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EVALUATING THE EFFICACY OF LEAN CONSTRUCTION PRACTICES IN CONSTRUCTION INDUSTRY OF PAKISTAN

Project submitted in partial fulfilment of the requirements for the degree

of

BE Civil Engineering

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This is to certify that the BE Civil Engineering Project entitled

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Dedication

We dedicate this research to
our beloved PARENTS and respected INSTRUCTORS, who prayed for us, and gave us encouragement and moral support throughout our endeavor

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Praise be to ALLAH ALMIGHTY Whose Divine Will is the reason for what we achieved.

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List of Abbreviations

LC	Lean Construction
IHITC	Isolation Hospital and Infectious Treatment Centre
TIP	Tunneling Institute of Pakistan
JSR	Jaglot Skardu Road
LP	Lean Practices / Principles
MES	Military Engineering Service
PEC	Pakistan Engineering Council
TFV	Transformation, Flow, Value
MRB	Multi-story Residential Building

ABSTRACT

The world's resources are gradually depleting due to human activity specially construction. Relatively stagnant productivity and waste have made construction projects vulnerable to cost and time overrun, and sustainability issues, which can be potentially addressed by using Lean Construction (LC) to remove inefficiencies and wasteful practices. Generally lean construction is considered as a complex phenomenon with difficulties in implementing it in existing system. Therefore, an effort has been made in this study to check the efficacy of implementing LC in construction projects. The projects that are completed within the cost and time are selected and compared with the projects that were completed late or with cost overrun. LC practices are then compared with both type of construction projects to streamline the practices of LC that have been followed respectively. Case study is developed for each of these projects. The important conclusions drawn by the comparison of these projects are further validated using a construction industry survey. The data collected from the survey is analyzed using different statistical tools for which software like SPSS and MS Excel are used. The result would indicate the potentials and benefits of LC if implemented in true spirits. Finally suitable recommendations for implementing LC in Pakistan based on the actual project scenarios would be formulated. The outcome of this research would help construction industry in reducing waste, improving productivity and duly meeting the goals of sustainability.

Chapter 1

INTRODUCTION

1.1 Background

Construction industry has always been prone to wastages. Almost every construction project has to face cost overrun and delays. Construction industry of Pakistan is facing serious issues in terms of wastage and project management. Pakistan is already facing shortage of resources such as raw material, artificial resources and skilled manpower, wastage in construction sector is making the situation worse. A lot of efforts have been implemented in Pakistan to manage the project delays and wastage but unfortunately the problem remained the same.

The traditional or conventional project management practices followed involves preparation of drawings and specifications by architects or engineers that are delivered to the client with a warranty that the design is complete and free from defects. The client then puts up the project for bidding, and after the bidding process the lowest bidder is selected for the execution of project. The construction documents are handed over to the contractor and a distant relation starts with the architect and engineer. For each problem in the project documents, contractor Requests for Information (RFI), each RFI takes a lot of time, which results in lower productivity and sometimes leads to bitter relations between the stakeholders. Various consultants supervise the quality of the construction, which the contractor must ensure. Often the quality of the work done by contractor is not up to the mark, which results in re-work causing wastage of resources and resulting in delays. As time, money and resources are interrelated, each influence the overall success of the project. This clearly indicates the importance of coordination between the stakeholders in all phases of the project. Bad work quality also increases the potential of workforce shortage during the execution of project, which result in cost overruns. Quality work force is yet another problem faced by under-developed countries like Pakistan. Health and safety related problems if confronted become very difficult to control, for example, in the current COVID-19 environment the construction projects have faced unplanned delays due to quarantine periods, closure of markets and strict COVID SOPs.

According to statistics, Productivity in the construction industry falls behind manufacturing. Some researchers have concluded that the integration of manufacturing into the construction industry, for example, by using prefabricated building materials, we can reduce the time and effort required. With the advancement of computer and information technology, the

construction industry integrated computer software into the construction processes, which aimed to reduce fragmentation in the construction (Koskela, 1992).

To find better solutions, a significant shift was the use of lean management principles followed by Toyota, which enhanced its productivity manifolds, formally known as the Lean Construction Principles. These principles differ in creating an environment of better coordination, minimizing waste, better sustainability, lesser overall cost and time, better quality, optimum utilization of resources, etc.

1.2 Objectives

1. To study lean construction principles and techniques.
2. To check the feasibility of lean construction practices in Pakistan.
3. To analyze lean construction practices followed by firms in Pakistan.
4. To give recommendations based on findings to construction industry of Pakistan.

1.3 Justification of the Topic

The solution provided can be easily adopted by construction industry, because the outcomes are based on the practices of real time projects that have already adopted Lean Construction Management. It can be further augmented with some previous findings. The construction industry in Pakistan is already following around 30 to 40 percent of LC principles without even knowing the concept. However, they are implementing it in haphazard manner. So, the solution provided by this study is not something new but it focuses on managing the existing practices in the same way as they are implemented in Lean Environment.

1.4 Advantages

Clients and contractors will be the necessitous of LC because they have to control their economy as well as meet their business objectives effectively. Pakistan's construction sectors provide up to 380 Bn Pkr in GDP with value of 944 Bn Pkr in 2020 and by the year 2029, construction industry value can reach 2705.5 Bn Pkr. Considering a likely cost overrun of 30 percent, the wastage would be enormous. So, Complete construction industry of Pakistan can improve its productivity by using the outcomes of this study.

The outcomes of this study will provide a workable solution for implementing Lean Construction. By comparing the practices done in the best projects with the relatively average project, this study would provide a reasonable solution to the construction industry of Pakistan.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

This chapter aims to discuss the different aspects of lean construction and why this topic is being discussed. It will present lean construction knowledge, origin, principles, and application in the construction industry. This chapter will elaborate on the benefits that the construction industry of Pakistan can achieve by adopting the new construction management philosophy i.e., Lean Construction. In Pakistan, lean construction principles are not being followed as standards. However, a history of some recent successful projects completed in Pakistan reflects that some principles of lean construction are being followed.

2.2 Problems in the construction industry of Pakistan

Even though time is most important in managing projects. Overall project delays are a global problem that has persisted for decades in the construction sector. Unfortunately, not much study is available regarding the project setbacks faced by Pakistan, that are causing serious troubles for the projects. Generally, In Pakistan, 80% of building projects are rescheduled due to delays, cost overruns, disagreements, and other issues. Delays can occur for various reasons, including late decision-making, late payments, an inaccurate schedule, bad planning, a lack of cooperation among stakeholders involved, revisions, mismanagement, design problems, and so on. The same issues may apply to Pakistan's construction sector (Haseeb et al., 2012). The terrible performance of construction projects compels the industry to reconsider current construction management practices (L Koskela, 1992).

The construction industry of Pakistan is facing delays in projects, mainly due to the issues related to the clients (Haseeb et al., 2012). The project sponsor or client must have outstanding economic ability and financial resources for the project, combined with a great sense of decision making. Timely funding is crucial for finishing the project within time. In conventional project management, any alteration in the project documents causes delay and increases the project cost. Such changes are called change orders. Change orders mighty also become a cause of dispute among the key stakeholder, further aggravating the situation. One of the primary issues Pakistan and the whole world’s construction sector is now confronting is a labor shortage. There may be several causes for this issue, but the most relevant reason in

case of Pakistan is the non-availability of skilled labor. A lack of trained workers emerges when the demand for labor rises (Ul Haq, 2013). Non trained workers adversely affect the quality of the project. Due to this reason, rework or change in the project occurs. Construction costs can be significantly reduced by executing a good quality job and preventing rework (Love & Irani, 2003). Construction wastes are unavoidable, but they can be decreased. The efficiency, cost, productivity, and timely completion of a project are all intimately related to following factors (Lauri Koskela et al., 2013).

1) Transport
2) Non-Value adding activities
3) Excess inventory
4) Movement
5) Waiting
6) Overproduction
7) Defects

Pakistan is a developing country with law-and-order issues, inflation, and a power shortage, which negatively influence the construction sector. Exchange currency fluctuations, weather patterns, civil unrest violence, and delayed approval are the top most crucial risks for completing a project on time (Razzaq et al., 2016).

2.3 Origin of Lean Concept and Lean Production

Consumers and competitors are exerting pressure on businesses throughout the globe. Increased product quality, shortening of the delivery time and reduced prices are every customer’s expectation. To remain competitive in the global marketplace, businesses must employ innovative manufacturing techniques. Ohno, a young Toyota Production System (TPS) engineer originally proposed the new production philosophy's concepts in Japan back in the 1950s. After World War II, Japan developed a technique that produced vehicles in tiny batches, unlike mass manufacturing. The Toyota Production System (TPS) or lean manufacturing was created due to the company's realization that mass production was inefficient and needed to be replaced. Implementing this new manufacturing method would be more productive and will result in more profit and lowered costs. All non-value activities and processes must be eliminated to come up to consumer’s desires. This can be done by removing all non-value activities to generate a product, which will increase efficiency and productivity and minimize the cost of production for the organization.

In the early 1990s, a philosophy, known as Lean Production, became the norm. Krafcik (1988) invented the word "Lean" to underline the idea of minimizing inventory and surplus labor, in contrast to other automakers "buffered" techniques.

When Koskela first introduced this theory of production in the construction sector in 1992, he introduced the notion of lean as a production management model that took three essential aspects of production: transformation, flow, and value creation (Aziz & Hafez, 2013). Through this approach, lean construction emerged as a new discipline in today's construction management landscape.

2.4 Inception of Lean Construction

The world's construction industry spends an estimated $10 trillion on construction-related services each year. There is $1.6 trillion deficit in the sector's productivity, resulting in a lack of progress compared to other businesses.

New technologies are the most critical variables in the construction sector's growth. However, despite the many improvements made to the industry's productivity over the past four decades, demand for construction services continues to outpace supply, resulting in a global downturn. Project delays and cost overruns are the most significant problems afflicting the global construction sector. The project's cost and time overruns can be improved from lean planning and management. Complex projects are also thought to be the source of delays and cost overruns since the standard construction management strategy is inadequate to handle various interactions between activities in complex projects.

In 1992, lean principles were established to help manage complicated projects more effectively (Lauri Koskela, 1992). When it came to building, he used lean production principles. He developed a new model of production management that included three distinct but interdependent methods of thinking about the production: (1) transformation, (2) flow, and (3) value creation. Lean construction was born out of this three-tiered vision of the production, which has supplanted the transformation-dominated construction management of today. Lean construction management differs from typical contemporary practice. It has a clear set of delivery process objectives; it aims to maximize effectiveness for the consumer, design features process contemporaneously and applies quality control procedures throughout the life of the task. There must be a thorough understanding of the physics of manufacturing, and how supplying and assembly chains interact with each other. Defining success criteria and developing methods for attaining and implementing these objectives are essential parts of lean

construction planning. A project's control and learning are two sides of the same coin that keep circling during the project's duration. It has been proven that the Lean Production concepts and methodologies can be applied in a variety of ways to improve construction management practices and bring numerous advantages, making the projects more stable and less challenging for all decision-makers by minimizing correlations to identify and eliminate waste, thus making the construction projects more sustainable and less chaotic for all involved parties.

2.5 Fundamentals and Principles of Lean Construction

This study looked into the history and origins of Lean Construction and its present application in the field. Many definitions of Lean Construction have been discovered, reflecting both the positive growth and diversity of lean methodology. The productivity and quality philosophy to the construction sector is to improve the quick adoption of new principles (Marhani et al., 2013).

Lean Construction is a production management system built on a new way of thinking focused on increasing the value of a construction project. Efforts to improve the project's value include cost savings, assuring high quality of the end product, increasing the confidence and safety of construction employees, and ensuring the project's long-term viability. For more holistic approaches, connecting LC key principles with other vital areas like health and safety, six sigma, and emergency management was required.

According to the existing literature, the beginning of safety and health, six sigma evaluation into a construction project will facilitate the construction project in controlling and guaranteeing their health, interacting with features and strategies, and ultimately increasing their performance. Furthermore, including an environmental management system (EMS) into the core ideas of Lean Construction will boost customer satisfaction while simultaneously lowering construction waste production. Because most of the fundamental principles are intertwined, contractors must utilize the "appropriate instrument at the appropriate time" to complete the job. Due to the limited amount of research that has been done on the conventional method of Lean Construction core concepts so far, there is an urgent need for additional research in this area. The prospects of merging safety and health, six sigma, and emergency medical services (EMS) into key Lean Construction concepts are still yet to be explored (Sami Abdelhamid et al., 2008).

According to the explanation above, there are seven significant impediments to Lean Construction implementation: managerial aspects, technical aspects, human attitude aspects,

Lean Construction process aspects, educational aspects, government aspects and financial aspects. To overcome these challenges, good tactics are vital while applying Lean Construction. The creation of structured training and research initiatives on Lean Construction and collaboration among construction companies are only a few examples. It is possible to instill proactive contact between stakeholders, which has resulted in a healthy competitive climate among partnership companies. It is envisaged that by incorporating Lean Construction into local construction management systems, the sector will accept the new understanding of LC, leading to a more sustainable and bright future for the Pakistan construction industry.

By studying their activities on-site, future research in this area will be undertaken on construction organizations implementing the Lean Construction idea. The actual core concept used in building projects can be investigated using a proper methodology based on the research. "Lean construction approach provide safer, faster, and higher-quality work, as well as less stressful experiences for all stakeholders". The implementation and effectiveness of Lean Construction conversion efforts will rely heavily on developing capabilities. It's important to understand that slight changes are systemic, not evolutionary, in the sense that everything has to change. As a result, construction industry must be patient with their implementation efforts and recognize that benefits will take time to realize fully. Continual and simultaneous improvement and change in what we create and how we do it is the heart of lean construction approach. The Lean Construction principles used in this study are enumerated and explained at appendix 1 attached at the end of this document.

2.6 Tools of Lean Construction Management

The construction sector may benefit from technologies developed for lean manufacturing that are translated and used. These instruments are used at various phases of the building process to accomplish multiple objectives across multiple work areas. These instruments make it possible to:

1. Evaluate the existing state of the project's progress and identify potential areas for improvement.
2. Create clear expectations for other actors and set clear objectives for them to attain to set an example for them.
3. Communication between the various actors should be done as efficiently as possible to eliminate time lag and identify potential confrontations rather than be subjected to them.
4. Identify, measure, and manage critical performance indicators.

5. Make improvements to the achievements and learn from the errors.

The following is a list of the essential tools addressed and their purposes and areas of interest.

2.6.1 Lean Project Delivery System (LPDS)

In 2000, Glenn Ballard introduced the lean Project Delivery System simultaneously. LPDS is a delivery strategy in which working groups support clients in acquiring precisely what they seek, rather than just realizing or carrying out activities. As it is a transitional production process, LPDS has been labelled a "Construction Production System". LPDS, in contrast to typical project delivery systems, identifies responsibilities and obligations immediately at the start of the project. It is a collection of interrelated functions, choice criteria, a strategy for execution, application aids and tools, which comprises the software and idea created by Ballard to help in the seamless deployment of Lean Construction on a construction production and manufacturing system. The stakeholders in LPDS are closely linked from the start of the project to maximize value and minimize waste.

2.6.2 Last Planner System (LPS)

Most construction project problems are caused by insufficient planning and control methods. Proper monitoring and scheduling systems are essential to ensure that operations operate smoothly throughout the project to improve the efficiency of the construction sector. Precise and efficient planning defines the procedures and criteria to attain the objectives and targets. Control ensures that each processor event happens in the sequence or series of events that have been defined by careful and efficient planning. The Last Planner System is one of the approaches connected with the pull approach.

When it comes to project management and the ongoing monitoring of planning efficiency, LPS is one of the most effective tools available. It supports creating a plan, which helps streamline the workflow by decreasing the variety and uncertainties that might be detrimental to the construction project's progress. It is a way to concentrate on project factors while also creating and understanding workflow processes. Creating a more efficient timetable for construction activities by organizing budget constraints and worker capabilities and increasing communication throughout the planning process is a primary aim of the Local Planning System. LPS is divided into the workflow section and the production section.

Several subcomponents are often used in the LPS. These components include a master plan, phases, look-ahead planning, weekly project scheduling, and the Percent Plan Completion

(PPC), which is critical to LPS performance and key to LPS success. PPC evaluates just the effectiveness of planning, not the productivity or output of the organization; nonetheless, it has an indirect influence on both production and productivity. Using a pull strategy to manufacture products in lean construction is among the most powerful tools you may have in your toolbox.

2.6.3 Just-in-Time

Using a pull approach as a manufacturing method is one of the essential tools of lean construction. Just-in-time (JIT) is one of the linked strategies to the pull strategy, and it simply means producing what is required, when it is necessary, and in quantity needed. It is a pull system that responds to actual consumer demand, resulting in lower stocks, material waste, and storage problems. It's also the most advanced and widely utilized lean construction technology for eliminating non-value-added tasks. It is founded on the idea that any stock on the site that does not provide value to clients is deemed waste. It indicates that when the material and equipment for the manufacturing are required or necessary, they must be provided.

2.6.4 Continuous Improvement

It minimizes unpredictability and optimizes workflow that begins at the start of a project and continues until it is completed. Process improvement and operation improvement are the two types of continuous improvement in construction projects.

2.6.4.1 Process Improvement

Simply said, it involves devising a more efficient technique of delivering the project to improve the overall process by shortening the lead time. The primary goal of process improvement is to shorten lead times, decrease waste, increase productivity, and make the process more visible and straightforward.

1) Present State Mapping depicts the current state of the project process, including any delays, disruptions, or waste.
2) Future State Mapping is the process of applying required lean approaches to a strategy to make it more effective so that workflows become more efficient; waste are eliminated, delays are avoided, roles and responsibilities are defined.

2.6.4.2 Operation Improvement

It is about improving the execution phase. The primary goal of operational improvement is to minimize cycle time by eliminating stages that do not add value to the activity. Additionally,

increasing production, minimizing faults immediately correcting the problem, monitoring and managing performance, and optimizing resources (Management & Rose, 2019).

2.6.5 Visual Management

Visual management is the primary method for improving and increasing transparency on the construction site. VM is one of the most essential Lean construction transparency principal instruments. It is the visual representation of the data on the website. Some of the most used VM tools on the construction site are:

1. Site Layout and Fencing
2. 5´s Technique
3. Visual Performance Boards
4. Standardization of the Workplace Elements
5. Pull Production through Kanban
6. Production Levelling through Heijunka Box
7. Prototyping and Sampling
8. Visual Signs
9. Visual Work Facilitator
10. Visualization of the VSM and Work Schedule

2.6.6 Takt Time Planning

The term "Takt" means "beat" in German. The unit of time in which a product must be produced (supply rate) to match its requested pace is known as takt-time (Demand rate). The primary goal of takt-time planning is to achieve a more consistent activities flow. Takt-time planning is a work organization that relies on the location-based management system (LBMS) to keep activities or work consistently. In building projects, the takt-time is the rate at which the construction work will be completed; when the production rate in a construction project exceeds the takt-time, the buffer time is extended so that it does not become waste. Suppose the production rate in construction projects is less than or slower than the needed takt-time, and the activities take longer to complete. In that case, this delays the following actions, lowering the output rate demanded by consumers.

2.6.7 Heijunka

Levelling is referred to as heijunka in Japanese. It's a lean strategy for reducing variation and unevenness in the manufacturing process while also reducing the risk of overburdening. It

assists in controlling fluctuations in consumer demand and maximizing the use of resources and labor. Implementing heijunka allows companies to stop producing in batches and instead respond to consumer demand, lowering inventory costs associated with maintaining or holding resources and products while orders are low. Even when the market is excellent, Heijunka is to carry out the process or flow of work at a takt-time.

Heijunka boxes are used as a virtualization and scheduling tool. A Heijunka box is a wall schedule made up of a grid of boxes where each box symbolizes the same length of time known as the takt time. Kanban cards, which are colored cards that indicate the things expected to be created at that time, are employed.

2.6.8 Kanban

Kanban is a JIT technique that was utilized in the automotive industry. It is a Japanese word for "visual cards". Kanban is a pull strategy that starts as a work order and is mainly used to keep materials flowing smoothly. Kanban is used in the construction sector to organise orders and serve as a visual management tool to improve communication among all stakeholders and ensure that the proper material or items are delivered in the right amount and at the right time.

2.6.9 Go and See

It's a process improvement tool that's tied to the lean agency. For the application, you have to identify the source of the problem. Once the cause of the problem has been determined, there are a variety of ways to participate in the process, including:

1. Hands-on experience
2. Observations
3. Interviews and Surveys
4. Reports

2.7 Application of Lean Principles in Construction

Every industry's business goals and priorities are the same, whether in manufacturing or construction: increase operational efficiency, eliminate inventory difficulties, reduce mistakes, and complete projects on time (Ayalew & Dakhli, 2016). Unpredictability is typical in construction projects due to many factors, including fluctuating weather conditions, untrustworthy suppliers, continually changing inventory needs and labor shortage. All these issues hinder building project development and should be avoided at all costs.

Lean construction emphasizes producing value throughout the project's life cycle, even as markets, technology, and methodologies change and business processes adapt. On the other hand, traditional building necessitates the centralization of all activities and a predetermined schedule. All activities in lean construction are synchronized utilizing pulling and continuous flow rather than pulling and halting. Lean construction's decentralized decision-making architecture encourages transparency and accountability by providing up-to-date information to all stakeholders, allowing them to take the appropriate action in the proper time to achieve the intended objective (Angelis & Fernandes, 2012).

A typical example of lean construction in action. The team applied lean building techniques to stay on schedule, maximize value, and reduce waste. The $78 million Marybelle and Sebastian P. Musco Center in California!

2.7.1 Application based on six Fundamental Principles of Lean Construction

There is no one-size-fits-all strategy for construction project management since no two construction projects are identical. Instead, various technologies and tactics are used to reduce building timetables, minimize waste, and reduce labor costs while enhancing productivity and efficiency (Byrne et al., 2007). On the other hand, the following are critical elements of lean construction:

2.7.1.1 Identifying Value from the Client's Viewpoint

Research shows that the only thing that counts in construction is what the customer wants, exactly what the specifications suggest by looking beyond what is to be created and understanding why lean construction prioritizes what the customer values.

Recognizing the client's perspective early in the planning phase and bringing all stakeholders together ensures that the customer gets exactly what they want. The engineer, architect, homeowner, contractor, supervisor, and suppliers may offer input and assist in bringing the plans into reality while ensuring correct execution, if they have a thorough grasp of the customer's demands.

2.7.1.2 Implementing Processes that Deliver True Value

To produce a value stream, one has to execute what the consumer values. Consequently, after values are defined from the client's viewpoint, one should create the processes and procedures that will be utilized to provide it, as well as correctly record each step (Tyagi et al., 2015).

Every aspect of the strategy should be assessed, from individuals to supplies to equipment, and also any activities that do not provide value should be eliminated right away.

2.7.2.3 Eliminating Waste at Every Point Possible

Lean construction's goal is to remove waste wherever feasible (Tyagi et al., 2015). This is accomplished by concentrating on seven key areas:

1. Transportation
2. Inventory
3. Wait Time
4. Utilization of Resources
5. Movement
6. Over Production
7. Excess Processing

2.7.2.4 Achieving a Collaborative and Continuous Workflow from Start to Finish

The ultimate objective of lean construction is to create a process that is both quick, efficient, consistent and reliable. Unlike conventional construction techniques, each stage of the lean construction process is meticulously planned and executed. Construction workers, for example, would not begin hanging drywall in a room until all plumbing and electrical work had been completed. To avoid delays and disruptions, all participants in the process must communicate and engage at all stages.

2.7.2.5 Using Pull Planning and Scheduling for a Streamlined Approach

Construction operations must be completed in response to downstream demand to provide a continuous and predictable workflow (Hines et al., 2006). According to lean construction principles, the most efficient approach is pull planning or scheduling, enabling participants to work closely together and promptly complete work. This entails establishing a definite deadline and sticking to it throughout the project's lifespan.

2.7.2.6 Continuous Monitoring and Optimization

The lean construction concept places a strong focus on continuous improvement, which offers the following benefits:

1. High-quality construction

2. Enhanced safety
3. Improved productivity
4. Better risk management
5. Reduced waste
6. Greater customer satisfaction
7. Fast track project delivery
8. Maximum returns

Like any other industry, construction relies on long-standing practices and is resistant to change. The many advantages of implementing lean principles, on the other hand, are forcing construction businesses to take up the challenge, change their current techniques, and invest in new construction equipment to stay up with demand. This might have far-reaching effects, which become apparent when projects are finished in time, within the budget and also provides total client satisfaction.

The Interdisciplinary Science and Technology Building in Arizona, which combined lean construction with building information modelling to save $2 million and 16 weeks on the project's timetable, is another real-world example of continuous improvement (Calantone et al., 2002).

2.8 Lean construction practices used around the globe

Lean construction is a strategy used in the construction industry to handle non-value-added operations and creation of physical and non-physical waste. Lean construction refers to a collection of methodologies and processes that may increase the productivity of construction projects considerably. The lean construction idea may be effectively implemented in the construction sector because of eleven well-established lean construction principles. Lean construction is a relatively new concept in Pakistan's building industry (Kayode et al., 2019).

It is true that reducing construction waste and boosting efficiency may minimize total project costs. Lean construction focuses on reducing project costs as low as feasible by acquiring fewer expenditures. The notion has gained considerable adoption in the construction sector throughout the globe. The Lean Building movement has offered construction professionals several tools and ideas for improving efficiency at different stages of a project (Memon et al., 2018).

This study looked at lean practices in Pakistan in relation to worldwide trends. The paper investigates and evaluates the possible advantages of using it in building projects and the

acceptability of various tools and techniques. The study aimed to gather information from four different categories of stakeholders: clients, consultants, contractors, and material suppliers. According to the research conclusions, the main lean methods used in the local construction sector today include the pull approach, standard of work, time-consuming, visualization tools, integrated project delivery strategies, and quality failure within acceptable boundaries. While minimizing waste has various benefits, increased customer satisfaction, improved communication, visual control, and better task management are the most essential benefits of lean construction to produce acceptable work (Khaskheli et al., 2020).

According to the study, the most significant component is waste reduction, followed by customer satisfaction, enhanced communication, efficient work management and visual controls, which are ranked third and fourth, respectively. As previously mentioned, waste is defined as time-consuming operations that add no value to a project and is the primary source of expenditures exceeding the original budget. Therefore, lean construction management techniques generate more profits than conventional methods. According to the results, almost all lean tools and practices are employed in the construction sector; however, they are not completely implemented due to a lack of support from construction organizations and lack of research on lean construction. Many individuals who use these strategies have no idea why they were invented in the first place.

While lean construction is still in its early stages, substantial progress has been made, and more work will be required to integrate Lean ideas completely. Three broadly accepted concepts emerged from the stakeholder survey: focusing control on the whole process, simplifying the process by lowering the number of stages and components, and boosting process transparency. Reducing variability, enhancing process transparency, and balancing flow and conversion improvements are all examples of lean construction approaches (Memon et al., 2018). By putting solid principles into practice, the whole performance of the construction industry may be improved.

2.9 Adaptability of Lean Construction in Pakistan Construction Industry

Around the globe, the building sector is seeing rapid growth. The construction industry is responsible for a significant portion of the economy in many countries worldwide. The construction sector is expected to be developed by 70% between 2013 and 2025, according to the "Construction 2025" an industrial plan paper produced by the United Kingdom government from 2013 to 2025. On the other hand, this business is connected with several risks, such as

environmental contamination, waste creation, and energy usage. Aside from them, management concerns, escalation, time and expense overruns are constant sources of fear for those connected to this industry. Lean construction refers to applying lean concepts at the operational level, during integrated delivery stages, in strategic decision-making, in leadership decisions, in transformational change, and on the job site for the management in the construction industry and other utilities, among other things (Memon et al., 2018). In recent years, lean construction has emerged as a hot issue among scholars throughout the globe, and it is widely regarded as a strategy or idea that should be used to boost productivity in the construction industry by decreasing waste during the building process.

By reducing construction waste and improving efficiency, the construction industry is working to lower the overall cost. This attitude has acquired a great deal of appeal in recent years, particularly in the construction industry. It has provided practitioners with various tools and approaches to use at different phases of a building project to help them apply Lean Construction practices. (Memon et al., 2018). The introduction of numerous technologies and procedures has benefited Pakistan's building projects business. Clients, consultants, contractors, and material suppliers are the four types of shareholders in the company. Waste reduction, customer satisfaction, improved communication, visual control, and effective task management to produce suitable work are just a few of the many primary advantages of lean construction. Other benefits of lean construction include faster construction and lower costs. There has been a relatively little investigative, experimental, and theoretical study on Pakistan's lean building methods and techniques. There is a need for quantitative research that focuses on identifying and assessing the current state of the degree of Implementation of Lean Techniques and the advantages of lean construction in construction projects. (Memon et al., 2018). There is an urgent need to determine the degree of execution of different lean tools and approaches and analyze the many advantages obtained via lean construction.

Many construction companies have adopted a few lean construction practices to expedite projects' completion. For example, Frontier Works Organization, Pakistan's construction giant, has adopted a few lean construction practices in projects such as "Construction of IHITC in Islamabad" during the Covid-19 pandemic to expedite project completion. This company achieved outstanding achievements while minimizing time and expense and increasing interdepartmental collaboration to the maximum.

Chapter 3

METHODOLOGY

3.1 Method

Due to the complexity of the concept of LC and its multifaceted nature originating from the lean characteristics, measuring the efficacy of LC is a challenging task. For this purpose, data collection from Pakistan's construction industry was required. In order to get the data, a questionnaire was developed based on LC principles that comprises of 31 questions. 27 questions were based on the principles of LC and remaining 4 questions were based on the project outputs i.e., delays, cost-overruns, quality and re-works and health/safety issues. The purpose of this questionnaire was to do market research to analyze the LC principles implementation and efficacy of LC principles in construction industry of Pakistan. 220 questionnaires were sent to individuals at management level in different construction firms of Pakistan out of which 72 questionnaires were received. 5 projects were selected for case studies whose collected data validated the result performed by test. The interviews were conducted face to face whereas market research was conducted online. The interviews were based on 16 questions. Out of these 16 questions 12 were linked with the LC principles while remaining 4 were related to the actual outputs of these projects. Schematic layout of the research methodology used in this research is given in Figure 3.1. After the preliminary study, detailed literature review is carried out and a number of already developed questionnaires were examined.

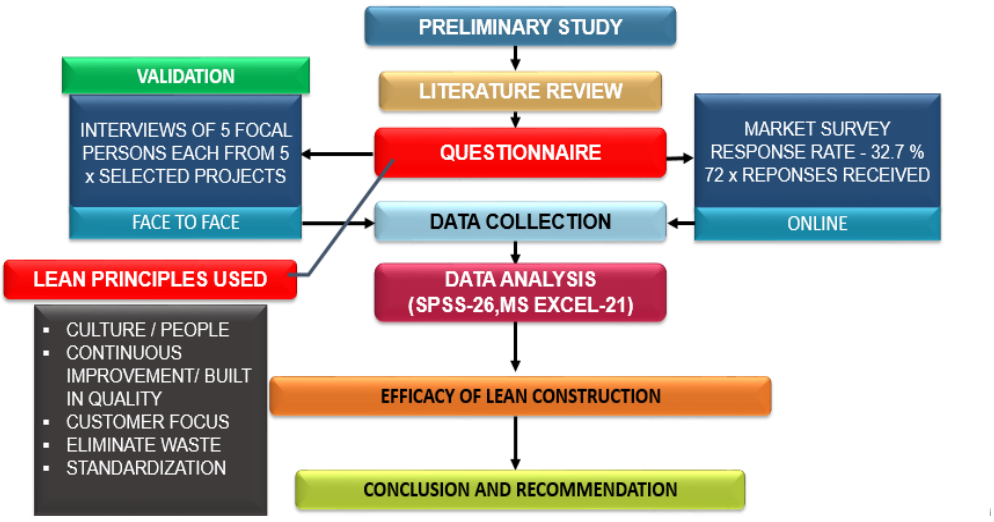

Figure 3. 1 Research Methodology

3.2 QUESTIONNAIRE PREPRATION

3.2.1 INTERVIEWS

Face to face interviews were conducted in office and site of 5 selected construction projects for respective case studies. These interviews were having 16 questions. 12 questions were based on the LC principles and remaining 4 were based on the real time outputs of the respective projects. The purpose of this was to prepare case studies of the respective projects to validate the result performed by test. Aim of these interviews is to relate the LC principles with the real time outputs of the respective projects. A sample question of the LC principal question is as under: -

Was coordination and cooperation among all the departments, like mechanical, electrical, architectural, civil, design, etc., given enough importance to minimize the internal conflicts?																			
Score																			
-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10

Questions were asked from employees and the interview worksheet, that is attached as Appendix 2, was filled in. A positive score means LC practices were followed and a negative score means that the respective LC practice was not followed by the firm during the project execution. For example, a positive 8 means 80% practice was followed. A negative 4 means that the practices followed by the firm was against the respective LC principle up to an extent of 40%. A 0 means no such practice was followed. The score was given by as per judgement of the interviewer.

A sample question for the project output investigation is as under: -

Were there any cost overruns?
If yes, then: - Initially planned cost of the project: Actual cost of the project: Percentage of cost overrun:

The answers were based on real time project outputs. The purpose of these particular questions was to compare the project outputs of those projects that have greater LC following percentage to the one that followed lesser LC practices.

3.2.2 INDUSTRY SURVEY

For the survey of industry another questionnaire was developed comprising 31 questions. Out of 31 questions, 27 were based on LC principles and the remaining 4 were based on the project outputs. The survey was conducted online. Employees answered these questions at management level of different construction firms across Pakistan. It was based on the practices followed by their firms generally and particularly for any recent project undertaken by their firm. The questionnaire is attached at appendix 4. The questionnaire was developed based on the model represented by fig 3.2 as following (Diekmann et al., 2003): -

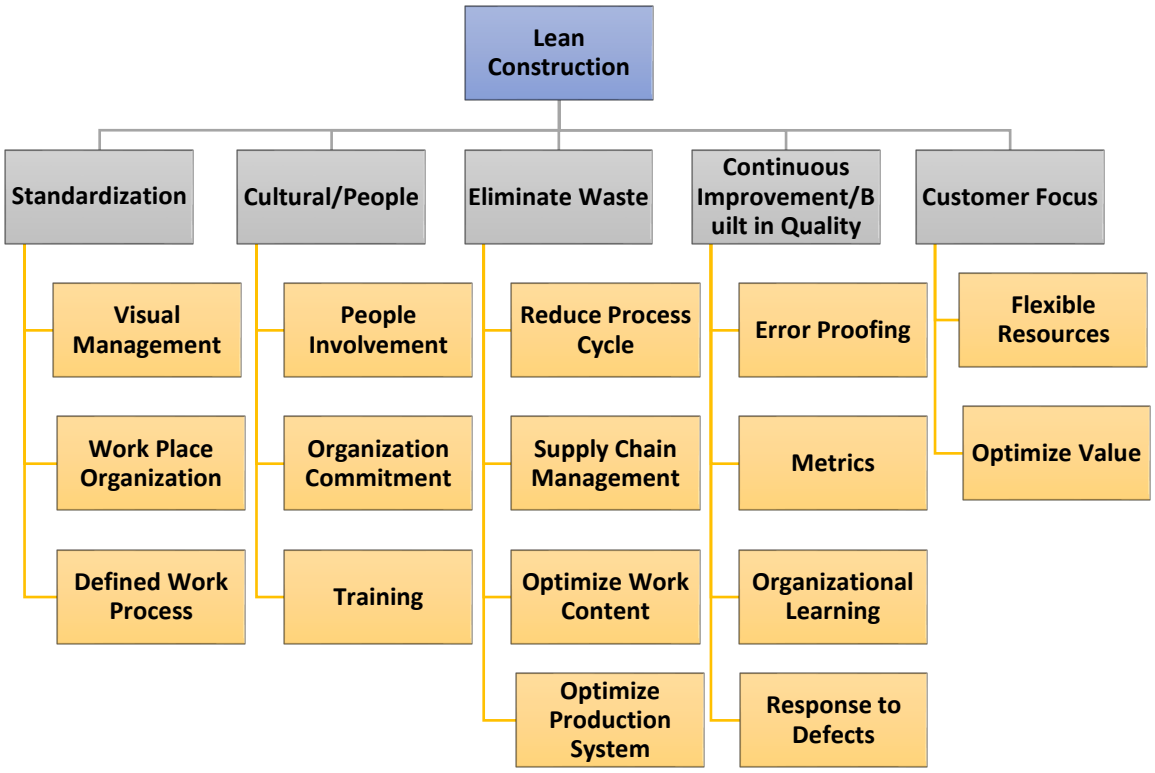

Figure 3.2 Lean Principles and Sub-Principles (Source Diekmann et al.,2003)

A sample question for investigating the LC principles is as following: -

Standard, prefabricated, preassembled, repetitively construction elements are preferred.	Never	Seldom	Sometimes	Often	Almost Always	N/A

A sample question for investigating the project output is as under: -

Project undertaken by the firm is/was not subjected to cost overruns	Never	Seldom	Sometimes	Often	Almost Always	N/A

This questionnaire was adopted to analyze the implementation of LC principles and its effect on project outputs. Each question was filled by the market experts. Answers against each question are in form of a Linkert Scale. The Linkert Scale is explained by the table 3.1.

Table 3.1 Linkert Scale

Response	Significance
Never	LC practice was never followed or the project output never happened
Seldom	LC practice was rarely followed or the project output rarely happened
Sometimes	LC practice was sometimes followed or the project output sometimes happened
Often	LC practice was frequently followed or the project output frequently happened
Almost Always	LC practice was always followed or the project output always happened
N/A	The respective question is not applicable

3.3 Sample Selection

3.3.1 Survey Sample

Statistical analysis is used after collection of relevant data. The data collection further requires the selection of a good population sample. Construction companies working in Pakistan and registered in PEC were selected for survey. There are 2462 supervisory engineers registered in PEC and employed against various construction firms in Pakistan. Effort was done to select samples from top of the enlisted firms that are actively executing construction projects around the regions of Punjab, Gilgit Baltistan and KPK. The survey was distributed among 220 individuals representing these construction firms and 72 responses were collected online.

3.3.2 Interview Sample

To investigate the LC implementation and its impact on the projects in tangible terms, interviews were conducted from 5 selected projects. Interviews were conducted face to face from employees of different tiers of the project management team. The projects were recently completed. 5 individuals were selected to be interviewed per project making a total of 25 interviews. The individuals were selected based on their responsibilities during different phases of the project specially the execution phase. Out of the 5 selected projects, 2 transportation

project and 3 building projects were chosen. Out of the 3 building projects 2 were prefabricated steel structures and 1 was RCC frame structure. The list of these projects is explained in table 3.2.

Table 3.2 Projects selected for case studies

NAME	LOCATION	TYPE
IHITC	Islamabad	Prefabricated Steel Structure
TIP	Islamabad	Prefabricated Steel Structure
High-Rise Residential Building	PAF Risalpur Cantt	RCC frame Structure
Ammar Chowk	Rawalpindi	Transportation
JSR	Gilgit-Baltistan	Transportation

3.4 Statistical Analysis Method

MS-Excel 21 and SPSS-26 were used to perform the following statistical analysis techniques with a significance level of 0.05: -

3.4.1 Tests for Normality

3.4.1.1 Skewness and Kurtosis

Data has become more vital in today's environment. A whole field of research has been devoted to the analysis and processing of data. Understanding the data from various sources and the accompanying attributes is so critical. Accordingly, the normal distribution is the most common sort of data and statistical model. It is defined by a symmetrical bell-shaped curve. The normal distribution, on the other hand, might be skewed by major factors. Skewness and kurtosis may be used to compute this distortion.

Symmetry, or more accurately, the absence of symmetry, is measured by the skewness of an object. It's symmetric if the distribution or data set appears the same on both sides of the center point. When illustrating skewness, the histogram is an excellent tool. The skewness formula for univariate data Y1, Y2,..., YN is:

$$g1 = \frac{\sum_{i=1}^{N}(Yi - \bar{Y})^3/N}{s^3}$$

In this equation, "Y is the average, s is the standard deviation, and N is the total number of data points. It is important to note that the skewness (s) is determined using the denominator N instead of N-1.

The Fisher-Pearson coefficient of skewness is the name given to this formula for skewness". The Fisher-Pearson factor of skewness is calculated by several software systems.

$$g1 = \frac{\sqrt{N(N-1)}}{N-2} \frac{\sum_{i=1}^{N}(Yi - \bar{Y})^3/N}{s^3}$$

This is a sample size modification. As N increases, the correction approaches 1, "the adjustment factor is 1.49 for N = 5, 1.19 for N = 10, 1.08 for N = 20, 1.05 for N = 30, and 1.02 for N = 100".

Skewness is always zero in a normal distribution; symmetric data should be close to zero. Data with negative skewness values have a leftward bias, whereas data with positive skewness values have a rightward bias. The left tail is longer than the right tail when tilted left. Similarly, a right-skewed distribution has a longer right tail than a left-skewed distribution. The sign of the skewness may be affected if the statistical data is multi-modal. In certain cases, the data has a lower limit and is biased to the right. A failure time cannot be negative in reliability studies for example.

The term "kurtosis" refers to the degree of heavy- or light-tailed distribution's data in comparison to a normally distributed. Outliers are more common in datasets with a high kurtosis. There are fewer outliers in data sets having low kurtosis. The worst-case scenario would be if the distribution was uniform.

For univariate data Y1, Y2, ..., YN, the formula for kurtosis is:

$$g1 = \frac{\sum_{i=1}^{N}(Yi - \bar{Y})^4/N}{s^4}$$

where "Y is the mean, s is the standard deviation, and N is the number of data points. Note that in computing the kurtosis, the standard deviation is computed using N in the denominator rather than N - 1".

3.4.1.2 Shapiro-Wilk Test

Random samples may be determined to be drawn from normally distributed distributions using the Shapiro-Wilk test. A normal curve is superimposed over the observed distribution in order to quantify the resemblance between the recorded and normal distributions. It then calculates the proportion of our sample that is similar to it: a resemblance percentage. For a final analysis, the Shapiro-Wilk test calculates the likelihood of discovering this reported similarity

percentage, or one even lower. It assumes that the distribution of the population is perfectly normal.

The test provides you a W value, which indicates that your data is normal if it has larger values. The W value may be calculated as follows:

$$W = \frac{(\sum_{i=1}^{n} a_i \, x_{(i)})^2}{\sum_{i=1}^{n} (x_i - \overline{x})^2}$$

where: xi represent the values of an ordered random sample

Covariances, variances, and means of sample (size n) are used to derive ai, which are constants.

The covariances, variances, and mean of the sample size n from a normally distributed sample are used to derive the constants ai. Because the test relies on a small sample size, there are several drawbacks. It is more probable that you will achieve a significant result if your sample size is big enough. Manually calculating the Shapiro-Wilk is quite uncommon. Doing the math may be done by a variety of programs. Significance of Shapiro-Wilk Test higher than 0.05 indicates that the data are normal. This indicates that the data is out of a normal distribution if the value is less than 0.01.

3.4.2 Relative Importance Index

When independent variables are connected, the relative relevance of predictor (independent variables) may be calculated using Relative Weight Analysis. Multicollinearity is dealt with in a different way, and the relevance rank of variables may be calculated as a result. By ranking variables according to their contribution to R-squared, it helps to answer the question, "Which variable is the most important and rank variables?" Independent variables might be difficult to forecast accurately when they are correlated. Due to our inability to accurately determine coefficients, ranking them is challenging. Statistics shows that multicollinearity may raise the coefficient estimates' standard errors, making them more vulnerable than usual to small changes in the model's parameters. In other words, the coefficients are skewed and hard to understand. With it, you may generate a new set of variables that are as closely linked to the originals as possible while being completely unrelated. The dependent variable may be projected onto this fresh set of independent variables to get a series of standardized regression coefficients since these newly transformed independent variables are not associated.

The formula for determining the relative index is as follows:

$$\mathrm{RI} = \sum \frac{w}{A*N}$$

w = the weight given to each answer

A is the heaviest.

N is the overall sample size.

For the two groups, the weighted average will be calculated based on the relative indices' (RI) rankings. High (H) (0.8 to RI = 1), medium (0.4 to RI = 1), medium-low (0.2 to 0.4) and low (0 to 0.2) are the five degrees of importance that are changed from the values of the RI values.

3.4.3 Chi Square Test

Models are compared to observable data using a chi-square (2) statistic. To calculate a Chi-square statistic, the data utilized in the calculation must be randomized, raw and mutually exclusive. Tossing a fair coin, for example, meets these requirements. In hypothesis testing, chi-square testing are often used. Because of the large number of factors at play and the small sample size, the chi-square statistic measures the extent of any discrepancy between the predicted and actual findings. Using the total number of factors and samples in the experiment, dof are used to assess if the null hypothesis may be rejected. With each statistic, the more accurate the findings are the greater the sample size.

Chi-formula Square's is as follows:

$$\mathbf{f}\chi_c^2 = \sum \frac{(Oi-Ei)^2}{Ei}$$

C is the degree of freedom

Oversight = Observed (s)

E stands for the anticipated outcome (s)

Using this procedure to get a crucial chi-square value by hand is very unusual. Every data point in your data collection will need a computation when you use the summation symbol. As you may have guessed, the computations may be quite time-consuming and laborious. Instead, you'll choose for the following technological solution:

1) SPSS's Chi Square Test.
2) Using Excel, the Chi Square P-Value.

To demonstrate the existence of a correlation between variables of two categories, the chi-square statistic is sometimes used instead. Two kinds of variables exist in statistics: countable

(numerical) variables and non-countable (categorical). Using the chi-squared statistic, you can see how large of a discrepancy exists in your observed and expected numbers if there were no association between them. Having a low chi-square score indicates that your two data sets are highly correlated. chi-square would be 0 if the observed and predicted values were equal, but this is unlikely to occur in practice. Confidence interval estimate for a population variance of a normal distribution from a standard deviation may be done using the chi squared distribution. Qualitative variables may be classified independently of each other based on two different criteria. Categorical variables and their relationships (contingency tables). When the underlying distribution is normal, a sample variance investigation may be performed. Deviations of the predicted and observed frequencies are tested for (one-way tables).

3.4.4 Independent Samples (Kruskal Wallis and One Way Anova)

To find out whether there are significant differences between three or more subgroups on your variable, the Kruskal-Wallis One-Way ANOVA is used. Each of your groups should have the same level of interest in the same subject matter. You should be able to gather enough data and separate your groups.

You may use the Kruskal–Wallis H test or one-way ANOVA on ranks to determine whether samples originate from the same distribution using a non-parametric test, all named after William Kruskal and W. Allen Wallis. It compares the results of two or more separate samples, each with a different number of individuals. Only two groups may be compared in a Mann–Whitney U test. The Kruskal–Wallis test's parametric counterpart is the one-way analysis of variance (ANOVA).

Statistical significance for the Kruskal–Wallis test indicates the presence of at least one sample that stochastically dominates the other sample. The test does not disclose where or how many groups are influenced by stochastic dominance. As a nonparametric approach, the Kruskal–Wallis test does not assume a normal distribution of the residuals, unlike the comparable one-way analysis of variance. Unless there are differences in medians, the researcher may assume an equally shaped and scaled distributions for all groups, which is the null hypothesis. The alternative hypothesis is that the medians of at least one group vary from those of at least one other group. A change in location or a dispersion of participants cannot be determined if the null hypothesis is rejected. The Mann-Whitney test is likewise susceptible to this issue.

For each set of data, the sums of rankings in each subgroup are totaled, and this yields the probability. The data is then sorted by size, from smallest (1) to biggest (N). H is the statistic.

$$H = \frac{12}{N(N+1)} \sum \frac{R_i^2}{n_i} - 3(N+1)$$

Where, "*N* is the total number, n_i is the number in the i^{th} group, and R_i is the total sum of ranks in the i^{th} group.

The chi-square distribution for k-1 degrees of freedom, where k is the number of groups, is used to test the value of H". Even if the scores are tied, a correction is applied; nonetheless, this seldom affects the outcome.

Chapter 4

ANALYSIS AND RESULTS

4.1 INTERVIEWS

The foremost objective of this study was investigation of the efficacy of some management method applicable in the construction industry of Pakistan. The construction industry of Pakistan is prone to construction wastages. An effective solution to this problem is LC management method. For this reason, a preliminary study of the construction industry of Pakistan was conducted by following ways: -

1) By visiting the recent construction projects.
2) By discussion with the engineers and managers known to the team regarding LC practices.
3) Internet.

The results of preliminary study indicated that few projects which were strictly following the conventional method of management underwent delays, cost-overruns, quality issues and health/safety issues. Another result indicated that few projects which had followed some LC practices were comparatively very successful in terms of outputs. This was the motivation behind conducting the interviews from employees of selective projects. 25 interviews were conducted, 5 per project, to investigate the LC principles followed by the respective firms during their execution. Interviews were conducted face to face at project sites/offices with important stakeholders of the respective projects. The individuals were investigated for their active involvement in the execution of their projects so that realist results could be obtained. Each project will be discussed case wise in the subsequent paragraphs.

4.1.1 CASE STUDY

For ease of analysis and interpretation of result the questions of the interview was mapped to the lean construction principles (J.E. Diekmann, 2003) and sub principles and are attached as appendix 3 whereas the interview questionnaire attached as appendix 2.

4.1.1.1 Technical Institute of Pakistan (TIP)

Tunneling Institute of Pakistan (TIP) was developed by Frontier Works Organization (FWO) in 2021. It was constructed by FWO to help strengthen the capability of the local tunneling sector, and also aid FWO in the planning, design, and implementation of all tunneling and subterranean construction projects both domestically and globally. The building is located in Shakarparian Islamabad. It is a prefabricated steel structure building. The project was

completed in approximately 6 months. The project underwent a smooth execution and there was a negligible delay in the project. There was no cost over-run in construction of TIP. The results are represented in fig 4.1 and 4.2.

The results show a high degree of LC principles followed by the firm during construction of TIP. Following 100% LC principles would be unrealistic conclusion in the current environment. The chart indicated that few LC principles trend are touching 80% which is a very high value. The results indicate that the FWO is familiar with new trends of LC approach and already applying it in some shape although not knowing that they are and also not familiar with its impact. Although if FWO had focused more on Training of workers which indicates approximately 0% value, then the project might have given much better outputs. To get an idea of the impact, average value of LC principles followed were compared to the project outputs and represented by the figure 4.1.

This indicates that more than 60% of LC principles were followed during execution of TIP. There was no cost over-runs, no health issues raised during execution of the project and a dedicated health/safety consultant was present at the site throughout the construction. There was only a delay of 1.67% in this project. Rework was done for 5 times during the execution of TIP which were minor issues. For a comparative study of the impact of LC principles, the other 4 projects shall be studied. It will be reasonable to conclude that LC practices followed by FWO during execution of TIP has led to high quality of outputs.

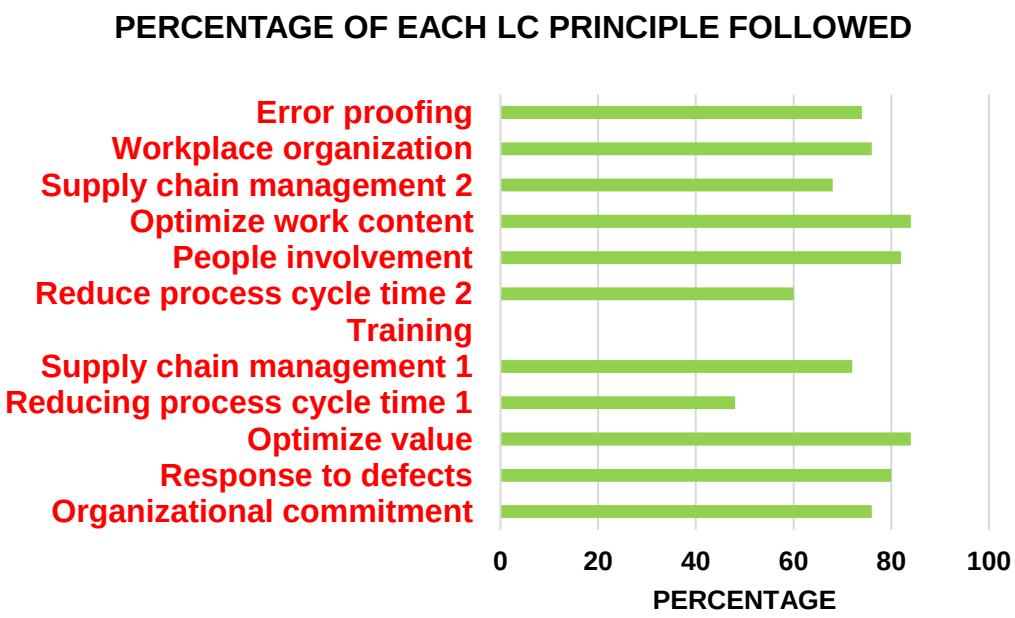

Figure 4.1 Percentage of LC Principles Followed During Construction of TIP

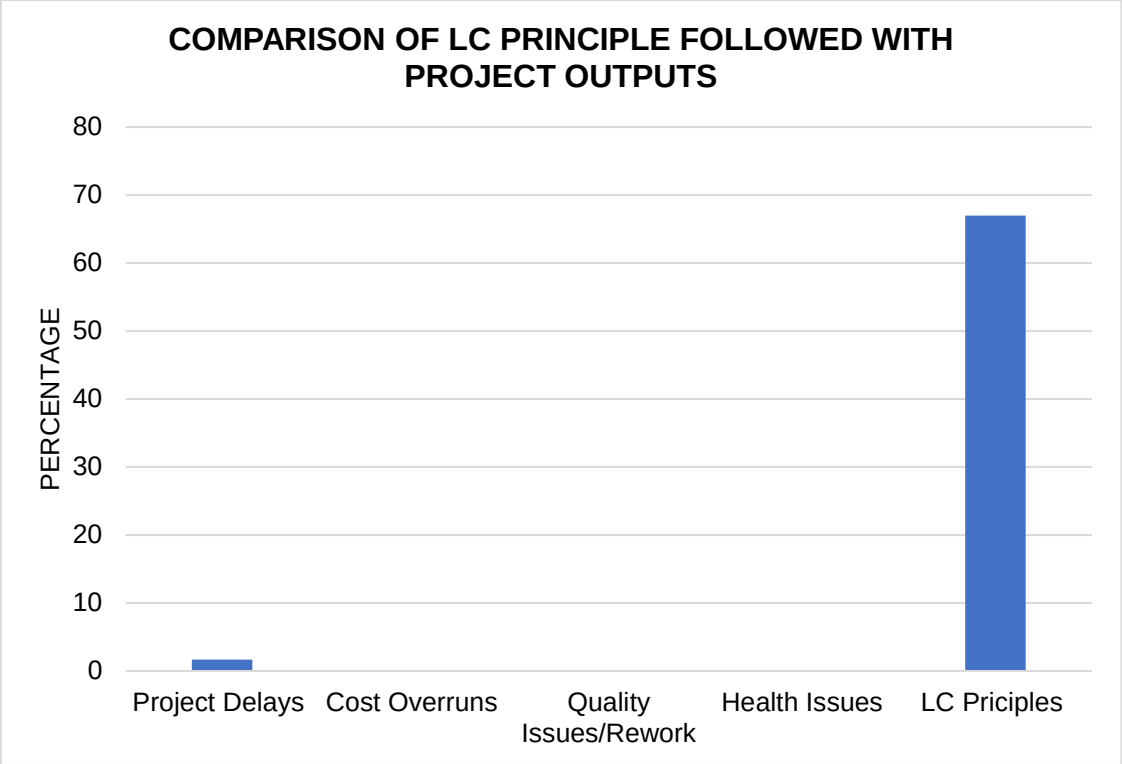

Figure 4.2 Comparison of Project Outputs of TIP With Percentage of LC Principles Followed During its Construction

4.1.1.2 Isolation Hospital and Infectious Treatment Centre (IHITC)

Isolation Hospital and Infectious Treatment Centre (IHITC) was developed by Frontier Works Organization (FWO) in 2020. It is Pakistan's first ever prefabricated hospital. It was constructed by FWO with assistance from partnering firms as specialized hospital for treating infectious diseases in Islamabad in a record time of just 40 days at a cost Rs 980 Mn to meet additional requirements to ease pressure from capital hospitals during COVID-19. Started on 26 March 2020 and completed on 10 May 2020. IHITC is 250 bedded prefabricated state of the art Isolation Hospital and Infectious Treatment Centre could be used not only for Coronavirus infected patients under best available equipment and medications, but also for treatment of other infectious diseases. The hospital spread over 40 kanals with covered area of 70,000 square feet. The project underwent different environmental and health challenges such as strict compliance of COVID-19 SOPs, all imports/exports were halted, all factories and transports were shutdown, the country was in complete lockdown situation, onset of Holy month of Ramzan and 11 days of rainfall hampered the construction activities. Even then project was completed in record time of 40 days with all these challenges. There was no cost over-run in construction of IHITC. After interviewing individuals who were key stakeholders during this project and analyzing the results following conclusion were drawn: -

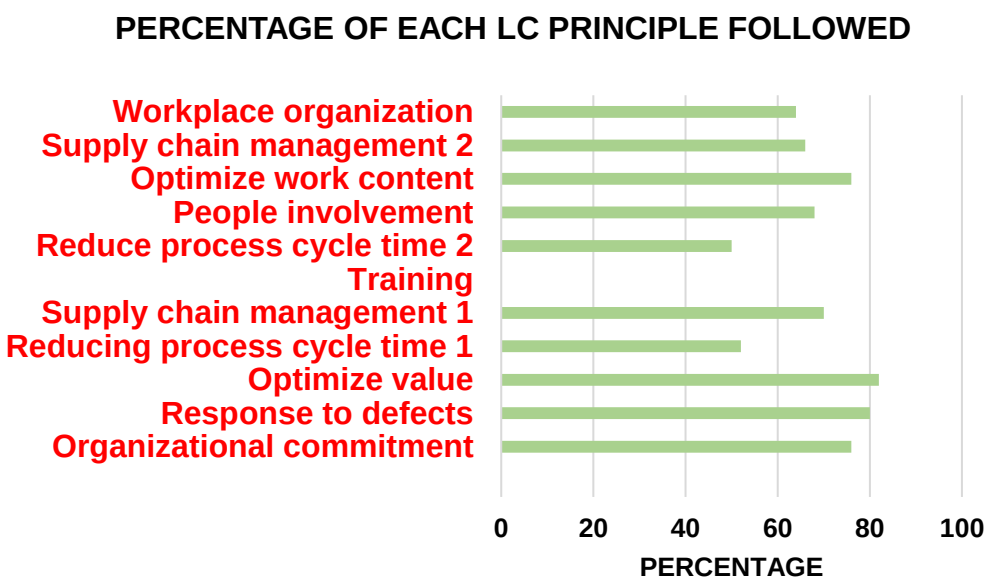

Figure 4.3 Percentages of LC Practices Followed During Construction of IHITC

Figure 4.3 shows a high degree of LC principles followed by the firm during construction of IHITC. The chart indicated that few LC principles trend are touching 80% which is a very high value. The results indicate that the FWO is familiar with new trends of LC approach and already applying it in some shape although not knowing that they are and also not familiar with its impact. Although if FWO had focused more on Training of workers which indicates 0 % value, then the project might have given much better outputs. To get an idea of the impact, average value of LC principles followed were compared to the project outputs and represented by figure 4.4.

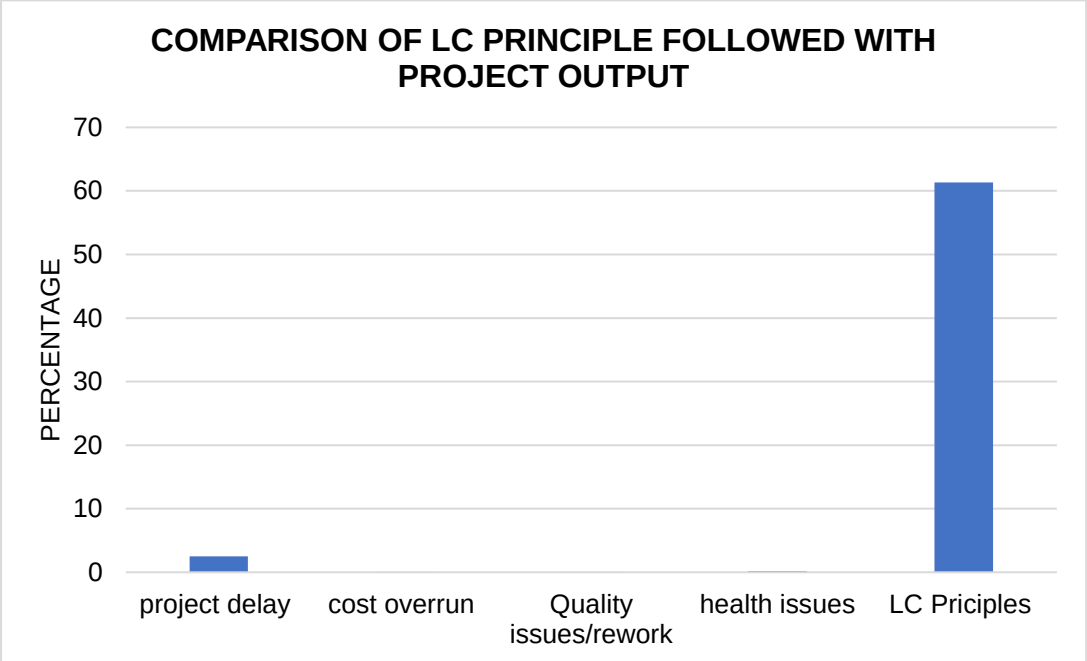

Figure 4.4 Comparison of LC Principles Followed During Construction of IHITC with the Outputs

This indicates that more than 60% of LC principles were followed during execution of IHITC. Similar method was used by FWO in construction of IHITC as it was done in TIP and high value of LC principles have led to very negligible cost over-runs, delays, quality issues and health issues. Hence unknowingly lean philosophy has been used by FWO to produce high quality of outputs.

4.1.1.3 Multi Story Building (Residential Block) for Officers at Paf Academy Asghar Khan

Construction of Multi Story Building (Residential Block) for Officers at PAF Academy Asghar Khan commenced on 4th April 2020. It was constructed by M/S Arris Associates under the supervision Military Engineers Services, PAF to help overcome the increasing shortage of residential houses for officers at PAF Academy Asghar Khan. The building is located in Shaheen residential complex Risalpur. It is a RCC frame structure building. The project was supposed to completed in 2 years. The project didn't undergo as per plan which results in a noticeable delay of 9 months. The cost over-run in construction of building was 0.03%. After interviewing individuals who were key stakeholders during this project and analyzing the results following conclusion were drawn: -

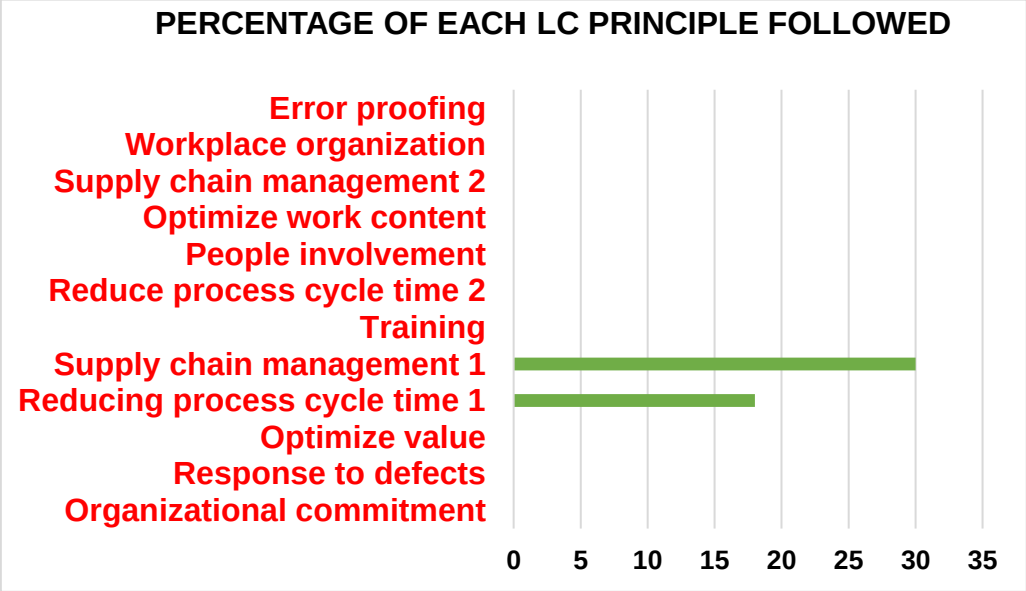

Figure 4.5 LC Practices Followed During Construction of Multistory Residential Building at Risalpur Cantt

The figure 4.5 represents results that show very few LC principles followed by the firm during construction of Multi Story Building. Only positive results were seen in project meetings which were carried out almost every day and rely on consistent suppliers. The chart indicated that very few LC practices trend are touching 20%-30% which is a very low value. The results

indicate that the construction firm is not familiar with the new trends of LC approach and also not familiar with its impact. Although if construction firm had focused more on LC principles, then the project might have given much better outputs. To get an idea of the impact, average value of LC principles followed were compared to the project outputs and represented by figure 4.6 below.

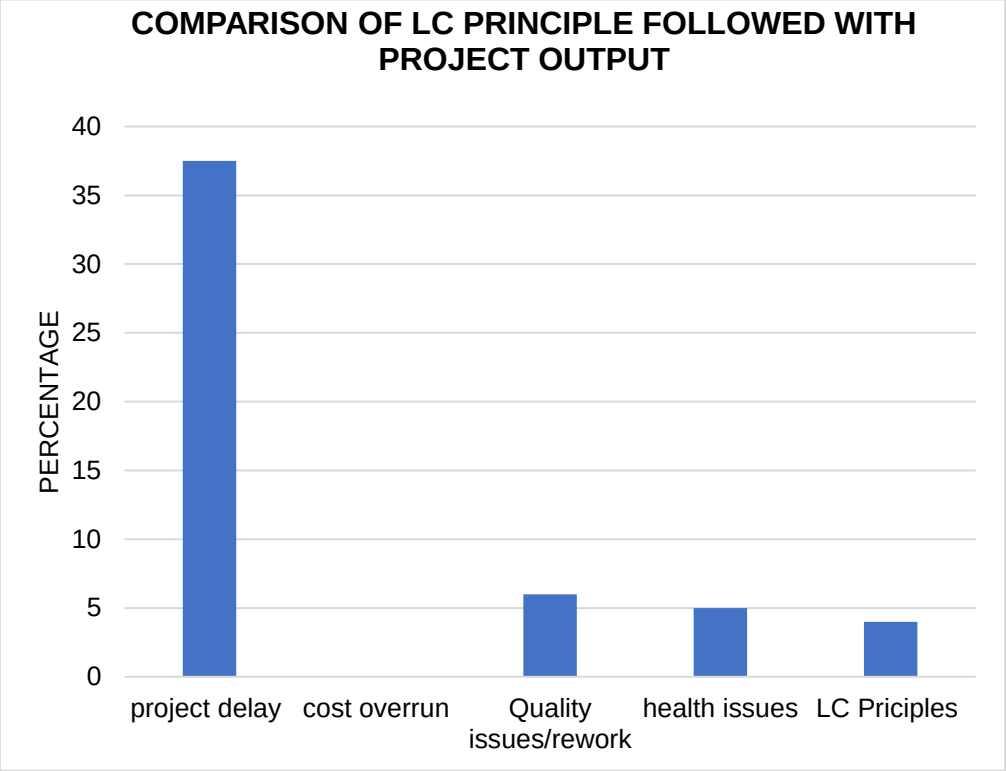

Figure 4.6 Comparison of LC Principles with Project Outputs

This indicates that LC principles followed during execution of Multi Story Building is in minus meaning almost every step was taken against the LC approach. There was 9 months delay in project, cost over-runs was 0.03%, health issues were raised during execution of the project and no dedicated health/safety consultant was present at the site throughout the construction. Rework was done for 6 times during the execution of Project. It will be reasonable to conclude that no LC practices were followed by the construction Firm during execution of Multi Story Building which has led to delay in project, cost overrun, re-work, health and quality issues.

4.1.1.4 Jaglot Skardu Road (JSR)

Jaglot-Skardu Road (Strategic Highway-1) has a length of 164 km and it is the lifeline of Skardu and Army troops employed in Siachen. The road condition remained deteriorated since 1984. repair works on smaller scale were being carried out time to time but there was a need felt to reconstruct the road. In 2017, Prime Minister Mr Shahid Khaqan Abbasi announced the

construction of this road on his visit to Gilgit. This contract was awarded to 491 Engineers Group, Frontier Works Organization. The construction commenced in August 2017 with a contract cost of 31 billion. The scope of work included improvement and widening of road and construction of breast wall, retaining walls, culverts and bridges. This project was expected to be completed by August 2020 but due to multiple issues it was completed in Sep 2021. Construction of this road was a difficult job as it is most dangerous road of Pakistan due to rigged terrain and natural calamities like intense snowfall and landslides, narrow curves and danger aggravated by River Indus flowing parallel to the road almost along its entire length where a driver or operator has fewer chance of survival after making a mistake. This road has reduced the travel time from Gilgit to Skardu from 8 hours to 3 hours. This road will attract inflow of tourists to multiple tourist destinations like Khaplu, K-2 Base Camp, Skardu, Deosai and surroundings.

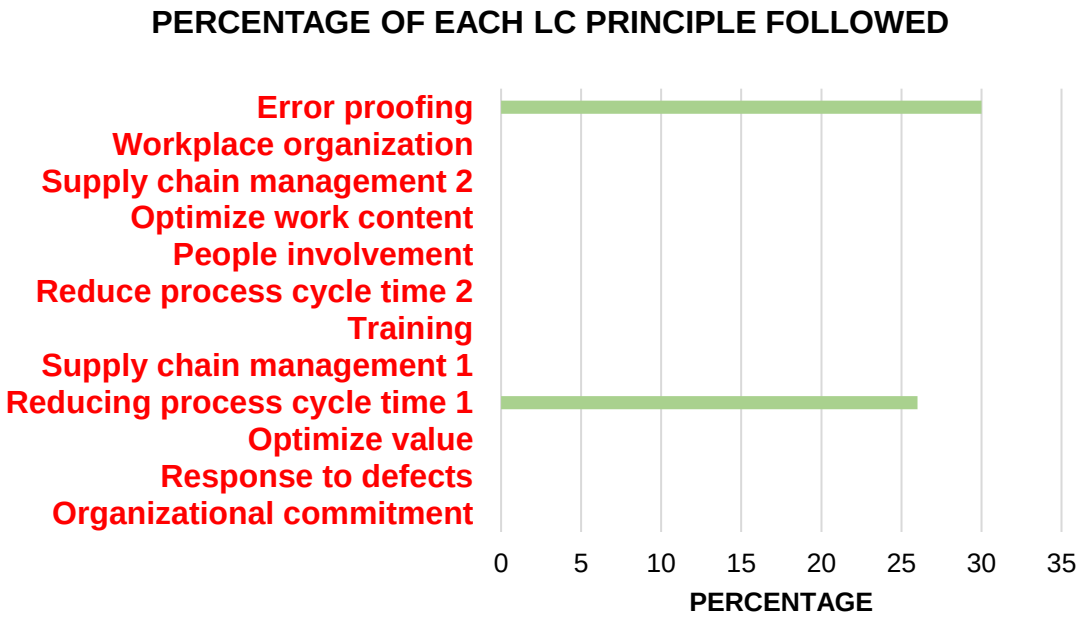

Figure 4.7 LC Principles Followed During Construction of JSR

In figure 4.7 the results are shown, a low degree of LC principles followed by the company during construction of this road. The chart indicated that few principles trend are touching 0% which is a very low value and indicates that concept of using prefabrication and adoption of project management technique was ignored. Only positive results were seen in project meetings which were carried out almost every day. Moreover, several factors contributed in delays and overruns. The road alignment was not finalized beforehand, land accusation and no coordination between departments for shifting of electric pylons stopped the work several times. Supply line was very long and was often disrupted due to poor weather and landslides.

This indicates that there was one year delay in the completion of project due to non-adherence to LC principles. Due to alignment issues almost 12 percent of work was redone. To get an idea of the impact, average value of LC principles followed were compared to the project outputs and represented by figure 4.8 below.

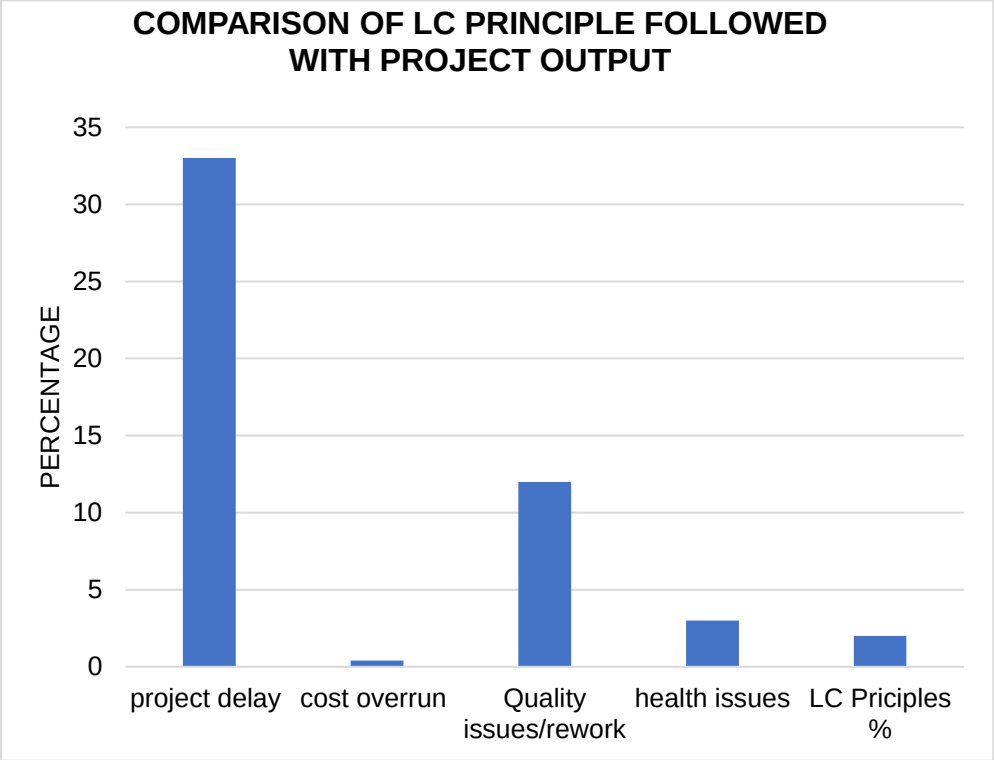

Figure 4.8 Percentage of LC Principles Followed Compared to Project Outputs of JSR

4.1.1.5 Ammar Chowk Rawalpindi

Initially started in March 2021 and completed in December 2021, the Ammar chowk project was undertaken by the Frontier Works Organization (FWO). It was built by the FWO to improve the mobility and transportation capability of the road network because of the expanding population and traffic. The construction of twin underpasses, the undergrounding of high-tension and low-tension cables, the installation of new service lines, and the construction of a reinforced earth panel are all part of this project. The project is in the city of Rawalpindi in the province of Punjab. Within approximately nine months, the project was completed. Because of this, FWO has taken a great effort to ensure that individuals experience the fewest number of inconveniences and are not concerned about their mobility being restricted while the building work is underway. The project was carried out without any notable delays, and there were no significant delays. The building of Ammar Chowk did not experience any cost overruns or safety concerns. The speed of work at the building site was greatly influenced by external circumstances such as working throughout the night hours due to the presence of heavy

traffic flow, Covid-19 protocols, and weather conditions, among others. Following interviews with persons who were significant stakeholders throughout the project and an analysis of the results, the following conclusions were drawn: -

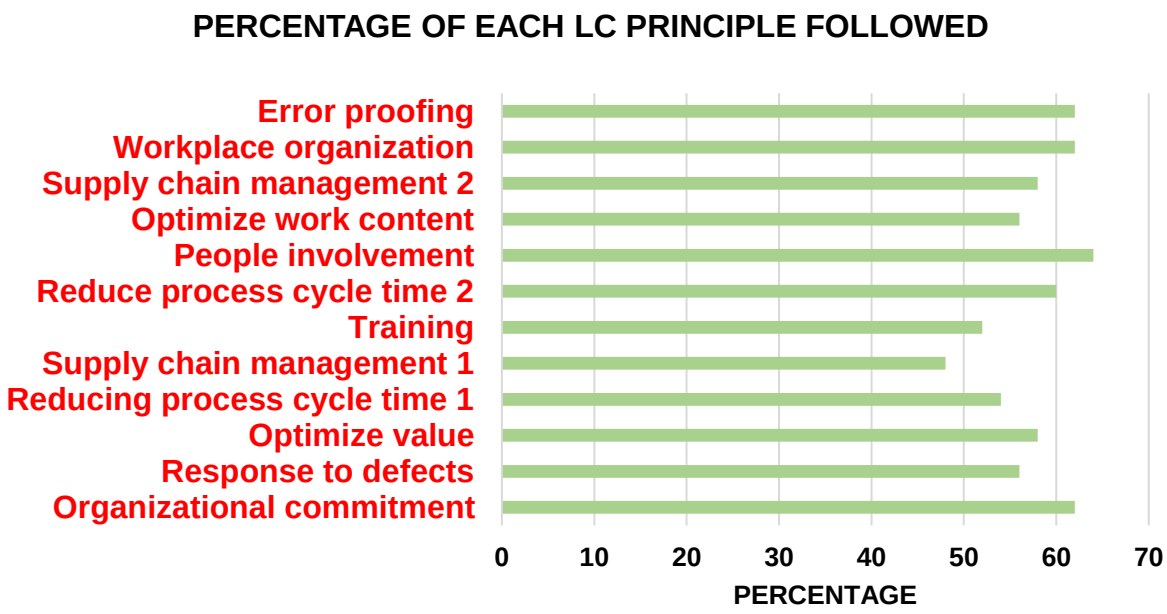

Figure 4.9 LC Principles Followed in Construction of Ammar Chowk

As shown in figure 4.9 the findings indicate that the firm adhered to a high degree of the LC principles during the construction of Ammar Chowk, as seen by the results. It is not possible to implement 100 percent of the LC principles. According to the figure 4.9, the trend for a few LC principles is approaching 70%, which is an extremely significant percentage of the overall trend. Overall, all of LC's patterns have been addressed and reviewed throughout the process. This has resulted in the project being completed on time and within the budget, with no rework, and no health-related concerns. Project management and execution were both outstanding throughout the process. Despite this, several circumstances contributed to the delays, including the presence of heavy traffic flow, the use of Covid-19 protocols, and the weather. Based on the findings, it appears that the FWO is aware of new trends in the LC approach and is already implementing it in some form, though without realizing it and without being aware of the consequences. LC principles were followed, and their average values were compared to project outcomes to gain an indication of the impact. The results are displayed in figure 4.10 below.

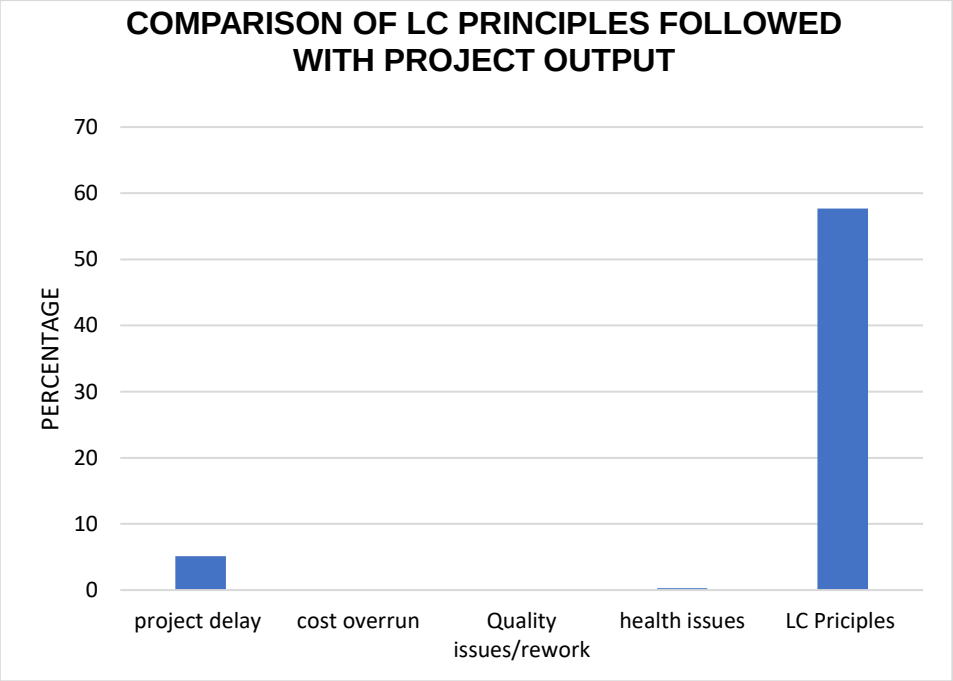

Figure 4.10 Comparison of LC Practices Followed with Outputs of Project Ammar Chowk

During execution of Ammar Chowk, more than 55% of the LC principles were observed. A professional health/safety expert was present at the construction site throughout the project, and there were no delays or cost overruns. The project was finished one month ahead of schedule. Three million dollars in building costs may have been avoided if LC principles had been implemented with more focus. During the construction phase, there was no rework. Implementation of LC principles has resulted in the removal of waste during the execution phase that leads to save time, money and quality of the project. It is plausible to argue that the high quality of Ammar Chowk's deliverables can be attributed to the LC procedures used by FWO during construction.

4.1.2 Conclusion

After reviewing the data, it has been observed that three projects were executed by following LC principles whereas 2 were executed by using conventional construction methods. The projects having greater practices followed has shown better outputs in terms of cost, delays, quality and health issues. It can be reasonably concluded that LC practices are effective in reducing the wastages and improving the outputs.

4.2 Survey

Results of the online survey which aimed at determining the efficacy of LC principles and their impact on project outputs of the firms shall be explained in following paragraphs: -

4.2.1 Data Presentation

4.2.1.1 Detail of Reponses

Surveys were targeted from the contractors in the construction industry of Pakistan that are actively executing construction projects. Project managers of these firms were asked to fill this survey questionnaires. 220 surveys were distributed among the construction project managers of the respective firms out of which 72 responses were received. Respondents' attributes required in the survey are as following: -

1. Name
2. Organization
3. Cost of Project

The details of the attributes are attached at Appendix 5.

4.2.1.2 Conversion of Data

Each question was answered by the respondents by choosing most suitable answer on the Linkert scale. These were in descriptive format for ease of interpretation by the respondents. In order to perform quantitative analysis, the data it became necessary to convert it into numerical form. The Linkert scale was converted in the following manner: -

Table 4.1 Conversion of Scale

Response	**Value**
Never	1
Seldom	2
Sometimes	3
Often	4
Almost Always	5

As shown in table 4.1 above highest value is given to Almost Always which means more than 80% of LC practices followed by firm whereas almost always given the value 5 as it shoes the maximum LC practices followed.

4.2.1.3 Mapping of LC Principles with Questionnaire

Each Question out of first 27 is related to a LC Principle and Sub Principle. The results will be presented in terms of the principles for ease of interpretation. Each question is linked with its respective principle the details of which are presented and attached as appendix 4.

4.3 Means of LC Practices

The means of LC Practices are tabulated as shown in table 4.2 below.

Table 4.2 Means of LC Practices Followed by the Firms		
Principle	**Sub Principle**	**Mean**
Culture/People	People involvement	3.875
	Organizational Commitment 1	3.653
	Training	3.708
Continuous Improvement/Built in Quality	Response to defects 1	3.667
	Response to defects 2	3.917
	Response to defects 3	3.583
	Error proofing	4.083
	Organization learning	3.514
Customer Focus	Flexible Resources 1	3.944
	Flexible Resources 2	3.681
	Flexible Resources 3	4.028
	Optimize Value 1	3.667
	Optimize Value 2	3.75
Eliminate Waste	Supply Chain Management 1	3.625
	Supply Chain Management 2	3.819
	Optimize Production System 1	3.722
	Optimize Production System 2	3.847
	Reduce Process Cycle Time 1	3.819
	Reduce Process Cycle Time 2	3.889
	Reduce Process Cycle Time 3	3.83
	Optimize Work Content 1	3.681
	Optimize Work Content 2	3.667
Standardization	Visual Management	3.903
	Workplace Organization 1	3.764
	Workplace Organization 2	3.792
	Defined Work Processes 1	3.986
	Defined Work Processes 2	3.847

Table 4.2 indicates a very high values of few LC Questions such as response to defects 2, error proofing, flexible resources 1, visual management and defined work processes 1 indicate that these practices are followed up to a high degree by the construction firms of Pakistan construction industry. The table also indicates that some practices less often by the construction firms such as organizational learning. Generally, the means indicate that all investigated principles of LC are actively followed by the construction firms but not in a standard way. The differences in the values also give a hint of the haphazard trend of following the investigated LC principles. A further analysis is done to compare the LC Practices followed by the firms with their project outputs and shown by figure 4.11.

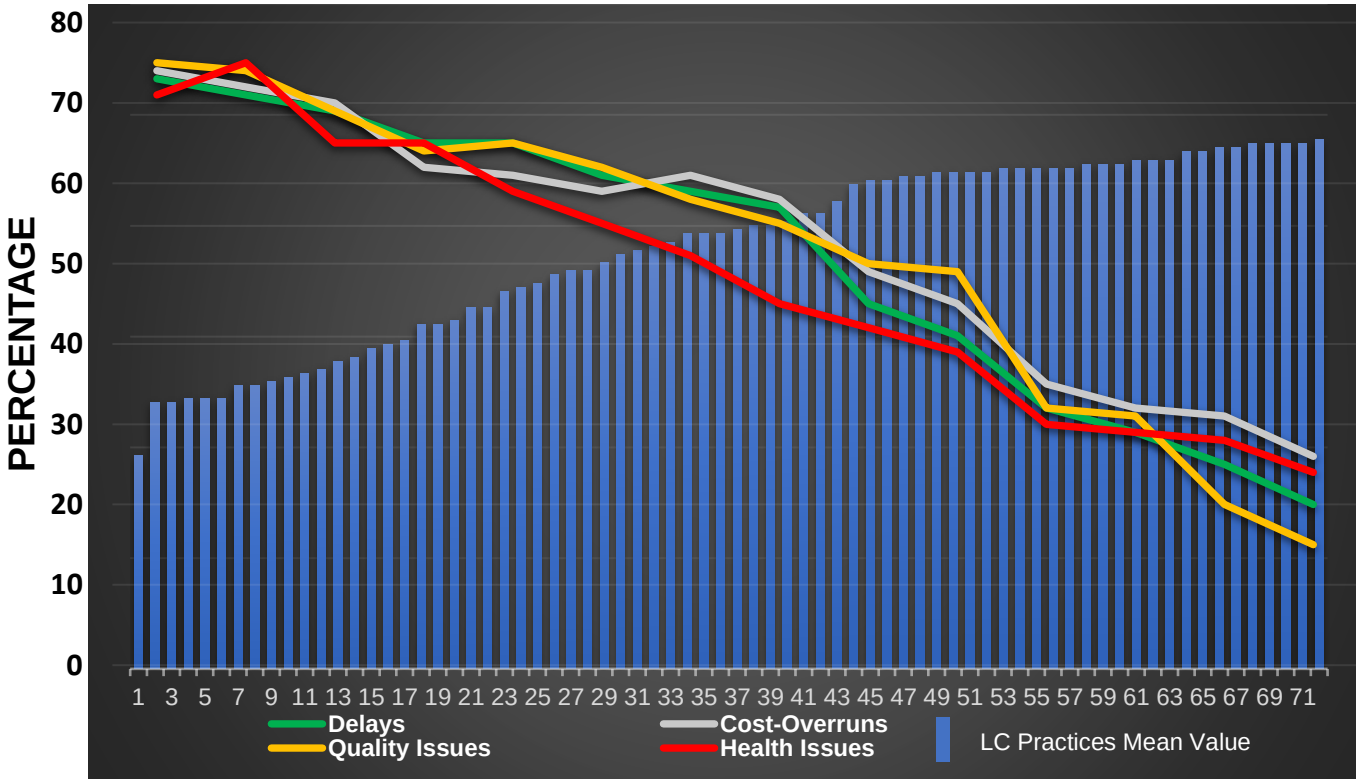

Figure 4.11 COMPARISON – LC PRACTICES FOLLOWED vs PROJECT OUTPUTS

The mean value of LC Practices followed by the responding firms were calculated using MS Excel and then these firms were ranked according to the mean values. The figure 4.11 indicates the increasing trend of the mean value and compares it with the respective outputs. The figure indicates that the project outputs of the representative firms are dependent on the LC Practices followed by them because as shown by the graph with the increasing mean percentage of LC Practices the trend lines of all of the project outputs are decreasing. Moreover, it presents that firms following very less value of LC Practices that is below 25 % are experiencing heavy

delays and other outputs. Also, those firms above 60 % experienced very little delays and cost over-runs. Thus, the results from the case studies are validated by this conclusion that it is true that LC Practices reduce delays, cost over-runs, quality issues and health related issues.

4.4 Data Analysis

In This section the data from the survey responses are further analyzed under different headings. The results of the analysis shall be used to interpret the impact of LC Practices on the Project Outputs to check the efficacy and potential of LC practices in construction industry of Pakistan. Finally, the results are validated using the case studies.

4.4.1 Tests for Normality

In this section the gather data through the survey is analyzed using various statistical tools to check the normality of the population. This is done to decide on the type of statistical test for hypothesis testing analysis to be performed. The results and their conclusions are described under each heading as following: -

4.4.1.1 Data Skewness and Kurtosis

The Skewness and Kurtosis tests were performed to check the symmetry of data and whether the data is heavily tailed respectively, MS Excel was used to perform this test and results are recorded in table 4.3.

Table 4.3 Skewness and Kurtosis Test Result

Principle	Sub Principle	Skewness	Kurtosis
Culture/People	People involvement	-0.825	-0.262
	Organizational Commitment 1	-0.628	-0.281
	Training	-0.52	-0.51
Continuous Improvement/Built in Quality	Response to defects 1	-0.672	0.283
	Response to defects 2	-0.781	-0.133
	Response to defects 3	-0.479	-0.826
	Error proofing	-0.921	0.342
	Organization learning	-0.6	-0.387
Customer Focus	Flexible Resources 1	-0.645	-0.459
	Flexible Resources 2	-0.663	-0.324
	Flexible Resources 3	-1.035	0.26
	Optimize Value 1	-0.86	0.178
	Optimize Value 2	-0.641	-0.657
Eliminate Waste	Supply Chain Management 1	-0.509	-0.698
	Supply Chain Management 2	-0.567	-0.875
	Optimize Production System 1	-0.861	0.062
	Optimize Production System 2	-0.811	-0.219
	Reduce Process Cycle Time 1	-0.633	-0.507
	Reduce Process Cycle Time 2	-0.852	-0.234
	Reduce Process Cycle Time 3	-0.597	-0.418
	Optimize Work Content 1	-0.57	-0.853
	Optimize Work Content 2	-0.45	-0.828

Standardization	Visual Management	-0.646	-0.654
	Workplace Organization 1	-0.619	-0.196
	Workplace Organization 2	-0.521	-0.908
	Defined Work Processes 1	-0.58	-0.79
	Defined Work Processes 2	-0.85	-0.018

Standard error in case of skewness test is 0.283 and in case of kurtosis it is 0.559. A skewness value greater than 1 or less than -1 indicates a highly skewed distribution of the data. The result indicates that all values lie between the range of -1 to 1 so the data is not highly skewed. The values are generally between the range of -0.5 to 0.5 which indicates that data is fairly symmetrical. Except few results that are lower than -0.5 but still in the range of moderate skewness i.e., -0.5 to -1. According to (Hair et al., 2019) a kurtosis value that is less than -1 is indication of a distribution that is too flat and none of the values are exceeding this limit. Hence, it can be concluded that the skewness and kurtosis test results show that the distribution is normal.

4.4.1.2 Shapiro Wilk Test

The Shapiro Wilk Test for the survey data was conducted using SPSS-26. For a normal distribution the p value of this test should be greater than 0.005. The results of the test are shown in table 4.4.

Table 4.4 Shapiro Wilk Test Result

Principle	Sub Principle	Shapiro wilk Test Value	p Value
Culture / People	People involvement	0.836	<0.001
	Organizational Commitment 1	0.879	<0.001
	Training	0.881	<0.001
Continuous Improvement / Built in Quality	Response to defects 1	0.877	<0.001
	Response to defects 2	0.845	<0.001
	Response to defects 3	0.867	<0.001
	Error proofing	0.822	<0.001
	Organization learning	0.838	<0.001
Customer Focus	Flexible Resources 1	0.845	<0.001
	Flexible Resources 2	0.862	<0.001
	Flexible Resources 3	0.806	<0.001
	Optimize Value 1	0.854	<0.001
	Optimize Value 2	0.851	<0.001
Eliminate Waste	Supply Chain Management 1	0.874	<0.001
	Supply Chain Management 2	0.845	<0.001
	Optimize Production System 1	0.853	<0.001
	Optimize Production System 2	0.845	<0.001
	Reduce Process Cycle Time 1	0.858	<0.001
	Reduce Process Cycle Time 2	0.829	<0.001
	Reduce Process Cycle Time 3	0.866	<0.001
	Optimize Work Content 1	0.857	<0.001
	Optimize Work Content 2	0.877	<0.001

Standardization	Visual Management	0.842	<0.001
	Workplace Organization 1	0.876	<0.001
	Workplace Organization 2	0.852	<0.001
	Defined Work Processes 1	0.832	<0.001
	Defined Work Processes 2	0.841	<0.001

The p value of all the LC questions lies below 0.001 which was indicated by SPSS-26 as 0. The point to consider is that all values are below 0.005 which means that the distribution is not normal.

4.4.1.3 Conclusion

As one of the results has proved distribution to be non-normal, in which case t-testing and z-testing is not done as these are not valid. For the hypothesis testing non-parametric tests were done and results are presented in the subsequent paragraphs.

4.4.2 Relative Importance of LC Test Variables

In order to get an idea of which LC Practice is relatively more important in influencing the Project Outputs or to analyze which practice was relatively more followed by the firms, Relative Importance Index (RII) test was performed using MS Excel. The test results are described in following headings: -

4.4.2.1 RII

RII was found for each sub principle using MS Excel. Afterwards the result was arranged in descending order and then it was ranked. The principle with highest RII was given rank 1 and the one with lowest value was given rank 27. The results are shown in table 4.5.

Table 4.5 RII Test Results

Sub Principle	RRI	Rank
Error Proofing	0.816667	1
Flexible Resources 3	0.805556	2
Defined Work Process 1	0.797222	3
Flexible Resources 1	0.788889	4
Response To Defects 2	0.783333	5
Visual Management	0.780556	6
Reduce Process Cycle Time 2	0.777778	7
People Involvement	0.775	8
Optimize Production System 2	0.769444	9
Defined Work Process 2	0.769444	10
Reduce Process Cycle Time 3	0.766667	11
Supply Chain Management 2	0.763889	12
Reduce Process Cycle Time 1	0.763889	13
Workplace Organization 2	0.758333	14
Workplace Organization 1	0.752778	15
Optimize Value 2	0.75	16
Optimize Production System 1	0.744444	17
Training	0.741667	18
Flexible Resources 2	0.736111	19

Optimize Work Content 1	0.736111	20
Response To Defects 1	0.733333	21
Optimize Value 1	0.733333	22
Optimize Work Content 2	0.733333	23
Organizational Commitment 1	0.730556	24
Supply Chain Management 1	0.725	25
Response To Defects 3	0.716667	26
Organizational Learning	0.702778	27

Rank 1 means the highest rank in the series. Error Proofing is ranked 1 which means that it is relatively most important factor among the sub-principles listed above. Organizational learning is ranked the lowest in the series which means It is relatively the least important practice. All other Sub Principles fall in between these variables. This indicates that error proofing is performed most out of all the listed LC practices whereas organizational learning is the least performed practice. A firm can improve its outputs by focusing on the LC practices on lower ranks such as organizational learning, response to defects 3 and supply chain management 1 etc.

4.4.3 Chi Square Test

The four Project Outputs were tested using Chi Square Test one by one for checking that LC practices improved project performance or not. The tests were conducted using SPSS-26. The mean values of Sub-Principles and each Project Output were taken as variables in Chi Square tests. The mean values were converted to whole numbers as SPSS Chi Square test uses whole numbers for this test. The responses (means) on Linkert scale can reasonably be converted to whole numbers and named as Lean Practices (LP) using the range defined by (Sözen & Güven, 2019) which is explained by the table 4.6.

Table 4.6 Conversion of Mean LC Practices Values into LP Values

	LP Value	**Range**
Never	1	1.00 – 1.80
Seldom	2	1.81 – 2.60
Sometimes	3	2.61 – 3.40
Often	4	3.41 – 4.2
Almost Always	5	4.21 - 5

Two groups were compared to perform this test firstly the bad practices i.e., mean value in the range defined by value “2” and good practices i.e., mean value in the range defined by value “5”. The outputs (delays, cost over-runs, quality issues and health issues) of these groups were listed and then chi square test was performed for the two groups using each output in SPSS one by one. The null hypothesis of this test was that LP did not improve the project performance whereas alternative hypothesis was that LP improved the project performance. Significance value for the test was 0.05 whereas in each case the p value obtained was less than 0.001. This

result was enough evidence against the null hypothesis and alternative hypothesis was adopted that LP improved the project performance. The results are presented in tabulated form for each output vs LP in the following paragraphs.

4.4.3.1 LP vs Delays in Projects

The results of the test are as shown in table 4.7.

Table 4.7 Chi Square Test - LP vs Delays

	value	Df	p value
Pearson Chi Square	33.800	4	<0.001
Likelihood Ratio	35.085	4	<0.001
N of Valid Cases	39		

The result indicates that the group of firms following more LC practices (value “5”) have performed better than the firms that have followed lesser LC practices (value “2”) hence there is a significant relationship between the delays in projects and the LC practices followed by the firms.

4.4.3.2 LP vs Cost Over-runs

The result of the test is as indicated in table 4.8.

Table 4.8 Chi Square Test - LP vs Cost Over-runs

	value	Df	p value
Pearson Chi Square	27.119	3	<0.001
Likelihood Ratio	28.704	3	<0.001
N of Valid Cases	39		

With the similar test conditions, the same two groups were used to test cost over-runs. The results indicate that we can reject the null hypothesis as p value is less than 0.001. So, there is a significant relationship between cost over-runs and lean practices of the firm. Hence alternative hypothesis is adopted that LC practices improved project performance by reducing cost over-runs.

4.4.3.3 LP vs Quality Issues / Rework

The analysis done via SPSS shows the result indicated in table 4.9.

Table 4.9 Chi Square Test - LP vs Quality Issues / Rework			
	value	**Df**	**p value**
Pearson Chi Square	21.104	4	<0.001
Likelihood Ratio	20.646	4	<0.001
N of Valid Cases	39		

To test the quality issues and rework similar test condition, same groups and hypothesis were used. The chi square test results show that p value is less than 0.001 hence in this case again the null hypothesis is rejected. Construction projects executed in Pakistan are prone to quality issues and lack of quality finishing. Results show that by increasing LP there is decrease in quality issues and rework.

4.4.3.4 LP vs Health Issues

Table 4.10 shows results as obtained by the analysis done using SPSS: -

Table 4.10 Chi Square Test - LP vs Health Issues			
	value	**Df**	**p value**
Pearson Chi Square	20.661	3	<0.001
Likelihood Ratio	19.845	3	<0.001
N of Valid Cases	39		

For health issues again the same test was performed and similar results are obtained. A p value < 0.001 is enough evidence to reject the null hypothesis and adopt the alternative hypothesis that LC practices improved the project performance. Providing a healthy environment to the employees is a great incentive and motivation to work better and perform more. LC practices provide a healthy environment to the employees due to dedicated efforts by the top management and commitment by all employees.

4.4.3.5 Conclusion

After reviewing all of the results of Chi Square Test it is thereby concluded that LC Practices improve the project performance in terms of better Project Outputs.

4.4.4 Independent Samples - Kruskal Wallis Test

The impact of LC Practices was further analyzed using Kruskal Wallis Test and the results are shown under different headings in this section. The test was done using SPSS and each project output was independently checked with mean LC practices of the firms. Two groups of data were formed in each case like it was done in chi square test using the same range of mean

values. The means of LC practices and outputs of firms that followed less LP "2" (table 4.6) and those that followed good practices "5" were taken as input for this test. Significance level for the test was 0.05. Null hypothesis for the test was that lean construction did not improve the project performance and the alternative hypothesis was that lean construction improved the project performance.

4.4.4.1 LP vs Project Delays

Table 4.11 shows the results of Kruskal Wallis test performed on LP and project delays.

Table 4.11 Kruskal Wallis Hypothesis Test Summary – LP vs Delays

Null Hypothesis	Test	Sig.	Decision
The distribution of **Mean LC Practices** is the same across categories of **No Project delays**	Independent-Samples Kruskal-Wallis Test	<0.001	Reject the null hypothesis

4.4.4.2 LP vs Cost Overrun

Table 4.12 shows the results of Kruskal Wallis test performed on LP and cost over-runs.

Table 4.12 Kruskal Wallis Hypothesis Test Summary – LP vs Cost Over-runs

Null Hypothesis	Test	Sig.	Decision
The distribution of **Mean LC Practices** is the same across categories of **No Cost Over-runs**	Independent-Samples Kruskal-Wallis Test	<0.001	Reject the null hypothesis

4.4.4.3 LP vs Quality issues

Table 4.13 shows the results of Kruskal Wallis test performed on LP and quality issues or rewrork.

Table 4.13 Kruskal Wallis Hypothesis Test Summary – LP vs Quality Issues

Null Hypothesis	Test	Sig.	Decision
The distribution of **Mean LC Practices** is the same across categories of **No Quality Issues**	Independent-Samples Kruskal-Wallis Test	<0.001	Reject the null hypothesis

4.4.4.4 LP vs Health issues

Table 4.14 shows the results of Kruskal Wallis test performed on LP and health issues.

Table 4.14 Kruskal Wallis Hypothesis Test Summary – LP vs Health Issues			
Null Hypothesis	**Test**	**Sig.**	**Decision**
The distribution of **Mean LC Practices** is the same across categories of **No Health Issues**	Independent-Samples Kruskal-Wallis Test	<0.001	Reject the null hypothesis

5.1.1.1 Conclusion

K related sample Kruskal Wallis test was performed on each output and result as tabulated in above paragraphs indicate that the p value is less than 0.001 in all cases. The test rejected the null hypothesis that LC Practices does not have a significant relationship with each project output. As the p value is very less than 0.05 it is enough evidence against the null hypothesis. In each case the alternative hypothesis is adopted that LC practices improved the project performance. The Kruskal Wallis test augments the results of chi square test and our inferences for the efficacy of LC practices in the environment of construction industry of Pakistan are true.

5.2 Validation of results and important conclusions for efficacy and adaptability of LC Practices in construction industry of Pakistan

The inferences drawn from the results of survey data analysis can now be reasonably be validated by the conclusions drawn from the case studies. It was observed that those projects which were following no or less LC Practices had poor project execution performance visible in the project outputs, for example JSR project and Multistory Residential Building at Risalpur. Whereas it was also observed that the projects in which some or high percentages of LC Practices were followed have better projects outputs. This has led to the hypothesis that LC Practices improve the project performance. To test this hypothesis the second method of analysis of the data collected from survey was used. After review of the results of the different analysis tests performed it is validated that the LC Practices have improved the project performance in terms of better project outputs.

There was not a linear trend observed in better performance of the projects which is the result of some factors that are not in the scope of this study. For example, the projects relatively compared are located in different territorial zones such as JSR located in the northern areas is compared to Ammar chowk located in Rawalpindi Punjab. The harsh weather of northern areas is one of the biggest reasons of difficulty of construction in that area. Politics, security, terrain and fatigue of work are also some other factors. During one of the interviews conducted from JSR Team it was revealed that during winters when snowfall was high, the work was completely stopped so this reduces the working months in the year to only 8. Trafficability in

the mountainous region is very restricted and at most of the sited if the road is closed for work there is no alternate route available. On the other hand, working in the environment of a city like Rawalpindi is very fluid. Work on Ammar Chowk was performed in more than 18 hours of a day whereas on the JSR project work was performed only in the daylight hours available. There are some reasons that contribute to the significant differences of results of very similar projects such as IHITC and TIP. During the COVID-19 environment there was dire need of an isolation hospital for treating the patients of COVID-19. Hence IHITC was on the focus of the Government of Pakistan and NDMA. IHITC was then no doubt a fast-tracked project and FWO had to do major changes in their construction techniques to meet the strained deadlines of the project. By following the principle such as prefabrication and on-site availability of designer and construction teams etc., has shown astonishing results. The same principles were followed in the construction of TIP yet it was not a fast-tracked project, but still it was finished before the forecasted timeline.

During the construction of Multi-Story Residential Building at Risalpur almost none of the LC Practices were observed and the construction team was totally unfamiliar with the practices. Even the conventional practices were not properly observed during the construction. There was no consultant in this project and MES supervised the construction themselves. The supervisory staff was even not present actively and the construction team had to wait even for days to get the work checked and approved from the supervisors. These are indeed totally opposite to LC Practices. The outputs of this project then speak themselves about the Impact of Non-Lean Practices.

Chapter 5

CONCLUSION AND RECOMMENDATIONS

5.3 General Conclusions

1) Lean construction improves the efficiency of construction industry of Pakistan. As we look in the table 5.1, All the firms are utilizing the lean construction principle to some extent as there is no data available for the firms practicing Lean construction within the range of 0-24.

Table 5.1 Comparison of LC practices Followed by the Firms with Project Outputs

LC Practices %	Delays %	Cost Over-runs %	Quality Issues %	Health Issues %
0 – 24	**No data available**			
25 – 40	66 – 73	63 – 74	66 – 75	56 – 71
41 – 55	46 – 65	50 – 62	51 – 65	43 – 55
56 – 70	20 – 45	26 – 49	15 – 50	24 – 42
71 – 100	**No data available**			

2) As the percentage of Lean construction increasing, percentages of delays, cost overrun, quality and health issues are decreasing. It shows that companies can overcome delays, cost overrun and quality issues by skillful implementation of lean construction principles.
3) Results of case studies also validate the tests results as the delays, cost overrun and quality issues in Isolation Hospital and Infectious Treatment Center, tunneling institute of Pakistan and Ammar Chowk were less than 10 percent whereas Jaglot-Skardu road and multi-story residential building were facing multiple issues regarding delays, cost overrun and quality issues.
4) Generally, all the construction firms are implementing some principles of LC in a haphazard manner,
5) LC method will provide a competitive advantage to firms over traditional construction project management method.
6) The construction industry of Pakistan is now shifting gradually towards new methods and techniques of construction management.

7) Many construction firms of Pakistan are totally ignorant of the philosophy of LC Principles.
8) The method of construction is not dependent on the financial status of a firm rather if this method is standardized it will reduce the cost of project manifolds directly by reduction in waste and indirectly by reduction in delays, lesser reworks.
9) The construction firms of Pakistan are following LC Principles in some form or the other, some more, some less and mostly none, but without knowledge of it as a standard method and philosophy of construction.
10) Adaptability of LC Principles in Pakistan will be a paradigm shift in thinking of the construction firms to develop the necessary understanding of its methods and techniques.
11) Standardization of LC Principles is possible after construction firms have developed the required change of approach and make themselves adaptable to changes.

5.2 Recommendations

The Pakistani construction industry is improving at a remarkable pace. The industry still has many flaws but many plus points are also present. The industrialist mindsets are getting inclined towards new and better approaches of construction by the gradual increase in education and awareness in general. Around the world, developed countries are focused towards making the world more sustainable. Hence in near or far future the construction industry of Pakistan must shift towards better and sustainable methods and approaches of construction and management such as Lean Construction. Currently the backbone of our Construction Firms are the foremen, supervisors and workers. They are unaware of philosophy of Lean Construction but awareness is present at the management levels. In this regards few recommendations are presented in following paragraphs.

5.2.1 Recommendations for Construction Industry of Pakistan

The Construction Industry of Pakistan can adhere to following recommendations for implementing LC in their industries: -

1) Awareness

The first step to inculcate the lean thinking is to increase the level of awareness for lean construction. Workshops/Seminars, training sessions, advertisements, special lectures at institutional level etc showing the benefits and gains of lean construction in the countries which has been implementing this philosophy be held at regular intervals.

2) Commitment by the top management

Top management should be encouraged through seminars/workshops and special motivational lectures at their construction sites by the support of Pakistan Engineering Council. Execution of one or more smaller activities by employing the lean construction is a good option to increase the confidence level of the top management

3) Self Sufficient Construction Teams

Each team is suggested to contain elements of all trades of employees so that work is performed competitively and independently in different divisions of the overall work. By the end of every day or week the challenges and achievements should be discussed by management and the teams.

4) Training and Development of Employees

Conventional method of construction can most swiftly be overtaken by LC Principles by development of the lean thinking in each individual of the firm most importantly the workers, supervisors etc., for this reason the firms must conduct LC based training of employees.

5) Technological Uplift

LC is most effective in collaboration with BIM using modern technological systems such as design and management software's and use of gadgets such as tablets and laptops. The firms that can afford to convert into technologically revolutionized companies should immediately do so to meet the competitive standards of the world.

6) Onsite Designer and Project Proceed Design

The role of consultant is very important and it is recommended that consultants and designers should be present at the site 24/7 and perform continuous quality checks. Also, the design of the project must be continuous as the project proceeds and changes to be incorporated keeping in view the user requirements.

7) Collaboration Between Stakeholders

A major challenge faced during construction of project is the conflicts in the project. As an effective change management plan the conflicts should be killing right from the outset so that minimum time is waste during the construction. In this regard high collaboration is required between all stakeholders in forms of regular meetings.

8) Reward Policy in Firms for Employees

To motivate the employees and increase their confidence in this new method of construction a reward policy can be of great use. The employees eager to learn new developments should be given some extra incentives by the top management.

5.2.2 Recommendations for Planning Commission of Pakistan

The government of Pakistan should play an active role for increase of awareness in the construction firms of Pakistan so that the industry may gradually shift towards new methods and techniques. Planning commission should add clauses for implementation of LC practices in contracts and play its role to increase the level of awareness for lean construction. This is possible by inviting management experts from international level to Pakistan and conducting of seminars. An international private firm should also be invited to train the local construction industry by working in collaboration and using the LC Practices in construction of a project by support of Pakistan Engineering Council (PEC).

5.2.3 Future Work

Few recommendations for the future researches are as following: -

1) Study for development of a framework of LC Principles practical application in line with its suitability in the construction industry of Pakistan.
2) Study of befitting contract agreements for bindings firms in construction industry of Pakistan to Lean Construction Method
3) Study of Lean Construction Principles purposefully applied in the design and construction management of a complete project and then evaluation of impact on project cost, duration and quality.

5.3 Conclusion

Lean production principles were developed by Toyota company and published by them at international level. Toyota has showed the world how it has utilized Lean Philosophy in their management and increased the value of their products. Overall, the production industry has seen a booming development whereas construction industry did not perform well comparatively. Researchers around the world started thinking for improvement in the construction industry and resultantly in 1990s LC Principles were developed and adopted internationally by few firms. This led to a change in perception around the globe that construction waste is inherent to the projects. The change in this regard has resulted in reducing the waste and increasing the project value. With the depleting resources of the world a change is very necessary to curb the wastage for meeting the goals of sustainability.

The construction industry of Pakistan remains backward and ignorant to the new methods but research shows that there is great amount of potential in our construction industry to adopt the LC Principles. The need of the hour is an attitude to change and development of necessary knowledge and awareness in all tiers of our construction firms. By making use of the recommendations of this study our industry can improve a lot in this regard. Pakistan is facing

an economic disaster and to preserve the resources reduction of wastage in every field and industry is necessary. These needs of our country can be achieved if the construction industry plays its role in bringing the revolutionary change in its management philosophy by adopting LC Principles.

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Appendix 1

PRINCIPLES OF LEAN CONSTRUCTION

Introduction

Lean Principles and Sub-principles used in this research project have been adopted from work of (J.E. Diekmann, 2003). The survey and interview questions have been developed using the same principles which are described in following paragraphs: -

Cultural/People: The aim of this principles is to transform the thinking of every employee of the firm or organization into Lean thinking and make them realize that it is the key to success of their organization. The potential of Lean Philosophy can be fully utilized by the participation of each individual of the firm resulting in a culture of Lean environment. Details of the sub-principles are as under: -

a. **People Involvement**: The degree of participation is true in all levels of the firm to develop their required understanding, obligation and commitment for reducing the waste of the construction and increasing its value.
b. **Organizational commitment**: The commitment of an organization is the dedication of all of its employees to commit themselves for improvements in execution of project by adopting Lean methods.
c. **Training**: For a fundamental change training as important as commitment to change. Training of employees increases their knowledge and makes them eager to learn more, perform better work and remain upright.

Continuous Improvement/Build-in-Quality: Lean Philosophy revolves around increasing the value of the project. Continuous improvement to enhance quality is the key to achieve goals of LC. There is always a room for improvement in the methods and techniques of the firm. Hence the firm must adopt an attitude of continuous improvement using the following Sub-Principles: -

a. Response to defects: This involves dealing with the defects by the employees of the firm. A problem should be identified as early as possible and necessary changes to be implemented.
b. Error Proofing: One way to improve the quality of construction is simply to strive for 0 error even before the start of work**.**

c. **Organization Learning**: It can be defined as the level of adoption of knowledge its retention and transfer into untrained employees to that the organization shall learn as whole.

Customer Focus: The aim of this principle is to minimize the changes required to fulfil the requirements of the user. The needs of the user are hence studied from beginning of the project and steps are taken to meet these needs. This method reduces the construction waste due to rework. It has following Sub-Principles: -

a. **Flexible resources**: This is defined as the organization should be in a state to quickly adhere to the changes required by the user/customer without losing time or money. A loss of time and money is wasteful in construction so by reducing this loss is in turn reducing the waste. The ease with which the firm adopts to the changes required by the user the fluid will be execution.
b. **Optimize Value**: Increasing the value focuses on what value is from the user's point of view. All actions done in this regard come under this principle.

Eliminate Waste: The elimination of construction waste is centered upon by all the other LC Principles. This Principle is itself defined as the reduction of waste by stop doing all activities that produce waste and doing all activities that reduce waste. Details of its Sub-Principles are as under: -

a. **Supply Chain Management**: This aims to minimize the unnecessary movement and relocation of materials and delivery on time in the correct amount.
b. **Optimize Production System**: This is defined as functioning of sequences of work and creating balance of resources.
c. **Reduce Process Cycle Time**: This is defined as decreasing the time of work cycles followed to make the execution fluid.
d. **Optimize Work Content**: This is related to the methods of prefabrication, using repetitive elements and standardization of work.

Standardization: This principle focuses on organizing the environment for optimum utility of the workers. By achieving an organized environment an optimum productivity is possible. Details of the sub principles are as under: -

a. **Visual Management**: Posters or multimedia system can be used in disseminating important information pertaining to work plans, schedule, safety instructions etc., on locations where masses of workers are present or at places frequently visited by them.

b. **Workplace Organization**: This sub-principle is defined as organization of tools, equipment and overall setting of the work sites and storage areas. It includes putting things in their right places in order of priority all the time. This sub-principle also encompasses the 5s's (Separate/Scrap, Straighten, Scrub, Sustain, and Systematize)

c. **Defined Work Processes**: The aim of a defined work process is that the critical processes are documented and known to all employees with respect to their worksites.

Appendix 2

INTERVIEW QUESTIONNARE

Name of Interviewee	
Name of Project	
Company	
Designation	

QUESTIONS

1. Were Changes in construction management techniques readily adopted by your firm at all levels of management (for example in terms of technological advancement, use of BIM for creating and managing data during the design, construction, and operations processes), and were these changes reflected in the training of employees to incorporate new skills in them?

score

-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10

2. Were Defects identified through continuous monitoring and effort was done to prepare quality plans that show detailed responsibilities, to minimize the occurrence of these defects?

score

-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10

3. Was your company focusing on the customer needs throughout the project and what effort was done by the company to execute the project based on these needs?

score

-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10

4. Was coordination and cooperation among all the departments, like mechanical, electrical, architectural, civil, design, etc., given enough importance to minimize the internal conflicts?

score

-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10

5. Did your company rely on consistent suppliers in terms of quality and time requirements and suppliers were not changed during project execution?

score

-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10

6. Did your company train and utilize employees for multi-skilled activities e.g., mason team employed for scaffolding or steel fixing if free etc.?																				
score																				
-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
7. Was Risk management carried out and planned?																				
score																				
-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
8. Was the input of foreman and key workers considered in preparation of plans and schedules?																				
score																				
-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
9. Did your company use repetitive, preassembled or prefabricated standard construction elements?																				
score																				
-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
10. Did your company identify construction wastages (i.e., transportation, extra storage, motion, overproduction, waiting, over-processing, defects, and under-utilized talent), and was there any effort made to minimize these activities?																				
score																				
-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
11. Was the workplace organized, clean, and exhibiting information using visual devices?																				
score																				
-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
12. Was there a trend of daily meetings between management and employees, instead of just site visits, to discuss the work methodologies, plans, schedules, or any changes, etc.?																				
score																				
-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
13. Were there any delays or unwanted waiting periods during execution of the project milestones or rather they were achieved as per the project schedule?																				

If yes, then: - Initially planned duration of the project: Actual duration of the project: Percentage of Delay:
14. Were there any cost overruns?
If yes, then: - Initially planned cost of the project: Actual cost of the project: Percentage of cost overrun:
15. Were there any significant quality issues and/or re-work?
If yes, then: - Number of issues raised: How were these issues addressed? Answer:
16. Were there any health and safety issues raised during execution of the project?
If yes, then: - Number of issues raised: How were these issues addressed? Answer:

Interviewed by	

Appendix 3

MAPPING OF INTERVIEW QUESTIONNARE WITH LC PRINCIPLES

QUESTIONS	LC PRINCIPLE	SUBPRINCIPLE
Were Changes in construction management techniques readily adopted by your firm at all levels of management (for example in terms of technological advancement, use of BIM for creating and managing data during the design, construction, and operations processes), and were these changes reflected in the training of employees to incorporate new skills in them?	**Culture/People**	**Organizational Commitment**
Were Defects identified through continuous monitoring and effort was done to prepare quality plans that show detailed responsibilities, to minimize the occurrence of these defects?	**Continuous improvement**	**Response to defects**
Was your company focusing on the customer needs throughout the project and what effort was done by the company to execute the project based on these needs?	**Customer focus**	**Optimize value**
Was coordination and cooperation among all the departments, like mechanical, electrical, architectural, civil, design, etc., given enough importance to minimize the internal conflicts?	**Eliminate waste**	**Reducing process cycle time 1**
Did your company rely on consistent suppliers in terms of quality and time requirements and suppliers were not changed during project execution?	**Eliminate waste**	**Supply chain management 1**

Did your company train and utilize employees for multi-skilled activities e.g., mason team employed for scaffolding or steel fixing if free etc.?	**Culture/ people**	**Training**
Was Risk management carried out and planned?	**Eliminate waste**	**Reduce process cycle time 2**
Was the input of foreman and key workers considered in preparation of plans and schedules?	**Culture/people**	**People involvement**
Did your company use repetitive, preassembled or prefabricated standard construction elements?	**Eliminate waste**	**Optimize work content**
Did your company identify construction wastages (i.e., transportation, extra storage, motion, overproduction, waiting, over-processing, defects, and under-utilized talent), and was there any effort made to minimize these activities?	**Eliminate waste**	**Supply chain management 2**
Was the workplace organized, clean, and exhibiting information using visual devices?	**Standardization**	**Workplace organization**
Was there a trend of daily meetings between management and employees, instead of just site visits, to discuss the work methodologies, plans, schedules, or any changes, etc.?	**Continuous improvement**	**Error proofing**

Appendix 4

SURVEY QUESTIONNARE

(Please TICK any column in front of the respective statement)

1ST Principle of Lean Construction	**Cultural/People**

People involvement

Employees are considered an integral member of improving the Firms and their viewpoints/suggestions for improvement and execution are given due consideration by the top management	Never	Seldom	Sometimes	Often	Almost Always	N/A

Organizational Commitment 1

Management at all levels and supervisory staff have developed a mechanism to keep themselves updated with new changes in construction management and give enough weightage to them	Never	Seldom	Sometimes	Often	Almost Always	N/A

Training

The firm focuses to incorporate new skills in its employees that are required to fulfil the firm's changing demands	Never	Seldom	Sometimes	Often	Almost Always	N/A

2nd Principle of Lean Construction	Continuous Improvement/Built in Quality

Response to defects 1

In the identification of defects, quality plans are prepared which clearly shows the responsibilities of the concerned members	Never	Seldom	Sometimes	Often	Almost Always	N/A

Response to defects 2

The defects are identified and remedial actions are recorded for future use	Never	Seldom	Sometimes	Often	Almost Always	N/A

Response to defects 3

Every team is quite responsible enough to ensure quality in its product/activity at their own	Never	Seldom	Sometimes	Often	Almost Always	N/A

Error proofing

The supervisors/foremen always plan their work methodologies by duly consulting the team members on regular meetings i-e daily, weekly and, monthly meetings	Never	Seldom	Sometimes	Often	Almost Always	N/A

Organization learning

All information related to techniques and/or changes are always and timely shared with the concerned department in the organization	Never	Seldom	Sometimes	Often	Almost Always	N/A

3rd Principle of Lean Construction	Customer Focus

Flexible Resources 1

The firm is in a flexible nature and can cope up the change by utilizing minimum number of resources.	Never	Seldom	Sometimes	Often	Almost Always	N/A

Flexible Resources 2

Firms do depend on the actual resources but change directions with the changing customer needs without losing much time or money.	Never	Seldom	Sometimes	Often	Almost Always	N/A

Flexible Resources 3

All changes are passed immediately via telephone call first then through proper channel.	Never	Seldom	Sometimes	Often	Almost Always	N/A

Optimize Value 1

The project value is defined with the customer and known to everyone.	Never	Seldom	Sometimes	Often	Almost Always	N/A

Optimize Value 2

The customer needs are studied throughout a project rather only taken initially, understood correctly and the necessary construction is executed by these needs.	Never	Seldom	Sometimes	Often	Almost Always	N/A

4th Principle of Lean Construction	**Eliminate Waste**

Supply Chain Management 1

Materials predominantly reach at the site just before their usage and minimum storage is kept.	Never	Seldom	Sometimes	Often	Almost Always	N/A

Supply Chain Management 2

Firms select supplier who is reliable and can meet all the requirements in time. Changing supplier is never planned.	Never	Seldom	Sometimes	Often	Almost Always	N/A

Optimize Production System 1

The employees are multi-skilled and can be utilized in diverse activities e-g mason team can be employed for scaffolding or steel fixing if free etc.	Never	Seldom	Sometimes	Often	Almost Always	N/A

Optimize Production System 2

Detailed sequencing, flow charts and scheduling is carried out and regularly consulted before and during the operations/activities.	Never	Seldom	Sometimes	Often	Almost Always	N/A

Reduce Process Cycle Time 1

Coordination and cooperation among all the departments like mechanical, electrical, architectural, civil, design etc. is/was given enough importance.	Never	Seldom	Sometimes	Often	Almost Always	N/A

Reduce Process Cycle Time 2

Risk management is/was carried out and planned	Never	Seldom	Sometimes	Often	Almost Always	N/A

Reduce Process Cycle Time 3

Master schedule, Back-schedule and look-ahead plans are/were created, taking into account the input of foremen and key workers	Never	Seldom	Sometimes	Often	Almost Always	N/A

Optimize Work Content 1

Standard, prefabricated, preassembled, repetitively construction elements are preferred.	Never	Seldom	Sometimes	Often	Almost Always	N/A

Optimize Work Content 2

Non value adding activities are properly identified like travelling, waiting, defective works etc. Efforts are made to either eliminate or minimum resources to be utilized on such activities.	Never	Seldom	Sometimes	Often	Almost Always	N/A

5th Principle of Lean Construction	**Standardization**

Visual Management

The jobsite uses visual devices like posters boards news bulletins etc. at office and public areas, showing requirements of schedule, quality, safety, and productivity	Never	Seldom	Sometimes	Often	Almost Always	N/A

Workplace Organization 1

The firm gives due emphasize on Organizing and structuring the jobsite materials, tools and resources. Materials and tools are separately stalked as per their type and in sequence in which they have to be utilized close to the site.	Never	Seldom	Sometimes	Often	Almost Always	N/A

Workplace Organization 2

The firm pay enough attention in keeping the offices and construction sites clean and in order.	Never	Seldom	Sometimes	Often	Almost Always	N/A

Defined Work Processes 1

Processes are Identified and continuously monitored.	Never	Seldom	Sometimes	Often	Almost Always	N/A

Defined Work Processes 2

Planned and regular meetings are carried out frequently on weekly, monthly etc. basis instead of restricting the interaction to only site visits or inspections	Never	Seldom	Sometimes	Often	Almost Always	N/A

Pertinent to Project Outcomes

Less Project Delays

Project undertaken by the firm is/was not subjected to delays and/or un-wanted waiting periods during execution.	Never	Seldom	Sometimes	Often	Almost Always	N/A

Less Cost Over-runs

Project undertaken by the firm is/was not subjected to cost overruns.	Never	Seldom	Sometimes	Often	Almost Always	N/A

Less Quality Issues

Project undertaken by the firm is/was not subjected to quality issues and/or re-work.	Never	Seldom	Sometimes	Often	Almost Always	N/A

Less Health Issues

Health and safety issues were raised during execution were actively addressed by a safety/health official.	Never	Seldom	Sometimes	Often	Almost Always	N/A

Appendix 5

ATTRIBUTES OF RESPONDENTS OF SURVEY

Name	Organization	Project Cost (Million Rs.)
Muzammil Shah	Cityscapes	140
Muhammad Asif	Dev Developers	65
Umar Sulehri	Us Construction	120
Mahad Ch	Mahad Construction Company	235
Hassam Ismail	Zaurez Constructions	80
Rahim Khan	REC	95
Adeel Shigri	Aajsons Enterprises	200
Brig Ashraf	Baher Builders	230
Ali Khan	Skytech Private Ltd	400
Shaukat Ali	Shaukat Builders	90
Zakir	Miran Builders And Engineering	65
Col Jameel Ahmed	FWO	600
Waseem ul Haq	ZKB Engineers And Contractors	450
Samiullah	Bk Builders	85
Adnan Ahmed	Pak Builders	135
Raheel Khan	MJ Construction	220
Gulfam	Hi-Ways Engineering	485
Amjad Razzaq	NLC	500
Iftikhar Khan	Vision Group	220
M Amjad	Allied Engineering	95
Sardar Khan	Sardar Group of Companies	66
Hashir	Living Standards	83
Shahbaz Ahmed	Jaffer Group of Companies	150
Shabab Raza	Beacon Investment	190
Zafar Ali	Mohsin Construction Company	175
Basit Afzal	Basic Construction	35
Hazik Ali	Omega Construction Company	285
Mubashir Hayat	Earthlink	470
Gulraiz Tariq	Nespak	650
Ali Warraich	AKC	220
Mohid Ali	Blitz Construction	156
Abdul Nasir	Ibux Constructor	154
Khurram Malik	Earthlink	85
Hassan Ali	Hakim & Sons Enterprises	73
Raheel	NHA	650
Uzair Afzal	Afzal And Sons	220
Mamoon Elahi	Elahi Construction Firm	100
ZKB Builders	Ahmed Hussain	250
Umair	Usmani	85
Bashir Ahmed	Pak Gulf	125

Hussain Bukhari	Hb Enterprises	180
Sohail Malik	Asset Plus	170
Usama Sajid Butt	FWO	320
Asad	Asad Construction	55
Zamman Tariq	Zaeem Constructions	90
Naseeb Khan	Habib Construction Services	150
Anchan Karim	FWO	300
Dr Shahid Nazeer	Nazeer Construction	150
Zeeshan	Raheem Construction	85
Saqlain Sahi	Saleem Construction	142
Farman Ali	Hassan Constructions	270
Mansoor Shah	Rite Builders	158
Anas Ali	Prismatic Construction	160
Waleed Niazi	Saleem Construction	225
M Ahmed	Metro Construction	300
Khubaib Badar	Dar Construction	120
Umer Murtaza	Janjua Builders	62
Waleed Niazi	Gull Builders	124
Bilal Khalid	Citi Builders	185
Moeez Durrani	FWO	320
Saad Hamayun	Prismatic	150
Anas Ali	Munir Builders	120
Adnan Tariq	FWO	425
Haroon Iftikhar	Prism	135
Mohsin Kamal	Prism	135
Abdul Manan	Janjua Builders	220
Saad Pasha	Hassan Builders	185
Zia Ur Rehman	FWO	220
Adnan Ahmed	MES	325
Fawad Khan	FWO	400
Salman Ahmed	Gul Contractors	525
Rizwan Ahmed	FWO	800