Water Proofing**				
	Compound roof System	m2	550	400	PKR 220,000.00
	Wet Area waterproofing	LS			PKR 110,000.00
9	**Paint Work**				
	Internal Paint	m2	470	1200	PKR 564,000.00
	External Paint	m2	380	1000	PKR 380,000.00
10	**Woodwork**				
	Main wooden door	NO	3	8000	PKR 24,000.00
	Room Wooden Doors	NO	11	5000	PKR 55,000.00
	Bathroom Wooden Doors	NO	9	3500	PKR 31,500.00
	Kitchen Cabinet	NO	15	890	PKR 13,350.00
	Wardrobes	NO	9	1200	PKR 10,800.00
11	**Gypsum work**				

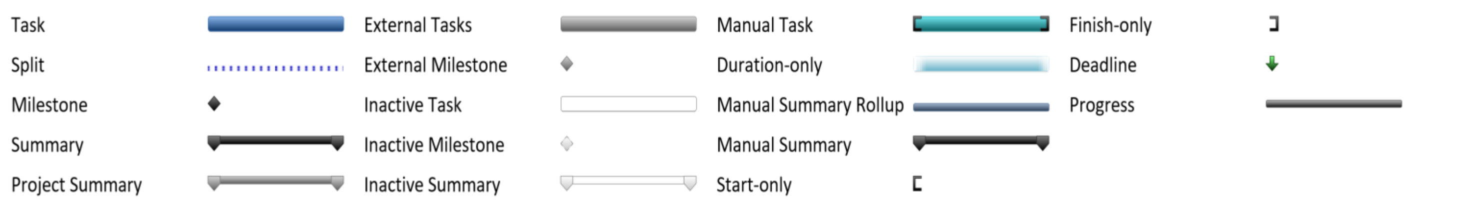
	Gypsum	LS			PKR 80,000.00
	False Ceiling 60*60	LS			PKR 120,000.00
12	**Plumbing**				
	Internal Drainage & Water supply	LS			PKR 280,000.00
	Water Tanks	NO	1	12000	PKR 12,000.00
	water pump	NO	1	19000	PKR 19,000.00
	Sanitary wares	LS			PKR 480,000.00
	Natural Gas Fitting	LS			PKR 40,000.00
	External Drainage	LS			PKR 80,000.00
13	**Electrical work**				
	Electrical work	LS			PKR 430,000.00
	light Fittings	LS			PKR 80,000.00
	AC work	NO	8	60000	PKR 480,000.00
14	**Aluminium Work**				
	Aluminium Windows	No	21	5000	PKR 105,000.00
	Internal railing	No	2	23000	PKR 46,000.00
15	**External Work**				
	Interlock	m2	250	1200	PKR 300,000.00
	Kerbstone	LS			PKR 500,000.00
	Roof Clay Tiles	m2	260	650	PKR 169,000.00
	Car Entrance & Pedestrian gates	LS			PKR 480,000.00
	Boundary Wall	LS			PKR 670,000.00
	Total			**PKR**	**15,172,775.00**

Work Schedule of Pakistani Villa

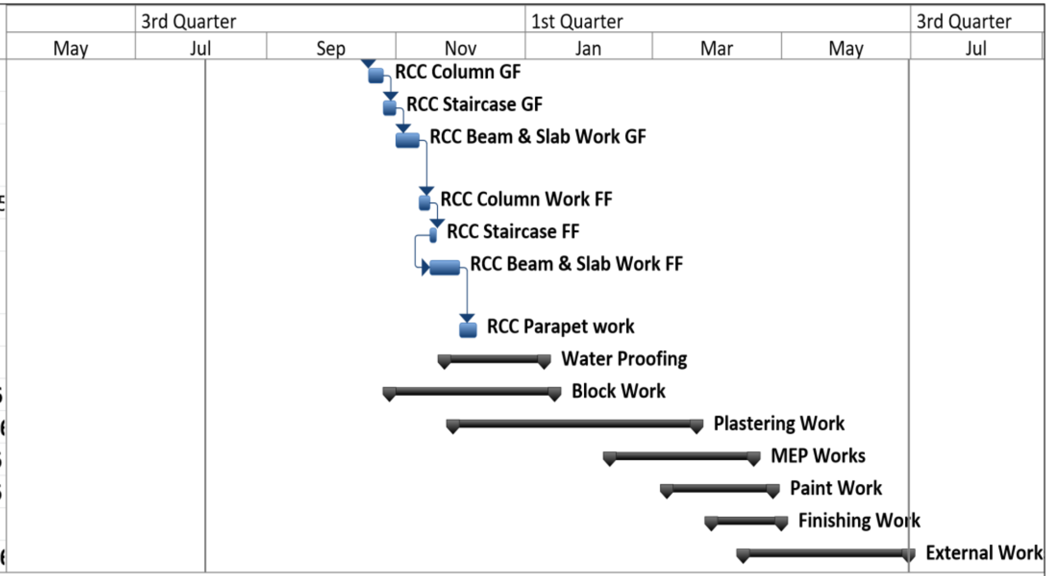
ID	Task Mode	Task Name	Duration	Start	Finish
1		**Emmar Villa**	**285 days**	**Mon 03/08/15**	**Wed 29/06/16**
2		**Mobilization**	**20 days**	**Mon 03/08/15**	**Tue 25/08/15**
3		Mobilization	20 days	Mon 03/08/15	Tue 25/08/15
4		**Substructure Work**	**44 days**	**Sat 22/08/15**	**Sun 11/10/15**
5		Antitermite treatment	1 day	Sat 22/08/15	Sat 22/08/15
6		GRANULAR filling under floor	1 day	Sun 23/08/15	Sun 23/08/15
7		Backfilling & Compaction	2 days	Mon 24/08/15	Tue 25/08/15
8		Layout of Foundation	1 day	Wed 26/08/15	Wed 26/08/15
9		PCC below Fdn	2 days	Thu 27/08/15	Sat 29/08/15
10		Formwork for foundation	2 days	Sun 30/08/15	Mon 31/08/15
11		RCC for Foundation	4 days	Tue 01/09/15	Sat 05/09/15
12		RCC Foundation Concrete work	1 day	Sun 06/09/15	Sun 06/09/15
13		RCC Plinth Beam (FW, RCC, FW)	3 days	Mon 07/09/15	Wed 09/09/15
14		RCC Stem Column work	6 days	Thu 24/09/15	Wed 30/09/15
15		Slab on Grade	9 days	Thu 01/10/15	Sun 11/10/15
16		Block Masonry on Grade	3 days	Thu 24/09/15	Sun 27/09/15
17		Backfilling & Compaction	7 days	Mon 28/09/15	Mon 05/10/15
18		**Super-Structure Work**	**44 days**	**Mon 19/10/15**	**Tue 08/12/15**



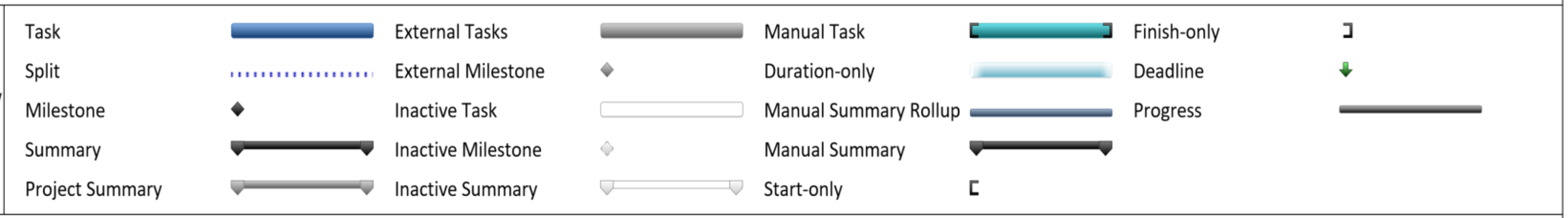
Project: Emmar Villa Pakistan New
Date: Fri 29/11/19



ID	Task Mode	Task Name	Duration	Start	Finish
19		RCC Column GF	6 days	Mon 19/10/15	Sun 25/10/15
20		RCC Staircase GF	5 days	Mon 26/10/15	Sat 31/10/15
21		RCC Beam & Slab Work GF	10 days	Sun 01/11/15	Wed 11/11/15
22		RCC Column Work FF	4 days	Thu 12/11/15	Mon 16/11/15
23		RCC Staircase FF	3 days	Tue 17/11/15	Thu 19/11/15
24		RCC Beam & Slab Work FF	12 days	Tue 17/11/15	Mon 30/11/15
25		RCC Parapet work	7 days	Tue 01/12/15	Tue 08/12/15
26		**Water Proofing**	**40 days**	**Tue 24/11/15**	**Sat 09/01/16**
28		**Block Work**	**67 days**	**Thu 29/10/15**	**Thu 14/01/16**
31		**Plastering Work**	**99 days**	**Sat 28/11/15**	**Mon 21/03/16**
36		**MEP Works**	**58 days**	**Wed 10/02/16**	**Sun 17/04/16**
46		**Paint Work**	**43 days**	**Tue 08/03/16**	**Tue 26/04/16**
54		**Finishing Work**	**28 days**	**Tue 29/03/16**	**Sat 30/04/16**
61		**External Works**	**67 days**	**Wed 13/04/16**	**Wed 29/06/16**



Project: Emmar Villa Pakistan New
Date: Fri 29/11/19



Appendix C: Questionnaire Survey

For visual management

What are the significance of Visual management (VM) and its effects on the construction project?

S.No	Questions	Very Low	Low	Medium	High	Very High	
1.	Position						
2.	How significantly the VM techniques can reduce the waste of time on the construction site?	1	2	3	4	5	No improvement
3.	Does the VM technique is significant for reducing or eliminating the waste of materials and resources?	1	2	3	4	5	No Answer
4.	To what extent VM techniques are important to enhance the communication on the construction site?	1	2	3	4	5	No Answer
5.	To what extent it is important to implement VM technique on a construction site?	1	2	3	4	5	Not Important
6.	How much 5´s technique of VM can reduce the duration of the activity on site?	0%	1-15%	15-30%	30-45%	>45%	No Answer
7.	How much the Health and Safety boards on site can enhance project performance?	0-5%	5-10%	10-15%	15-20%	> 20%	No improvement

8.	How much prototyping of the construction activity can enhance the performance of the project?	0%	10-15%	15-30%	30-45%	>45%	No Answer
9.	To what proportion VM helps in communicating the information on the construction site in a more easy and simple way without the help of other entities?	0%	30%	60%	90%	100%	No Answer
10.	To what extent VM can enhance the transparency on the construction site?	0%	1-15%	15-30%	30-45%	> 45%	No Answer

Detail Results of Data Analysis

Reliability Statistics

Cronbach's Alpha	N of Items
.874	11

Frequency Table

Position

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Civil Engineer	40	44.9	44.9	44.9
	Architect	24	27.0	27.0	71.9
	Construction Manager	15	16.9	16.9	88.8
	Project Manager	8	9.0	9.0	97.8
	Senior Management	2	2.2	2.2	100.0
	Total	89	100.0	100.0	

How significantly the VM techniques can reduce the waste of time on site?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	15	16.9	16.9	16.9

	Medium	44	49.4	49.4	66.3
	High	8	9.0	9.0	75.3
	Very High	22	24.7	24.7	100.0
	Total	89	100.0	100.0	

Does the VM technique is significant for reducing or eliminating the waste of materials and resources?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	14	15.7	15.7	15.7
	Medium	13	14.6	14.6	30.3
	High	31	34.8	34.8	65.2
	Very High	31	34.8	34.8	100.0
	Total	89	100.0	100.0	

To what extent VM techniques are important to enhance the communication on the construction site?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	10	11.2	11.2	11.2
	Medium	22	24.7	24.7	36.0
	High	26	29.2	29.2	65.2
	Very High	31	34.8	34.8	100.0
	Total	89	100.0	100.0	

To what extent it is important to implement VM technique on a construction site?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Medium	48	53.9	53.9	53.9
	High	16	18.0	18.0	71.9
	Very High	25	28.1	28.1	100.0
	Total	89	100.0	100.0	

How much 5´s technique of VM can reduce the duration of the activity on site?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0%	3	3.4	3.7	3.7
	1-15%	13	14.6	16.0	19.8

	15-30%	19	21.3	23.5	43.2
	30-45%	25	28.1	30.9	74.1
	>45%	21	23.6	25.9	100.0
	Total	81	91.0	100.0	
Missing	System	8	9.0		
Total		89	100.0		

How much the Health and Safety boards on site can enhance project performance?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	10	11.2	11.2	11.2
	Medium	24	27.0	27.0	38.2
	High	9	10.1	10.1	48.3
	Very High	46	51.7	51.7	100.0
	Total	89	100.0	100.0	

How much prototyping of the construction activity can enhance the performance of the project?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0%	3	3.4	3.8	3.8
	1-15%	15	16.9	18.8	22.5
	15-30%	12	13.5	15.0	37.5
	30-45%	17	19.1	21.3	58.8
	>45%	33	37.1	41.3	100.0
	Total	80	89.9	100.0	
Missing	System	9	10.1		
Total		89	100.0		

To what proportion VM helps in communicating the information on the construction site in a more easy and simple way without the help of other entities?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	12	13.5	13.5	13.5
	Medium	28	31.5	31.5	44.9
	High	29	32.6	32.6	77.5
	Very High	20	22.5	22.5	100.0
	Total	89	100.0	100.0	

To what extent VM can enhance the transparency on the construction site?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0%	3	3.4	3.8	3.8
	1-15%	4	4.5	5.1	9.0
	15-30%	23	25.8	29.5	38.5
	30-45%	32	36.0	41.0	79.5
	>45%	16	18.0	20.5	100.0
	Total	78	87.6	100.0	
Missing	System	11	12.4		
Total		89	100.0		

Questionnaire for Barriers

What are the possible reasons and factors that hinder the Lean application concept in the United Arab Emirates and Pakistan?

1 (Strongly Disagree) 2 (Disagree) 3 (Neutral) 4 (Agree) 5 (Strongly Agree)

S.No	Questions	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1.	Position and country					
2.	Lack of Commitment of top management is the cause of not implementing LC in the industry.	1	2	3	4	5
3.	Human attitude to adopt new techniques is a factor of not applying LC in industry.	1	2	3	4	5
4.	Lack of understand and knowledge of lean principles are the causes of not implementing LC in the industry.	1	2	3	4	5
5.	Lack of Skilled professionals of LC is the cause of not implementing LC in construction projects.	1	2	3	4	5
6.	The application time of LC is lengthy due to which companies are hesitant to implement LC in projects.	1	2	3	4	5
7.	Lack of Interest from the Government or the stakeholders is the cause of not implementing LC in the industry.	1	2	3	4	5

8.	The benefits of LC in the industry are not well known is the cause of not implanting LC in the industry.	1	2	3	4	5
9.	Due to high competition among the construction companies, companies do not want to share information with other companies to implement LC in the projects.	1	2	3	4	5
10.	Lack of literate labors and skilled workers in industry is the reason of not implementing LC in Industry.	1	2	3	4	5

Detail results of Barriers to LC implementation:

Reliability Statistics

Cronbach's Alpha	N of Items
.829	9

Frequency Table

Lack of Commitment of top management is the cause of not implementing LC in the industry

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Agree	12	15.4	15.4	15.4
	Strongly Agree	66	84.6	84.6	100.0
	Total	78	100.0	100.0	

Human attitude to adopt new techniques is a factor of not applying Lean Construction (LC) in industry.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Partially Agree	20	25.6	25.6	25.6
	Agree	54	69.2	69.2	94.9
	Strongly Agree	4	5.1	5.1	100.0
	Total	78	100.0	100.0	

Lack of understand and knowledge of lean principles are the causes of not implementing LC in the industry.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	6	7.7	7.7	7.7
	Partially Agree	4	5.1	5.1	12.8
	Agree	54	69.2	69.2	82.1
	Strongly Agree	14	17.9	17.9	100.0
	Total	78	100.0	100.0	

Lack of Skilled professional of LC is the cause of not implementing LC in construction projects

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	13	16.7	16.7	16.7
	Disagree	1	1.3	1.3	17.9
	Partially Agree	8	10.3	10.3	28.2
	Agree	37	47.4	47.4	75.6
	Strongly Agree	19	24.4	24.4	100.0
	Total	78	100.0	100.0	

Application time of LC is lengthy due to which companies are hesitant to implement LC in projects

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Partially Agree	7	9.0	9.0	9.0
	Agree	64	82.1	82.1	91.0
	Strongly Agree	7	9.0	9.0	100.0
	Total	78	100.0	100.0	

Lack of Interest from the Government or the stakeholders is the cause of not implementing LC in the industry.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	11	14.1	14.1	14.1
	Disagree	3	3.8	3.8	17.9
	Partially Agree	5	6.4	6.4	24.4
	Agree	47	60.3	60.3	84.6
	Strongly Agree	12	15.4	15.4	100.0
	Total	78	100.0	100.0	

Benefits of LC in industry are not well known is the cause of not implementing LC in the industry

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	10	12.8	12.8	12.8
	Disagree	1	1.3	1.3	14.1
	Partially Agree	13	16.7	16.7	30.8
	Agree	8	10.3	10.3	41.0
	Strongly Agree	46	59.0	59.0	100.0
	Total	78	100.0	100.0	

Due to high competition among the construction companies, companies do not want to share information with other companies to implement LC in the projects

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	10	12.8	12.8	12.8
	Disagree	1	1.3	1.3	14.1
	Partially Agree	6	7.7	7.7	21.8
	Agree	43	55.1	55.1	76.9
	Strongly Agree	18	23.1	23.1	100.0
	Total	78	100.0	100.0	

Lack of literate labors and skilled workers in industry is the reason of not implementing LC in Industry.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	2	2.6	2.6	2.6
	Partially Agree	11	14.1	14.1	16.7
	Agree	41	52.6	52.6	69.2
	Strongly Agree	24	30.8	30.8	100.0
	Total	78	100.0	100.0	

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