ASSESSMENT OF LEAN CONSTRUCTION PRACTICE IN ETHIOPIA USING ANALYTICAL HIERARCHY PROCESS METHOD

MSC THESIS

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This is to certify that the thesis entitled **"Assessment of Lean Construction in Ethiopia using Analytical Hierarchy Process;** The Case of Sidama Region" submitted in partial fulfillment of the requirements for the degree of **Masters of science** with specialization in **Construction Technology and Management,** the Graduate Program of the **Faculty of Civil Engineering**, and has been carried out by **Muluken Fikadu** ID.No. **GPCoTMR/0016/13** our supervision. Therefore we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

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Declaration

I hereby declare that this MSC thesis entitled 'Assessment **of Lean Construction in Ethiopia using Analytical Hierarchy Process;** The Case of Sidama Region'' is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledge.

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ABBREVATIONS

AHP	Analytical hierarchy process
BC	Building contractor
CE	Concurrent engineering
DHM	Daily huddle meeting
GDP	Growth domestic product
JIT	Just in time
LC	Lean construction
LP	Lean principles
LPS	Last planner system
MoWUD	Minister of work and urban development
NVA	Non value-adding
RII	Relative importance index
5S	Sort, set in order, shine, standardize and sustain
TQM	Total quality management
UK	United Kingdom
USA	United States of America
VSM	Value stream mapping
VM	Visual management

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ABSTRACT

The performance of the construction industry is hampered by physical and non-physical waste. Hence, the requirement to embrace the implementation of Lean Construction (LC) practices that encompasses working culture, tools, and concepts to maximize value whereas additionally minimizing all kinds of wastes. The aim of this thesis is to assess the implementation of lean construction in Ethiopia, specifically in sidama region public projects. The paper investigates the implemented lean construction techniques and tools and identifies the benefits of implementing lean construction. In addition to this, the barriers to implement and critical success factors for improvement of lean construction are prioritize. The study was conducted using relative importance index (RII) and analytical hierarchy process (AHP) on Microsoft excel. Both qualitative and quantitative research approach is adopted to address research. The primary data were gathered from project managers, site engineers and site supervisors through questionnaire survey and interview and secondary data obtained from journals and research proceedings. The result obtained from respondents were correlated and discussed in detail. The findings revealed that pursue perfection, create smooth flow in process, allowing customer to pull, map the value stream and identify customer value are most significant lean techniques and last planner system, 5s, concurrent engineering, just in time and daily huddle time are the most significant lean tools implemented in construction projects. Similarly, increased productivity, reduce waste and production cost, eliminate all non-value adding activities, continuous improvement and reduce project time are top five benefits of implementing lean in descending order according to their RII value. The twenty five barriers to implement lean are categorized in to seven groups and prioritized using AHP. The result showed as lack of top management support and commitment, fragmentation and subcontracting nature of industry, resistance to change, incomplete and inaccurate design and influence of traditional management practice are most significant barriers based on their global weight. Also, from sixteen critical success factor, management commitment and involvement, understanding of technical requirements in lean, employee morale and motivation, strategy planning and training employees are most significant factors according to their global weight. Finally, the research concluded that lean implemented in Ethiopia with some barriers and recommended project managers to encourage improving its implementation in project site.

Key words; *Lean construction, lean tools and techniques, lean barriers and success factors*

CHAPTER ONE

1. Introduction

1.1 Background of the study

The construction industry contributes significantly to economic growth, both directly and indirectly, by delivering buildings and infrastructure for the smooth operation of businesses (Ahmed et al., 2021). The construction industry is the backbone of every nation, as it is one of the forces driving the world's socioeconomic growth and development. It raises the standard of living by providing infrastructures such as roads, schools, hospitals, and other necessities. In any country, the construction industry is the most important sector (Eze et al., 2017). The construction industry could be a basic economic sector that permeates most of the other sectors because it transforms numerous resources into constructed physical economic and social infrastructure necessary for socioeconomic development. It embraces the method by which the physical infrastructure are planned, designed, procured, constructed or produced, altered, repaired, maintained, and demolished. The construction industry has vital contributions to the Ethiopian economy, as demonstrated by its share within the gross domestic product (MoUDC, 2012).

To ensure continuous improvement in the performance of the construction industry, its challenges must be identified so that integrated solutions tailored to the context can be provided. The Ethiopian construction industry, like those found in most developing countries, faces several challenges that delay its progress (Mengistu and Mahesh, 2020). The construction industry's performance is hampered by waste, which contains material resources, costs, time, and labor, among other factors. As a result, it is crucial to embrace the implementation of Lean Construction (LC) practices, which include culture, plans, tools, and concepts for maximizing value whereas minimizing all types of waste produced (Oguntona et al., 2019).

The construction industry is trying to meet client value and end-user satisfaction, which is impacted by customers' dynamic demands for quality and speedy delivery without having to sacrifice value. The lean concept has been advocated as a perfect solution for poor project performance, and it has a high level of understanding but limited implementation among construction organizations, particularly in developing countries (Nwaki et al., 2021).

The positive impact of the construction industry on achieving the objectives of social and economic development of countries, it is continuously among various challenges within which 70% of projects are exposed to time delay, 14% of projects are exposed to cost overrun, and 10% of projects' materials cost are wasted. In line with world statistics in 2010, it absolutely was detected that 45% of the world energy and 50% of the water are consumed by the construction industry. Moreover, 23% of air pollution, 40% of water pollution, and 40% of generated waste are caused by construction projects. The main reason of the previous issues is that the unsustainable practice utilized in construction projects and therefore the inappropriate approaches of handling the various kinds of wastes generated throughout construction projects. These challenges inspired several countries to enhance their construction practices by applying Lean Principles within the industry that is known as Lean Construction (Ayman Ahmed and Maha Ahmed, 2018).

Lean Construction is a philosophy that aims to maximize the value delivered to the consumer whereas minimizing material, time, cost, equipment, and energy waste during the course of construction projects in order to achieve client satisfaction. This might be achieved through using and mixing existing approaches comparable to just in Time (JIT), total quality management (TQM), time-based competition and concurrent engineering, to call a number of lean approach (Verma et al., 2017).

As per Ayalew and Dakhli,(2016) study known that there's some level of awareness among professionals concerning lean construction, although lean construction isn't nevertheless practiced in the Ethiopian construction industry. Therefore, this thesis aims to assess the implementation of lean principles and tools, the benefits and barriers of lean construction, and critical success factors to improve implementation in the Sidama Regional government.

1.2 Statement of the problem

The development of construction industries has had negative impact on the environment, especially in terms of environmental change and generation of waste. One of the causes of construction waste is the over consumption of natural resources in the construction process (Adekunle et al., 2015). Construction material waste refers to the materials from the construction location that can't be used for construction functions and should be removed for any reasons. Within the implementation of a building construction project, it will be avoided the residual of construction material or usually known as construction waste. Beside effects on the cost, construction waste additionally affects to the environment (Rani, 2017). Construction waste will increase burden onto land fill that have become scare. If the waste isn't properly managed it causes water and soil pollution. Therefore it’s become essential for any construction company to reduce the construction waste to reduce environmental damages and enhance the construction process (Mhaske et al., 2017).

The construction industry is responsible for providing the basic structural components that are required for life to live and survive. Increased development efforts have resulted in a massive amount of waste generation in developing countries. It has become even more essential as a result of poor site management, and it has numerous adverse effects on society and the environment. This unused waste material has a negative impact on the

environment and requires a substantial amount of money for recycling, reusing, and disposal (Akhund et al., 2019).

Material waste has been known as a serious drawback within the construction industry. Studies from numerous sites confirmed that even the materials that are least wasted like glass, electrical fixtures, paints etc. represents a comparatively certain proportion on construction cost. These materials even have an adverse impact on surroundings. Materials are vital on building sites, and all the materials that are delivered don't seem to be used for the purposes that that they had been ordered and disappearance of those materials represent a part of waste and it's a negative effect on environment and additionally effects the contractors profit (Shankari et al., 2017). Waste has been recognized as a significant problem in any construction project. It affects the performance of construction comes severely and this is often a problem that interprets to a harmful impact on the economy at the national level (Teka, 2018).

The construction wastes clustered into physical and non-physical waste and its larger impact to environment, economy and social of every country (Nagapan et al., 2012). The Non-physical waste is usually generated during the construction process. Non-physical wastes, as opposed to material waste, are time and cost overruns in construction projects. Similarly, other activities such as repair, waiting time, and delays are also included in this category. Furthermore, waste in construction includes not only the quantity of materials on-site, but also overproduction, waiting time, material handling, inventories, and worker movement that is unnecessary (Akhund et al., 2019; Nagapan et al., 2011). Minimizing or eliminating those wastes from construction projects by using lean construction principles and tools helps in enhance the performance of construction project.

1.3 Objectives

1.3.1 Main objectives

The main objective of the study is to assess the lean construction practice in Ethiopia.

1.3.2 Specific objectives

1. To investigate the current implementation of lean construction tools and principles in Sidama region construction projects.
2. To identify the benefits of implementing lean construction concept on sidama region construction projects.
3. To prioritize the factors that barrier to implementing lean construction in sidama region construction projects using AHP.
4. To prioritize the critical success factors for improving lean construction implementation in sidama region construction projects.

1.4 Research questions

1. What are the lean construction techniques and tools implemented in sidama region construction projects?
2. What are the benefits of implementing lean construction in sidama region construction projects?
3. What are the factors that barriers to implement lean construction in sidama region construction projects?
4. What are the critical success factors for improvement of lean construction implementation in sidama region construction projects?

1.5 Scope of study

The research will assess the implementation of lean construction tools and principles, benefits of implementing lean, barriers to implement and critical success factors to implement lean construction in sidama region public construction projects. Limited in the scope to the following:

- The study is limited geographically to sidama regional government.
- The study was focus on construction professionals who are working on building projects.
- Public construction projects were considered as the research population where the sample is drawn.

1.6 Significance of the study

The main concept of lean construction is minimizing both physical and non-physical wastes in construction projects to increase the performance of contractors and the satisfaction of end users of construction project. Hence, the aim of the study is to contribute to the body of knowledge on the implementation of lean construction principles and tools, the barriers to implement lean construction, the critical success factors to improve the adoption of lean construction and the benefits of implementing lean construction concept in Ethiopian construction industry. This research provides for contractors improved method of work and waste minimization technique which is lean construction approach. It helps in minimizing the additional cost and time incurred by a project. Also, it will provide secondary document for higher educational institution for academic purpose and may use as teaching material of lean construction.

1.7 Limitation of the study

The study focused on assessment of lean construction practice in construction projects. The research limited to public building projects. The study was selects contractors greater than grade seven to target experienced professionals in construction projects and respondents were project managers, site engineers and site supervisors working in construction projects. Those factors makes the study could not cover large population. Therefore, Types of construction project and grade of contractors are limitation of study.

1.8 Organization of the study

Chapter one: introductions, it includes background of the study, statement of problem, objective of the study, research questions, significance of the study and limitation of the study.

Chapter two: literature review, it includes different scholar literatures on waste in construction industry, lean construction, lean principles and tools, benefits of implementing lean, barriers to implement lean and critical success factors to implement lean construction.

Chapter three: material and methods, it describe the study area, research design, research approach, population of the study, sampling technique, source of data, data collection instrument, data analysis technique, validity and reliability of data and ethical consideration in research.

Chapter four: result and discussion, in this chapter the result obtained from analysis are discussed briefly to answer research objectives of implementation of lean construction principles and tools, benefits lean construction implementation, barriers to implement lean construction and critical success factors to implement lean construction.

CHAPTER TWO

2. Literature Review

This chapter gives theoretical review and conceptual perspectives of lean construction, lean construction concepts and principles, benefits of implementing lean construction and its barriers to implement in construction industry. Also, the comparison of lean approach and traditional approach are included here.

2.1 Waste in construction industry

2.1.1 Definition of waste

Waste can also be seen as a by-product of an activity or process that is no longer of value to the owner who sees it as waste, but could also been seen as a resource by another (Henriques et al., 2009). Waste is any activity that absorbs sources and does not have any value adding. In another word waste is the loss of any kind of sources-materials, time (labor and equipment), and capital- produced by activities that generate direct or indirect costs but do not add any value to the final product from the point of view of the client (Bodkhe & Waghamare, 2016).

2.1.2 Construction waste

Construction waste refers to any material produced through human or industrial activity that has no residual value. Unwanted products or materials are referred to as waste. Construction waste is that any unwanted material produced either directly or indirectly by the construction or industrial processes. Construction and demolition waste is generated whenever there is a construction as well as demolition activity. Construction wastes in any project take the form of building debris from the demolition process, destroyed buildings, earth material, concrete waste, steel waste, timber waste, and mixed site clearance construction materials, which result from various construction activities on site including such land excavation or formation, civil and building construction materials, site clearance waste, demolition activities waste, roadwork waste, and building renovation waste (Gulghane & Khandve, 2015).

Construction waste clustered into two groups namely the physical and non-physical waste (Lau et al., 2008; Nagapan et al., 2012):

a) Physical waste

   Physical construction waste is waste generated by construction, renovation, and demolition activities such as land excavation or formation, civil and building construction, site clearance, demolition activities, roadwork, and building renovation. Some, however, limited their description to solid waste: Sand, bricks, blocks, steel, concrete debris, tiles, bamboo, plastics, glass, wood, paper, vegetation, and other organic materials comprise the majority of inert waste (Nagapan et al., 2011).

b) Nonphysical waste

   Non-physical waste is frequently generated during the construction process. Non-physical waste, as opposed to material waste, is time and cost overruns throughout construction projects. Waste is associated with not only material waste but also with other activities such as repair, waiting time, and delays. Furthermore, waste can be described as any inefficiency in the construction process that results in the use of equipment, materials, labor, and money. In other words, waste in construction includes not only the quantity of materials on-site, but also overproduction, waiting time, material handling, inventories, and unnecessary worker movement (Akhund et al., 2019; Nagapan et al., 2011).

2.1.3 Categories of waste in construction

The studies of (Akhund et al., 2019; Ayalew et al., 2018; Hossain et al., 2019) summarized and categorized construction wastes as the following;

Overproduction: related to Production of a quantity greater than required or earlier than necessary, which may cause waste of materials, man-hours or equipment usage. It usually

produces inventories of unfinished products or even their total loss, in the case of materials that can deteriorate.

Waiting time: This kind of waste related to idle time caused by lack of synchronization and leveling of material flows, and pace of work by different crew or equipment.

Transportation: Concerned with the internal movement of materials on site. It is usually related to poor layout, and the lack of planning of material flows. Its main consequences are: waste of man hours, waste of energy and the possibility of material waste during transportation.

Processing: This one is related to the nature of the processing (conversion) activity, which could only be avoided by changing the construction technology.

Inventories: This is due to excessive or unnecessary inventories, which result in material waste (due to deterioration, losses caused by inadequate stock conditions on site, robbery, and vandalism), in addition to monetary losses due to capital tie-up. This could be a result of a lack of resource planning or uncertainty in quantity estimation.

Movement: Concerned with unnecessary or inefficient movements made by workers during their job. This might be caused by inadequate equipment, ineffective work methods, or poor arrangement of the working place.

Production of defective products: It occurs when the final or intermediate product does not fit the quality specifications. It can be caused by a wide range of reasons: poor design and specification, lack of planning and control, poor qualification of the team work, lack of integration between design and production, etc.

2.2 Lean construction

2.2.1 Definition

Lean construction is a set of techniques to identify and eliminate waste from operations. System of organization principles to maximize value and eliminate waste (Dodiya, 2020). Lean Construction is a new production philosophy that has the potential to revolutionize

the construction industry. It is the most basic method of designing production systems to minimize waste of materials, money, time, and energy in order to maximize potential value. Lean makes an important contribution to the construction industry's efficiency. Lean philosophy is all about designing and implementing the right resources at the right time with the right systems. Lean construction incorporates two critical construction tools: production control and work structuring. Lean Construction is also about gaining control through collaborative efforts within and between team members and stakeholders (Ahmed et al., 2021).

2.2.2 Lean approach

The pull system, employee involvement, continuous improvement, as well as other methods are utilized in lean production to eliminate waste and maximize productivity. Much has been said about how to eliminate waste and increase productivity by implementing the lean concept. However, as environmental sustainability becomes an increasingly important part of construction culture, there is a need to investigate the applicability of the lean approach to achieve environmental sustainability, which is frequently used interchangeably with the term eco-friendly (Shaik Md Sami Pasha, 2019).

2.2.3 Lean construction concepts

The study of Thakkar and Shah, (2021) stated that the principal idea of lean construction is to maximize client value whereas abetting waste; furthermore, it will be simplified as a method to make a lot of value. Lean technique understands customer value and focuses its key processes to continuously appreciate it. The principal agenda is to supply perfect value to the patrons through a perfect value creation process that has nominal or zero waste. To attain this, lean thinking changes the main focus of management from optimizing individual technology, assets, departments and agencies, to optimizing the flow of product and services through entire value streams that flow equally across technologies, assets, and departments to customers. It additionally allows the flow of steps by ruling out the non-

value added activities that are resources, time or area consuming (Ingle and Waghmare, 2015). It focuses on process improvement through the reduction of duration for every activity. The thought of lean provides the base for the effective management of the project. Lean construction is a new way to design and build capital facilities. It advocates the concurrent consideration of product and process development using simultaneous engineering. This philosophy has challenged the belief that there's continuously a trade-off between cost, time and quality (Mohammed Fadhil Dulaimi & caroline Tanamas, 2001).

2.2.4 Lean construction principles

2.2.5 Identify customer value: -

Specify the value from the perspective of ultimate customer. It is essential to meet the required specifications and to deliver the value desired to the end customer. By clearly defining value for product or service, customer value becomes the common focus for parties involved in the project (Ansah et al., 2016). What customers value the most and what the team that has been organized for work values to discrete the value-adding from waste activities. Because value is everything that customer pays for it (Thakkar & Shah, 2021).

2.2.6 Map the value stream:-

Clearly identify the aspects that add value to the customer and the aspects that do not add value to the customer in both production flow and design flow. This is also known as value stream mapping, which also includes eliminating all the non-value added tasks and resources used within the flow (Halling, 2013). Identify all the steps in the value stream for each product or family, closing out the steps which do not add any value to the project to deliver the project efficiently (Shah et al., 2021a).

2.2.7 Create flow: -

Make the value-creating steps occur in sequence so the product will flow smoothly and with better-integrated disciplines and iterations (Aziz & Hafez, 2013a).Taking the remaining value adding steps in to flow without interruption by managing all co-related

activities to achieve best sequence of work. This will simultaneously minimize the waste production as well as increase the value (Knotten et al., 2017) .

2.2.8 Use Pull logistics: -

All components and information of the work are made and supplied at a predetermined time and to produce what customers want by obviating delays and overproduction (Shah et al., 2021a). Compile the production line as per the customer demand and when the production is needed, making the production lines much speeder (Jacobs, 2010).

2.2.9 Pursue Perfection: -

A cardinal part of the lean concept is continuous improvement. Continuous improvement can be achieved with the help of method like Plan-Do-Check-Act, known as PDCA to deplete the waste (Shaqour, 2022b). It aims at the perfect solution and continuous improvement, Deliver a product which lives up to customer's needs and expectations within the agreed time schedule and in a perfect condition without mistakes and defects. The only way to do so is by having a close communication with the customer/client as well as managers, and employees are between (Aziz & Hafez, 2013b).

2.3 Lean construction tools

With the continuous decline in profit margins and increased competition in construction projects, construction contractors are continuing to search for ways of eliminating waste and increasing profit (Salem et al., 2005). Numerous approaches have been developed to improve efficiency and effectiveness of construction processes, lean construction techniques offer the promise to minimize, if not completely eliminate, non-value adding work (Salem et al., 2006). The lean techniques (LT) are the backbone of lean construction and have advanced since the start of its application within construction industry. (Oke et al., 2019) defined Lean Construction Techniques as procedures, structures, conceptions, models, methodologies, and products which when implemented assist corporations apply lean across the workplace.

Lean production has several tools and techniques that have evolved since the beginning of it is application in the construction industry. These tools and techniques continue to develop as more understanding and experience develops (Abdelrazig, 2015). There are various lean techniques that have analyzed and adopted throughout the construction research field. Process mapping technique, 5s techniques, last planner technique, increased visualization, fail for safe quality, daily huddle meeting first run studies and many more lean techniques are available. Enshassi and Zaiter, (2014); Salem et al., (2005) discussed six tools in their study, (M. S. Bajjou et al., 2017) discussed nine tools, (Koohestani et al., 2020a) studied five tools also Ayalew and Dakhli, (2016) study focused on seven tools of lean. The study by Aslam et al., (2020) revealed that from twenty three (23) enumerated lean tools Out of the total twelve (12) objectives, last planner system (LPS), visual management and daily huddle meeting target seven (7) objectives followed by firsts run study and 5S which are targeting the six (6) objectives and fail safe for quality and safety, six sigma, kanban, Just in time, kaizen, concurrent engineering and prefabrication targets five (5) objectives of lean construction. LPS has been identified as being in conformance with LC, thereby targeting the most number of objectives. Whereas tools like fail safe for quality and safety (FSQS), kanban and poka yoka (PY) are targeting two objectives. According to Ayalew and Dakhli, (2016) study many lean construction practices aren't established in Ethiopian construction industry. For instance GPS control and poka yoka which is related to technology use is rare. Therefore this study focused on last planner system, visual management, daily huddle meeting, first run studies, 5s, fail safe for quality, six sigma, kanban, just in time, kaizen concurrent engineering and prefabrication.

Since managing construction waste is one of the most significant management processes necessary to achieve project objectives, it is hereby recommended that companies should use lean construction to identify and analyze waste to improve productivity, minimize time

and accidents, improve reliability, improve quality and ensure more client satisfaction. This study deals with main lean construction tools or techniques that reduce both physical and nonphysical waste. Some of the lean techniques which are used to reduce waste are discussed below.

2.3.1 Last Planner System (LPS):

The Last Planner System (LPS) is a collaborative planning process that involves work trades in planning in greater and greater detail as the time for the work to be done gets closer. In construction, LPS is considered an effective tool to control workflow and reduce project variability (Ahmed et al., 2021). It is an effective solution that could considered as an alternative to the traditional planning system (A Push Planning System). It aims at promoting people involvement and reducing wastes that are caused by ineffective tasks synchronization (M. S. Bajjou et al., 2017). Minimize the project uncertainty by planning backwards of a target, increasing the commitment of team members that involves with project flow and variables (Wellman, 2011).

2.3.2 Visual management

Visualization in general and particularly in construction projects is a convenient and intuitive way of conveying project information among various project parties (Enshassi & Zaiter, 2014). It makes the construction process transparent, simple and safe for all stakeholders on site through digital billboards, signs of security and graphical dashboards of PPC facilitate the construction process and increase the performance of communication between the coordinators of the project, which make the site of construction safer and more transparent. Each material/equipment identified using visual signs easy to understand by labor which helps to minimize unnecessary displacements/movements and increase the transparency of the flow(Aziz & Hafez, 2013b; Mohamed Saad Bajjou et al., 2017b).

2.3.3 Daily huddle meeting

Daily huddle meetings provides a platform for the team members to share their views and to share what has been achieved, at the same time, discus problems they are facing during the production process (Aziz and Hafez, 2013b).This a technique of everyday meeting process of the project team in order to accomplish workers involvement with project awareness and problem-solving contribution (Ahmed et al., 2021). The huddle-up meeting is a great communication tool and can be used to address other project issues such as weather, environment, security, quality, or schedule. The huddle-up meeting provides a format to communicate coordination, quality, security, and schedule issues that must be addressed and, like safety, critical issues may require a work pause or stop work order until they are remedied; a warning may be issued for lesser events (Vimal Kumar & Ramasamy, 2016).

2.3.4 First run studies

First run studies include productivity studies and review work methods by redesigning and streamlining the different functions involved. Using video files, photos or illustrations to show the process or illustrate the work instruction. First Run Studies are used to redesign critical assignments and it is one part of continuous improvement effort; and includes productivity studies and review work methods by redesigning and streamlining the different functions involved (Enshassi and Zaiter, 2014). The first run of a selected craft operation should be examined in detail, bringing ideas and suggestions to explore alternative ways of doing the work. A PDCA cycle (plan, do, check, act) is suggested to develop the study: Plan refers to select work process to study, assemble people, analyze process steps, brainstorm how to eliminate steps, check for safety, quality and productivity. Do means to try out ideas on the first run. Check is to describe and measure what actually happens. Act refers to reconvene the team, and communicate the improved method and performance as the standard to meet (Le Gratiet, 2017).

2.3.5 Five s (5S)

It improves the organization of the construction site by keeping each material in its place and removing all unnecessary components (Fardhosseini & Soltaninejad, 2021). A systematic housekeeping process which is performed by its five distinctive steps: Seiri "Sort", Seiton "Set in order or Straighten", Seiso "Shine", Seiketsu "Standardise", and Shitsuke "Sustain" (Alarcón et al., 2005).

Method 5'S has 5 steps from the initial Japanese word representing successive stage of its implementation (Maske & Valunjkar, 2020).

1. Seiri (sorting) - the removal of all unnecessary tools and parts, putting in order;

2. Seiton (set in order) - deployment of work, workers, equipment, parts and instructions in such a way that the flow of work is free from inefficient tasks.

3. Seiso (Shine) - cleaning workplace and the all of the devices used.

4. Seiketsu (standardization) - making sure procedures are standardized and reproducible.

5. Shitsuke (sustain) - helps maintain introduced procedures and rules.

2.3.6 Fail safe for quality

Fail safe for quality is about being constantly focused on quality and safety issues from the beginning till the end. Potential quality and safety improvement practices are constantly investigated. Quality is sought to be reached at the source of any failure before a mistake's taking place (Enshassi and Zaiter, 2014). Fail safe for quality and safety introduced Poka-Yoke as new elements that prevent defective ports from flowing through the process. Fail safe for quality relies on the generation of ideas that alert for potential defects. It can be extended to safety but there are potential hazards instead of potential defects, and it is related to the safety risk assessment tool from traditional manufacturing practice (Genaidy et al., 2004).

2.3.7 Six sigma

It is a collection of methods for enhancing quality in the construction process by removing flaws and decreasing variances (Hossain et al., 2019). Lean Six Sigma is a process that improves performance by methodically eliminating waste and minimizing variance throughout a collaborative team effort. In construction continues improvement is very helpful for organization and also construction. With the help of six sigma tool we can improve customer satisfaction and make it more valuable as per customer requirements (Chhabra and Rathore, 2011). Six Sigma based tools have emerged and have been successfully applied to simple and complex construction projects. In general, six sigma projects are easier to manage, safer, completed sooner, and cost less and are of better quality. Six sigma is reportedly easier to apply than many other quality management programs because it provides information about the change needed and the programs to execute the change. The strategy it uses is a five step improvement process: Define Measure, Analyze, Improve and Control (DMAIC). This process is deeply integrated with the overall goals of the organization and as such, requires top down implementation (Sathe and Allampallewar, 2017).

2.3.8 Kanban

This Japanese word stands for sign or card. It is used in controlling the amount of material/ components in the Stock. It regulates the movements or flow of resources so that parts and supplies are ordered and released as they are needed (Ahmed et al., 2021). The strategy of Kanban is grounded on key components, i.e., market place, supplier kanbans, collection vehicle, satellite stores, and inventory management system. Market places are site warehouse that allocate different materials and small tools to the workers. Similarly, satellite stores are situated on site, where they get products from market places. Collection vehicle collects materials from preferred suppliers to the operational site (Aziz and Hafez, 2013b).

2.3.9 Just-in-Time:

The Just-in-Time or JIT is an inventory management system wherein the material or the products are produced and acquired just a few hours before they are put to use. The Just-in time system is adopted by the firms, to reduce the unnecessary burden of inventory management, in case the demand is less than the inventory raised. The objective of Just-in-time is to increase the inventory turnover and reduce the holding cost and any other costs associated with it (Patel, 2019). It facilitates the transfer from a push strategy to a pull strategy using kanban cards which allows reducing the amount of inventory (Mohamed Saad Bajjou et al., 2017). Minimum number of inventories made according to the requests only, construction leveling and minimizing the amount of activities (Adegbembo et al., 2016). It is a technique to reduce time flow of production as well as reduce the response time from suppliers to the end-users. It is also a method of thinking, working and controlling waste in production (Ahmed et al., 2021).

2.3.10 Kaizen

This is a Japanese production and process philosophy of continuous improvement. It use to improve the quality and efficiency by reduce waste of any workflow (Ahmed et al., 2021). Kaizen is concerned with reducing waste in a particular process by incrementally addressing the existing process before they occur or when they occur. The processes here may be in the project planning or construction phase. Kaizen is an innovative concept which is also known as continuous improvement in construction evaluate process quality, time, resources, and demand (Shaqour, 2022a).

2.3.11 Concurrent engineering

Concurrent engineering can be described as parallel execution of various tasks by multidisciplinary teams with the goal of obtaining most favorable products concerning functionality, quality, and productivity. Many enhancements can be accomplished by using concurrent engineering. Scheduling could be recovered by network analysis (CPM and

PERT). Many other opportunities can be achieved through overlapping activities, splitting activities and reducing the transfer time between different activities. The important planning parameters for scheduling concurrent activities are lead time, quantity, and risk under ambiguity. Concurrent engineering is focusing on the team efforts; communication and information sharing are the keys for discovering new ideas. While partnering with subcontractors and suppliers can also be good changes regarding concurrent engineering, the success of lean production is depending on the involvement of all participants in the early stages of the design (Aziz and Hafez, 2013b).

2.3.12 Prefabrication

It is a tool for trial execution of a process with a specific final goal to decide the best means, strategies, sequencing, among others to perform it (Hossain et al., 2019). It consists of using modularization and prefabricated construction components aiming to eliminate the common issues (waste, low output quality, low productivity, high variability, and poor safety) (Ahmed et al., 2021). Prefabrication is one of the new techniques to ensure that the components are manufactured and assembled off-site. Several practical cases have shown the efficacy of this technique in reducing waste (M. S. Bajjou et al., 2017). The prefabricated construction has become an important area over the last decade, not only for its agility, but also for its adherence to the Lean Construction philosophy, that promotes the reduction of the volume of waste in building and contributes to a lower environmental impact. The concern with the generation of waste and emission of gases in the stages of construction and demolition has been the main reasons for the development of new construction systems. Prefabrication is capable of addressing the three dimensions of sustainability: economic, social and ambient (Corvello et al., 2020).

2.4 Benefits of adopting lean construction

There are frequent failures within the project delivery in time and increasing the waste in the construction industry. Lean Construction (LC) principles that are lean thinking in design and construction process are also an attainable solution (Shah et al., 2021b).In rapid, construction projects, it's unacceptable to manage the project through the standard ways. it's been determined over and over that the productivity of the construction depleting and leads to rework and produces several wastage such as over production, inventory, unnecessary transportation, staff displacements, over processing, defect, waiting of materials, unused worker creativity, work accident, and so forth so practical concepts and techniques need to be utilized in construction which will facilitate projects groups to handle wastage in construction with the utilization of optimum resources and this could be achieved by using lean construction principles and techniques. The advantages of Lean Principles are: exactly specify value from the attitude of the ultimate client, Clearly determine the process that delivers what the customer values, Delivering comes on time or in some cases prior to schedule and eliminates all non-value adding steps, Crating a smooth work flow and eliminates the waste, rising relations with vendors and improving customer satisfaction, will increase profit and market share, Pursue perfection by continuous improvement., rising the project cost, quality and time (El-sawalhi et al., 2018). According to Salunkhe, (2018) the benefits of lean construction are Precisely specify value from the perspective of the ultimate customer, Clearly identify the process that delivers what the customer values, Delivering projects on time or in some cases ahead of schedule and eliminates all non-value adding steps, Crating a smooth workflow and eliminates the waste, Improving relations with vendors and improving customer satisfaction, Let the customer pull don‘t make anything until it is needed, Increases profit and market share,

Pursue perfection by continuous improvement, Improving the project cost, quality and time.

Lean construction allows an effective collaboration with advanced technologies and it brings out appreciable benefits of schedule, quality, safety and productivity in the construction projects (Ahmed et al., 2021). Although the construction industries worldwide encountered several challenges when implementing LC, some industries have recognized the opportunity to embrace improvements through lean implementation (Kharade, 2019). Various benefits and advantages have been recognized by the researchers. The most important benefits of using LC in organizations are the reduction of waste. By eliminating waste in the construction, LC encourages the following: Minimize double handling and movement of equipment and workers, Balance team, coordinate flows, Take off material constraints, Minimize variance in input, Minimize changeovers and difficult setups, Reduce interpersonal dynamics (O. Akinradewo et al., 2018).

Lean construction is implemented through various lean-based tools or in other words lean techniques. Implementation of these techniques in simple and complex projects makes the projects easier to manage, safer, completed sooner, and cost less and is of better quality (Ghosh et al., 2014). There are numerous benefits from implementation of lean tools and techniques these benefits are as follows: quality performance, fewer defects and rework, fewer machine and process breakdowns, lower levels of inventory, less space required, higher efficiencies, more output per man hour, improved delivery performance, faster development, greater customer satisfaction, improved employee morale and involvement, improved supplier relations and increased business (El-sawalhi et al., 2018).

The study by Gerasimos Siasos, (2017) revealed that many project-related items could be enhanced after implementing Lean Construction tools such as time-saving, material waste reduction, labor waste reduction, and space-cost saving. The study also classified benefits

of lean construction into economic, environmental, and social benefits. The environmental benefits are safety control improvement, preventing pollution and emissions, material waste reduction; improve the quality of the environment and reduction of energy consumption. The economic benefits are rework minimization, increase productivity, time and cost reduction, improve quality, improve process control, improve prediction of risk and improved planning. The social benefits are customer satisfaction, minimization of conflicts, enhancing transparency, improving decision making, enhancing team work and improve communication between project stakeholders.

The introduction of the Lean Construction concept and its application within the construction industry is reported to have birth a lot of benefits. Evidence of the use of lean thinking has shown that there are many benefits to be made from applying lean principles to construction. These benefits claimed includes; delivery of products and service on time and within budget, more satisfied client, less idle time, increase percent plan complete, increment in worker motivation, improvement of project delivery methods and minimization of risk and maximization of opportunities (Adegbembo et al., 2016). Lean construction is the continuous process of eliminating waste, meeting or exceeding all customer requirements, focusing on the entire value stream and pursuing perfection in the execution of construction project. The application of a lean production system would allow companies to achieve the following benefits: Reducing waste and production cost, decreasing manufacturing cycle times, improving quality and increasing profits, increasing system flexibility in reacting to changes in requirements, Reducing labor while maintaining or increasing throughput, and reducing inventory while increasing customer service levels (Ayman Ahmed & Maha Ahmed, 2018).

2.5 Barriers to implement lean construction

Several studies have been carried out in different countries worldwide to identify the barriers in implementing the LC approach. Some of these studies focused on investigating barriers that prevent the diffusion and implementation of LC. Others focused on identifying barriers that exist during the execution of LC practices. These barriers could affect the application process of LC and hinder the project performance, if not properly managed. By not understanding the factors that affect the successful implementation of LC, organizations will not be able to know what improvement efforts need to be made, where these efforts should be focused, or which efforts could obtain best results (S Sarhan & Fox, 2013).

According to Huaman-Orosco and Erazo-Rondinel, (2021) and Movaghar, (2016) studies showed that the main barriers to implement lean construction are: Lack government policies, Lack of cooperative work between academic and business, High cost of implementation, and Lack of information of lean in professionals graduated from universities, lack of keeping things within the right places, lacking build able designs, lacking a participant management technique for the workforce, not having compatible management leadership, not using standard elements, lacking communication within teams, lacking constant work commitment, no understanding of the wants of customers, lacking project team talent and not having a well-defined focus for the team.

It was found that the major clusters of barriers to lean implementation are technology and knowledge barrier, leadership and management barrier, culture and complexity barrier, engagement and relationship barriers, financial barriers, and communication barriers. It was recommended that adequate management and leadership support is needed for entrenching lean construction techniques into the culture of operations of construction organizations. These key barriers to LC will enable managers of construction organizations

and projects to better prepare for the challenges ahead, especially as they have to do with the reduction of wastages and maximization of projects and value (Nwaki et al., 2021).

The construction industry is fragmented and dynamic. Therefore, the construction industry is dealing with several uncertainties and claims as well as safety, quality, productivity, project delivery, and waste problems. To preclude and make improvements in these aspects, the lean technique was introduced in the construction sector. The study of Thakkar and Shah, (2021) concludes that the dominant barriers of lean construction in the construction industry are Resistance to change and culture. To overcome these barrier practitioners could use new technologies like BIM modeling, make preschedules, update daily tasks in an online portal, or train the employees and make them aware of novel methods which are dominant in the market. The second barrier, design detailing and process, can be prevailed by making parametric estimates rather than detailed estimate or by curtailing time in the designing process. Furthermore, other major obstacles were pertinent to waste, culture and human attitudinal issues, and lack of coordination and communication. These can be subdued by proper material management, motivating the employees/workers, and improving communication technique between different agencies.

Barriers when implementing lean construction are identified as very important focus area and extremely relevant for future success and further development of lean construction in pursue of an efficient construction process (Wandahl, 2014). Lack of long term policies and clear vision in construction business also, often leads to failure of lean adoption. Similarly, lack of systematic and cross functional process supportive procurement approaches also hinders the lean adoption. As the main aim of lean adoption is waste reduction and to streamline the cross functional and functional process through continuous improvement, so lack of construction firms' attention among design details and its coordination can act as obstacle in its successful adoption (Hajj, 2018). From construction

management's perspective, lack of professional recruitment and ineffective human resources working for the company, also increases wastes and enhances cost and results in delayed performance (Sayed et al., 2019).

The above discussed barriers are summarized and categorized by Enshassi et al., (2019) as follows; management barriers, financial barriers, educational barriers, governmental barriers, technical barriers and human attitudinal barriers.

2.5.1 Management barriers

Management barriers are referred to various issues related to the support of the top management. Since the successful implementation of LC or any new innovative strategy needs to be supported by top management. Therefore, these barriers are lack of time for innovation, lack of transparency, Lack of communication among participants of the production process, Poor coordination between the project parties, Inadequate planning to implement LC, Lack of top management support and Inefficiency in resource planning (Demirkesen et al., 2019; Enshassi et al., 2019).

2.5.2 Financial barriers

The successful implementation of LC requires adequate fund to provide relevant resources, incentives and reward systems and sometimes to employ Lean specialist in the early stages to guide the organization in implementing the concept of Lean. These barriers are Low tender prices, Cost of training, consultancy fees and cost to conduct workshops, poor salaries of professionals, Lack of incentives and motivation, corruption and inflation (Demirkesen et al., 2019; Enshassi et al., 2019).

2.5.3 Educational barriers

Educational barriers included lack of understanding of Lean concept and inadequate knowledge of LC. This can be traced to the fact that LC is a concept evolved from the manufacturing industry. Lack of technical skills is another barrier impedes the implementation of LC in construction projects. Furthermore, lack of education and

training; and lack of awareness programs and Lack of experiences and information sharing is another educational barrier to the implementation of LC in construction projects (Demirkesen et al., 2019; Enshassi et al., 2019).

2.5.4 Governmental barriers

The barriers of LC implementation are due to government attitudes and support towards the construction industry in some countries. Governmental barriers are related to the government bureaucracy and instability. Moreover, inconsistency in policies and unsteady price of commodities needed for construction projects are government related barriers (Bayhan et al., 2019; Enshassi et al., 2019).

2.5.5 Technical barriers

Technical barriers have a direct impact on the application of certain LC principle and tools such as reliability, simplicity, flexibility and bench-marking. Lack of agreed implementation methodology to implement LC is identified as technical barrier prevented the successful implementation of LC in construction projects. Moreover Complexity of Lean philosophy and terms, long implementation period, incomplete designs, poor performance measurement strategies and fragmented nature of the construction industry and implementation time are some of technical related barriers (Bayhan et al., 2019; Enshassi et al., 2019).

2.5.6 Human attitudinal/cultural barriers

Human attitude or cultural issues are one of the major factors affecting the implementation of LC in construction industries. Selfishness among professionals to provide their experience of the LC implementation as a human barrier prevented the successful implementation of LC in construction projects. Resistance to change, Fear of unfamiliar practices and Diversity in adopting Lean culture are proved a barrier impedes the successful implementation of LC in construction projects (Demirkesen et al., 2019; Enshassi et al., 2019).

2.6 Critical successes factors for implementation of lean construction

Successful implementation of lean principles in the construction industry depends upon certain key enabling factors. These need to be identified, documented and clearly communicated to a wider set of stakeholders to improve the chances of success (Watfa & Sawalha, 2021). The review of the literature in the fields of Lean Management and Lean Construction reveals a list of reported factors that were most commonly cited as "critical" for the successful implementation.

2.6.1 Management and leadership factors

Management commitment, specifically the top management, is crucial to successful implementation of lean. Full support of the top management shapes progress but lack of commitment of the top level staff may lead to partial engagement in the change process, lack of attendance at events, and a visible reluctance to implement the workforce's ideas (Oyedolapo, 2014). Management commitment and involvement in the Lean implementation is a very important factor for the success of this initiative. Researchers argue that it is top management who should drive the change mind-set into the organization by setting up goals and objectives and ensure working towards achieving them. It is essential for management to create a quality culture by empowering and motivating other employees and by creating the right working environment characterized by openness in order to eliminate the fear factor. This can only be achieved by strong leadership from management (Watfa & Sawalha, 2021).

Changes can be made easily with support from the top management in an organization. Good leadership will be able to promote the integration of lean thinking in the production of building components. With the aid of leadership, effective management of information flow in the production process can be achieved. Leaders can also play the role of an employee who is able to wield influence at whatever level of seniority and responsibility. Having a responsible leader alone in an organization is incomplete without teamwork

among the employees. Teamwork, along with commitment is vital to ensure that employees work together in a coordinated and mutually supportive way (Yunus et al., 2017).

2.6.2 Workforce factors

Learning is possible with creating a shared environment and working with the professional teams. In this respect, workforce is critical to create an environment open to learning and new opportunities. Moreover, working relationships with suppliers and supplier selection control mechanisms can enhance the quality of exchange, which results in going Lean. Workforce is key to success of an organization in terms achieving goals set and promoting Lean practices (Demirkesen & Bayhan, 2020).

2.6.3 Technical factors

Technical factors consist of a clear understanding of the technical requirements in Lean practices, availability of consulting team members in Lean, the technical capacity for implementing Lean tools, and the availability of Lean tools and techniques. Unfamiliarity with the technical requirements for Lean leads to lower performance in achieving a successful Lean implementation process, due to the time spent in repeating processes. Hence, it is essential to review standards and requirements before the implementation takes place. Lean implementation might be conducted with success given the existence of the necessary Lean tools and techniques (Bayhan et al., 2019). Technical competency as an element of Lean management and emphasize that Lean professionals must acquire competencies in construction techniques, project management, and tools for a successful Lean implementation. For instance, building information modeling (BIM) tools offers various advantages for construction professionals to visualize and coordinate work. Hence, firms benefit from BIM applications in their projects to experience enhanced performance in work processes. BIM might be successfully integrated with Lean tools so that construction practitioners might visualize things and error proofs the processes. Thus, it is

essential that companies implementing Lean have the technical capacity available for the appropriate use of construction techniques and tools (Design, 2018).

2.6.4 Resource factors

Despite the practice of resource planning in multi-project organizations, resource management and resource optimization were considered as scarce. Schedules were barely checked against resource availability. Therefore, work interruption due to resource conflicts was found to be common in projects (Koohestani et al., 2020a). Lean concept focuses on creating value for customers; hence, it is important to building relationship with Customers in order to have their support for the Lean program. Within Lean Construction context, suppliers include subcontractors and material suppliers, while Customers refer to Consultants and Owners. Supplier's Quality is critical in Lean System (Watfa & Sawalha, 2021), Quality here is supplying material or performing a subcontracted job at the right time and in proper quality without need for further inspection, performing this consistently is necessary to eliminate the process variability. Suppliers' Quality and Reliability enables them to perform Just in time (JIT) delivery (Found and Harrison, 2012), which a core elements in Lean since it reduces the process cycle time by eliminating the waste.

2.6.5 Organizational culture and governmental factors

The organizational culture elements have been extensively investigated by the researchers as a key factor for implementing Lean and Lean Construction. It can be seen that organization culture which doesn't accept failure or change will fail in implementing any new improvement initiative. It's important to realize that the transformation to Lean requires massive changes by creating the right culture, and the conditions which can become the foundation for implementing change, moreover, the culture in Lean includes encouraging people to participate in the process; if the organization can engage people to participate, and convince them to accept the changes, it will result in creating a lean culture with more people motivated towards the change (Watfa & Sawalha, 2021). Organizations

are often made up of top management and employees with different personalities and goals, so each one of them have a distinct culture. In order to survive, organization and their cultures must continuously evolve and change. In addition, three essential elements can affect organizational change, which are: beliefs, diversity of employee and leadership behavior that can facilitate or inhibit change in the organization (Houti et al., 2019).

2.7 Comparison of traditional management with lean construction

The growing context of globalization permanently increases pressure on the construction companies to improve their performances in order to resist to the constraints of competitiveness in the international market. It has become ineluctable to look for introducing a new alternative capable of bringing creative improvement to the traditional production system (Mohamed Saad Bajjou et al., 2017).

The Lean construction is different from the typical/traditional construction in many aspects. In the typical construction, the conversion activity takes place, that is, every input is converted into output through a process. The typical construction focuses on the finishing the things thus achieving the efficiency but lacks in the value. The typical construction aims to achieve efficiency by implementing new technology whereas the lean approach focuses on eliminating or reduction of non-value adding activities and increasing the efficiency of the process through continuous improvement. The efficiency in Lean approach is improved by redesigning the process Lean construction is different from current construction management because it aims at increased performance at the project level, it possess and focuses on a clear set of objectives for the delivery process, its designed the process and the product simultaneously and, it looks towards the efficient productivity throughout the life cycle of the project (Gaikwad et al., 2020).

2.8 Summary of literature review

Lean Construction is a new production method which might bring in revolutionary changes within the construction industry. It's the simplest way to design production systems to reduce waste of materials, money, time and energy so as to come up with the most potential amount of value.

This study focused on lean construction principles and tools, benefits of implementing lean construction, barriers to implement and critical success factors to improve implementation.

Table 2.1 Principles of lean construction

Principles of lean construction	Source
Identify customer value	Ansah et al.,(2016); Dodiya,(2020); Jayaraman et al.,(2008); Raaj & Kumar, (2019)
Map the value stream	W. Ahmad, (2019); Ansah et al.,(2016); M. S. Bajjou et al., 2017; Dodiya, (2020)
Create smooth flow	Bae & Kim, (2001);Jacobs, (2010);Koohestani et al., (2020);Mohammed Fadhil & Caroline Tanamas, (2001)
Use Pull logistics	El-sawalhi et al., (2018);Jacobs, (2010);Jayaraman et al.,(2008);Yahya & Mohamad, (2009)
Pursue Perfection	Adegbembo et al., (2016); Ansah et al., (2016);

Table 2.2 Lean construction Tools

Tools of lean construction	Source
Last planner system	Alarcón et al., (2005); Ghosh et al., (2014); Koohestani et al., (2020); Salem et al., (2005); Sariyildiz & Veer, n.d.)
Visual management	Aziz & Hafez, (2013); Le Gratiet, 2017; Raaj & Kumar, (2019)
Daily huddle meeting	Alarcón et al., (2005); Ansah et al., (2016); Sariyildiz & Veer, n.d.; Vimal Kumar & Ramasamy, (2016)
First run studies	Aziz & Hafez, (2013); Le Gratiet, (2017); Mohd Arif et al., (2019); Salem et al., (2005); Wellman, (2011)
Five S (5S)	Demirkesen & Bayhan, (2020); Ghosh et al., (2014); Hossain et al., (2019); Mohd Arif et al., (2019); Wandahl, (2014)
Fail safe for quality	Aziz & Hafez, (2013); Genaidy et al., (2004); Koskela,

	(2004); Raghavan et al., (2014); Salem et al., (2005)
Six sigma	Aziz & Hafez, (2013);Ghosh et al.,(2014); Le Gratiet, (2017); Mohd Arif et al., (2019); Vimal Kumar & Ramasamy, (2016)
Kanban	Ansah et al., (2016); Demirkesen & Bayhan, (2020); Enshassi & Zaiter, 92014);Ghosh et al.,(2014); Raghavan et al., (2014)
Just in time	Saad Bajjou et al.,(2017);Jayaraman et al.,(2008);Koskela, (2004); Nekouimehr, (2020);Verma et al., (2017)
Kaizen	Ayalew et al., (2018); Ballard, (2016); Enshassi & Zaiter, (2014); Howell & Ballard, (2010)
Concurrent Engineering	Aziz & Hafez,(2013);Bajjou et al., (2017); Khaleel & Al-Zubaidy,(2018);Koohestani et al.,(2020); Verma et al., (2017)
Prefabrication	Adegbembo et al., (2016); Babalola et al., (2018); Howell & Ballard, (2010); Salunkhe, (2018)

Table 2.3 Benefits of implementing lean construction

Benefits of implementing lean construction	Source
Increase productivity	El-sawalhi et al., (2018); Gerasimos Siasos,(2017); Ghosh et al., (2014); Reinbold, (2017)
Reducing waste and production cost	Ayalew & Dakhli, (2016; Demirkesen & Bayhan,(2020); Ingle & Waghmare, (2015); Shah et al., (2021)
Eliminates all non-value adding steps,	Ayalew & Dakhli, (2016); Babalola et al., (2018);Javkhedkar,(2006);Reinbold, (2017)
Pursue perfection by continuous improvement	(O. I. Akinradewo et al., 2018; Ayalew & Dakhli, 2016; Babalola et al., 2018; Salem et al., 2005)
Reduce project time	O. Akinradewo et al.,(2018; Gerasimos Siasos, (2017); Reinbold, (2017); Shah et al., (2021)
Fewer defect and rework	O. Akinradewo et al., (2018); Gerasimos Siasos, (2017); Oguntona et al., (2019); Shaqour, (2022)
Improving client satisfaction	Demirkesen & Bayhan, (2020); Gerasimos Siasos, (2017); Oguntona et al., (2019); Shah et al.,(2021)
Will increase profit	O. Akinradewo et al., (2018); Ayalew & Dakhli, (2016); Babalola et al., (2018); Reinbold, (2017)
Crating a smooth work flow	Gerasimos Siasos, (2017); Reinbold, (2017); Shah et al., (2021); Shaqour, (2022)
Improved employee morale and involvement	Al-Aomar, (2012); Amirhossein Karimzadeh, (2015); Ghosh et al., 2014; Raaj & Kum ar, (2019)
Better quality of work	Enshassi & Zaiter, (2014); Le Gratiet, (2017); Mohd

	Arif et al.,(2019); Salem et al., (2006); Shaqour, (2022)
Makes the projects easier to manage	Aziz & Hafez, (2013); Enshassi & Zaiter, (2014); Vimal Kumar & Ramasamy, (2016)
Minimize double handling and movement of equipment and workers	O. Akinradewo et al., (2018); Demirkesen & Bayhan, (2020); Enshassi & Zaiter, (2014)
Improves process transparency and communication	Allu & Emuze, (2018); Ghosh et al., (2014); Koohestani et al., (2020)
Improve prediction of risk	Mohamed Saad Bajjou et al., (2017); Mohamed, (2016); Polat & Ballard, (2004)
Lower levels of inventory	Ansah et al., (2016); Enshassi & Zaiter, (2014); Shaqour, (2022)
Improve the quality of the environment	Ayman Ahmed & Maha Ahmed, (2018); Bodkhe & Waghamare, (2016); Koohestani et al., (2020)
Construction site safety control improvement	O. I. Akinradewo et al., (2018); Dr. Amade, (2000); Raghavan et al., (2014)
Minimization of conflicts	Ahmed et al., (2021); Demirkesen & Bayhan, (2020); Ingle & Waghmare, (2015)
Preventing pollution and emissions	Al-Aomar, (2012); Amirhossein Karimzadeh, (2015); Ghosh et al., 2014; Raaj & Kumar, (2019)

Table 2.4 Barriers to implement lean construction

Barriers to implement lean construction	Source
Management related barriers	Halling, (2013); Ong & Sui Pheng, (2021); S Sarhan & Fox, (2013)
Awareness and educational related barriers	Enshassi et al.,(2019);Enshassi & Zaiter, (2014); Mohammed Fadhil & caroline Tanamas, (2001)
Financial related barriers	Devaki & Jayanthi, (2014); Le Gratiet, (2017); Shaik Md Sami Pasha, (2019)
Cultural and human related barriers	Mohammed Fadhil Dulaimi & caroline Tanamas, (2001); S Sarhan & Fox, (2013)
Technical related barriers	Bodkhe & Waghamare, (2016); Cano et al., (2015); Le Gratiet, (2017)
Government related barriers	Amade et al., (2019); Devaki & Jayanthi, (2014); Shah et al., (2021)
Resource related barriers	Enshassi et al., (2019); S Sarhan & Fox, (2013); Silva et al., (2021)

Table 2.5 Critical success factors

Critical success factors	Source
Management and leadership factors	Demirkesen & Bayhan, (2019); Koohestani et al., (2020); Yunus et al., (2017)
Workforce and resource	Bayhan et al.,(2019); Demirkesen & Bayhan, (2020)
Technical factors	Belay et al., (2022); Watfa & Sawalha, (2021); Yunus et al., (2017)
Cultural and government	Doğan et al., (2015); Farooqui et al., (2019); Houti et al., (2019)

2.9 Research Gap

As part of fulfilling the requirements of these thesis objectives, different literatures and journals were reviewed. Lean in construction, tools, and techniques of lean construction, and waste in lean construction were also briefly discussed in this chapter. Many researches have been conducted on construction waste, starting from identifying their source up to assessing waste management and disposal strategies all over the world. Local authors like Ayalew and Dakhli, (2016) conducted their research on awareness of lean construction in Ethiopia. On the other hand, Sahlu, (2017) studied construction site waste based on lean thinking by classifying them as value-adding and non-value-adding activities and recommended for a study to be conducted on the implementation of lean techniques to reduce wastage and improve performance in the construction industry. Based on his recommendation and through intense literature review, the research gap is identified as a study on the implementation of lean techniques on waste reduction. This study also is conducted on real estate companies, because most of the previous researches focused on the other sectors of the construction industry.

CHAPTER THREE

3. Material and Methods

3.1 Introduction

This chapter deals with the research approach will utilize in the study so as to accomplish the study objective. The population sample, research design and the geographic area where the study was carried out are also explained. Moreover, the instrument will utilize in gathering the information, as well as the procedures managed to sustain validity and consistency of the instruments are defined in order to carry out the assessment of the level of awareness, the barriers, the benefits of lean concepts and the measures of improving lean implementation in Ethiopian construction industry.

3.2 Study area

The Sidama Region is a regional state in southern Ethiopia. It was formed on 18 June 2020 from the Southern Nations, Nationalities, and Peoples' Region (SNNPR) and transformation of the Sidama Zone after a 98.52% vote in favor of increased autonomy in the 2019 Sidama referendum. Sidama is the name of both the Sidama people and Sidama territory. Sidama is bordered to the south by the Oromia Region (except for a short stretch in the middle where it shares a border with Gedeo zone), on the west by the Bilate River, which separates it from Wolayita zone, and on the north and east by the Oromia Region. Towns in Sidama include Hawassa, the capital of Sidama and SNNPR, Yirgalem, Wondogenet, Chuko, Hula, Bona, Bursa, Bensa, and Aleta Wendo. Sidama has a population of around 3.2 million in 2017 who speak the Cushitic language Sidama (also known as *Sidaamu Afoo*).

Sidama has geographic coordinates of latitude, north: 5'45" and 6'45" and longitude, East, 38' and 39'. It has a total area of 10,000 km2, of which 97.71% is land and 2.29% is covered by water. Hawassa Lake and Logita falls are water bodies that attract tourists. Based on the 2007 census conducted by the CSA, the region has a total population of

2,954,136, of whom 1,491,248 are men and 1,462,888 women; with an area of 6,538.17 square kilometers, Sidama has a population density of 451.83. While 162,632 or 5.51% are urban inhabitants, a further 5,438 or 0.18% are pastorals. A total of 592,539 households were counted in this region, which results in an average of 4.99 persons to a household, and 566,926 housing units.

As the regional government formed recently, there are different public buildings are under construction for different sector offices.

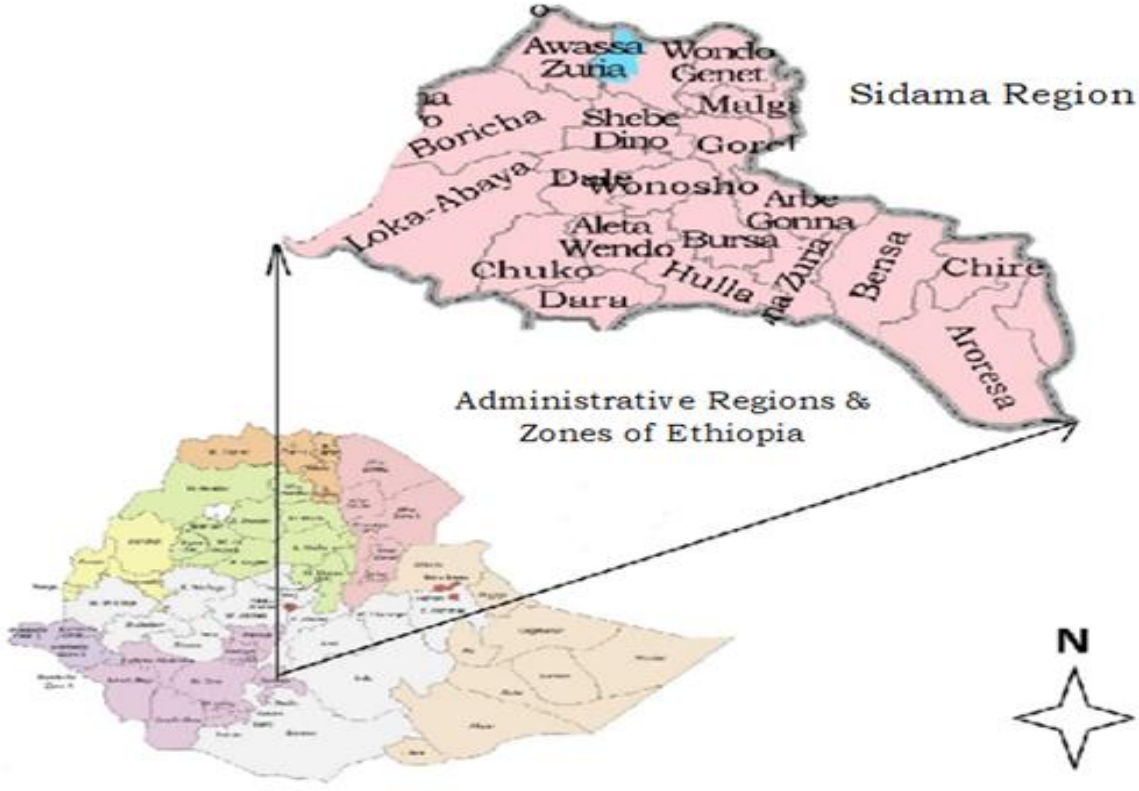

Figure 3.1 Geographical map of sidama regional government

3.3 Research design

According to (Zohrabi, 2013) definition a research design is simply the framework or plan for a study that is used as a guide in collecting and analyzing the data. It is a blueprint that is followed in completing a study. Research design is the blue print for collection measurement and analysis of data. Actually it is a map that is usually developed to guide the research.

The research on assessment of lean construction in Ethiopian construction projects began with detail literature review which is clearly define and helps to understand the concept of lean construction. Those literatures could gather from journals, thesis, research proceedings and books. Following the collection and organizing of literature review, structured questionnaire and interview questions are designed to collect the opinion of professionals who are working in construction projects. The questionnaire was distributed and interview questions are asked to construction professionals like project managers, site engineers and site supervisor who are working in building contractors. The research obtains both qualitative and quantitative data. The data gathered to investigate the implementation of lean tools and principles and benefits of implementing lean construction were analyzed using SPSS (version 26) and also the factors that barriers implementation of lean construction and critical success factors to implement could be analyzed and prioritize by analytical hierarchy process (AHP), which is one of multiple attribute decision making method. To analyze collected data through qualitative way, it needs summarizing (condensation) of meanings, categorization (grouping) of meanings and needs structuring (ordering) of meanings using narrative. All of these can be used on their own or in combination, to support interpretation of the data.

3.4 Research strategy

A plan or scheme by which the activity of searching for and assessing information found is carried out is called a research strategy. A research strategy usually involves a number of steps; Firstly, the analysis of major concepts of topic, Secondly, defining the relevant keywords and their synonyms. Thirdly, searching appropriate information sources (e.g. databases), and fourthly, assessing the quantity and quality (relevance) of the information found. The research strategy, a subset of research design, includes elements of data

collection and interpretation and emerges from both the research purpose and question (Mohajan, 2017).

There three research strategies are qualitative, quantitative, and mixed methods. Qualitative research is used to gain an in-depth understanding of human behavior, experience, attitudes, intentions, and motivations, on the basis of observation and interpretation, to find out the way people think and feel. It is a form of research in which the researcher gives more weight to the views of the participants (S. Ahmad et al., 2019). Qualitative studies typically have what, how, and why questions to address research questions that involve the collection of qualitative data rather than quantitative data.

Quantitative Research is the systematic empirical investigation of observable phenomena via statistical, mathematical or computational techniques. The objective of quantitative research is to develop and employ mathematical models, theories and/or hypotheses pertaining to phenomena (Gobind, 2015). Quantitative research is a form of research that relies on the methods of natural sciences, which produces numerical data and hard facts. It aims at establishing cause and effect relationship between two variables by using mathematical, computational and statistical methods (S. Ahmad et al., 2019). A mixed methods research design is a procedure for collecting, analyzing, and "mixing" both quantitative and qualitative research and methods in a single study to understand a research problem. A mixed methods approach is one in which the researcher tends to base knowledge claims on pragmatic grounds. It employs strategies of inquiry that involve collecting data either simultaneously or sequentially to best understand research problems. The data collection also involves gathering both numeric information (e.g., on instruments) as well as text information (e.g., on interviews) so that the final database represents both quantitative and qualitative information (Gobind, 2015). While quantitative research is applicable to phenomena that can be expressed in terms of quantity and an objective

measurement of problem. However, the qualitative research is concerned with qualitative phenomenon and subjective measurement of problem. In this research a mixed approach was used. It integrates both the qualitative and quantitative data and provides best understanding of the problem.

3.5 Research population

The target population is the specific, conceptually bounded group of potential participants to whom the researcher may have access that represents the nature of the population of interest. To be successful in defining the target population, one must examine all the boundary considerations in an iterative manner to ensure that the end description of the target population is inclusive enough to provide sufficient data to the study (Casteel, 2017). The target population for this study has focused on public construction projects which are owned by sidama regional government different sector bureaus. Those bureaus have been constructing various types of projects for educational, office, health center, mixed use and institutional purpose. The list of construction projects undertaken was obtained from sidama regional government construction bureau. The main respondents were site engineers, site supervisors and project managers.

3.6 Sample size determination

The sample size is a significant feature of any empirical study in which the goal is to make inferences about a population from a sample. A sample is a small proportion of a population selected for observation and analysis .It is a collection consisting of a part or sub-set of the objects or individuals of population which is selected for the express purpose of representing the population (Taherdoost, 2017). The sampling techniques, on the other hand, are commonly used for research investigations to better estimate at low cost and less time with greater precision. The selection of sampling methods and determination of sample size are extremely important in applied statistics research problems to draw correct

conclusions. If the sample size is too small, even a well conducted study may fail to detect important effects or associations, or may estimate those impacts or associations too imprecisely. Similarly, if the sample size is too large, the study would be more complex and may even lead to inaccuracy in results. Moreover, taking a too large sample size would also escalate the cost of study. Therefore, the sample size is an essential factor of any scientific research (Israel, 2010).

For this research from non-probability sampling type, purposive sampling method is selected. It used to select samples from population in order to get genuine information from limited number of primary data source. Purposive or judgmental sampling is a strategy in which particular settings persons or events are selected deliberately in order to provide important information that cannot be obtained from other choices (Taherdoost, 2017). It is where the researcher includes cases or participants in the sample because they believe that they warrant inclusion. The study area for this research is sidama regional government, which is recently formed the 10^{th} regional state in Ethiopia. According to sidama regional government construction bureau in this region there are 125 public projects nowadays and the researcher takes research sample purposively which is suitable for the study. From public projects under construction 63 are active and the rest 62 are not active and almost completed. From active projects, 26 projects which have cost more than 11,000,000 birr are selected for study. Because the project holders are contractors which are above grade seven (7) and theirs staff believed that includes professional and experienced engineers. The projects are educational, health care, recreational, administrative office and justice center buildings located in different woredas of sidama region. A total of 78 questionnaires were distributed to project managers, site engineers and site supervisors who are working on those construction projects.

3.7 Research instrument

These are the fact finding strategies. They are the tools for data collection. They include Questionnaire, Interview, Observation and Reading. Essentially the researcher must ensure that the instrument chosen is valid and reliable. The validity and reliability of any research project depends to a large extent on the appropriateness of the instruments (Zohrabi, 2013).

3.7.1 Questionnaire

A questionnaire is the main means of collecting quantitative primary data. A questionnaire enables quantitative data to be collected in a standardized way so that the data are internally consistent and coherent for analysis. Questionnaires should always have a definite purpose that is related to the objectives of the research, and it needs to be clear from the outset how the findings will be used (Roopa, 2012). Questionnaires are doubtless one of the primary sources of obtaining data in any research endeavor. However, the critical point is that when designing a questionnaire, the researcher should ensure that it is "valid, reliable and unambiguous". On the whole, questionnaires can appear in three types: closed-ended (or structured) questionnaires, open-ended (or unstructured) questionnaires and a mixture of closed-ended and open-ended questionnaires (Zohrabi, 2013).

Both open ended and close ended questionnaire survey are selected as a research instrument, owing to its suitability to high level of information required from the high number of participants and to researchers to have budget and time limitation. The questions centered on the idea of the research objectives and focused on answering the research questions. The questionnaire has two parts; the first part which has eight (8) questions was about general information of respondent and the second part has four (4) questions are focus on research objective. Those questions are prepared from literature review of different journals, research proceedings and papers.

3.7.2 Interview

Interviews become necessary when researchers feel the need for in depth investigation on study objectives and generate ideas in a discourse that borders on mutual interest. It is an interaction in which oral questions are posed by the interviewer to elicit oral response from the interviewee. Specifically with research interviews, the researcher has to identify a potential source of information, and structure the interaction in a manner that will bring out relevant information from his respondent (Fardhosseini & Soltaninejad, 2021). The interview is used as a tool to assess lean construction implementation in projects. Interview questions were developed to obtain information on the issues the questionnaire targets and enhance the reliability of data obtained by questionnaire.

3.7.3 Observation

When the topic and the objectives are not well defined we can always carry out a direct observation. It is called direct observation because you write down information of a phenomenon or event that is taking place at that very moment. After a while of observing you might have a better idea of the research problem and start writing the topic, research objectives, questions, or hypothesis of action or change if you need them. The direct observation begins with the first interaction the researcher has with the phenomenon to be studied (S. Ahmad et al., 2019).

For this study, Hilton hawassa hotel and spa project which is constructed by sunshine construction was observed. The observation focused on implementation of different lean tools that minimize waste in construction site.

3.8 Source of data

The study uses both primary and secondary data related to the research topic for analysis and discussion. The primary data was obtained through questionnaire survey and interview and the secondary data was taken from secondary source of data such as journals, books,

research papers, conference proceedings and other related articles. Those Secondary data sources then used to prepare questionnaires and interview in relation to the topic under discussion. Open ended and closed ended questionnaires prepared and distributed for all selected respondents. Also, the interview was done to clarify and deep understanding of study.

3.9 Data analysis

Data Analysis is in short a method of putting facts and figures to solve the research problem. It is vital to finding the answers to the research question. Another significant part of the research is the interpretation of the data, which is taken from the analysis of the data and makes inferences and draws conclusions (Ashirwadam, 2014).

3.9.1 Relative importance index (RII)

Relative importance index is a non-parametric technique widely used by construction and facilities management researchers for analyzing structured questionnaire responses for data involving ordinal measurement of attitudes (Sakhare & Patil, 2019). A quantitative statistical analysis for questionnaire data was done by using statistical package for social science (SPSS, 26) and Microsoft excel (2010) for the first objective which is investigate the implementation of lean tools and techniques, and second objective which is identify benefits of lean tools. Based on the data received from respondent, the software was further used to calculate each variables frequency and on Microsoft excel tabulate the given variables according to their relative importance index in descending order.

The Relative Importance Index (RII) is calculated as follows:

$$RII = \sum W / \sum A*N$$

Where:

W=the weight given to each factor by the respondents and ranges from 1 to 5

A=the highest weight = 5

N = Total number of respondents

3.9.2 AHP

Multi Criteria Decision Making (MCDM) approaches are more popular and widely acceptable for complex decision making problems. MCDM methods are used to find the best alternative by evaluating the conflict criterion. Analytical Hierarchical Process (AHP) is one of the widely accepted MCDM approaches which are accepted by researchers because of its nature to make optimal and best decisions (Lee, 2016).

Analytical Hierarchy Process is a multi-criteria decision-making approach and one of the most inclusive systems which is considered to make decisions with multiple criteria because this method gives to formulate the problem as a hierarchical and believe a mixture of quantitative and qualitative criteria as well (Taherdoost, 2017).

AHP is a decision making technique to find out the best criteria to attain their goal. It thus provides the best technique to reduce qualitative and quantitative complex constrains by formulating a series of one-on-one comparisons. It not only helps decision makers choose the best option, but also provides justifications for the most part (Ravikumar et al., 2014). The core of AHP is the comparison of pairs instead of sorting (ranking), voting (assigning points), or the free assignment of priorities. Validation of the method in practical testing shows surprisingly good agreement with actual measured values (Abdelrazig, 2015).

3.9.2.1 The calculation process of AHP

The procedure can be summarized as follows (Saaty, 2002):

Step 1-Develop the decision tree or hierarchy structure which is the proper definition of the problem and goal.

Step 2-making the pairwise comparison of criteria and forming a matrix of pairwise comparison. The entries of this matrix represent priorities (weight, importance, effectiveness, or value).

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nm} \end{bmatrix}$$

Step 3-Comparing alternatives in relation to different criteria and forming a matrix of pairwise comparison. The obtained results can be expressed by numbers. For this purpose, the proposed scale by Saaty has been used.

$$A = \begin{bmatrix} 1 & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & 1 & \cdots & \frac{w_2}{w_n} \\ \vdots & \vdots & \vdots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & 1 \end{bmatrix}$$

Table 3.1 Fundamental scale for comparison

Scale	Ranking	Explanation
1	Equally important	Both criteria or alternatives contribute to the objective equally
3	Moderately important	Moderate preference is given to one criterion or alternative over the other
5	Strongly important	Strict preference is given to one criterion or alternative over the other
7	Very strongly important	Very strict preference is given to one criterion or alternative over the other
9	Extremely important	The highest preference is given to one criterion or alternative over the other

Step 4-Determination of inconsistency index of matrices obtained from the two previous Steps: Decision-makers should reconsider their pairwise comparisons if the inconsistency index exceeds the allowable limit.

$CR = CI/RI$

$CI = (\lambda max - n)/(n - 1)$

Table 3.2 Random consistency index

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.4	1.45	1.459

Step5-Normalizing the obtained matrices from previous steps: In this regard, all entries of each column should be divided into the sum of that column to determine the normal value of each entry.

$$\begin{bmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \cdots & \frac{w_2}{w_n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & \frac{w_n}{w_n} \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_2 \end{bmatrix} = n \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_2 \end{bmatrix}$$

Step 6- Calculating the row average of normalized matrices: The average of entries at each row represents the weight and importance of each alternative with respect to the related criteria.

Step 7- Forming decision-making matrix: The entries of this matrix are obtained through the product of the weight of each criterion.

3.10 Validity and reliability

3.10.1 Validity

Validity explains how well the collected data covers the actual area of investigation. Validity basically means “measure what is intended to be measured. Validity of a research instrument assesses the extent to which the instrument measures what it is designed to measure (Khalid, n.d.2016). For this study, first face validity measure is conducted by having academicians who understand the topic to go through the questionnaire to evaluate the content, and based on their evaluation and comment the questionnaire is modified. The comments are simplifying words on questionnaire to respondents, defining some terms to easily understand and eliminate factors that not fit with our country construction projects.

After that, a pilot survey is conducted by questionnaire to be filled. By checking if the questionnaires are filled correctly, the data is collected and checked for its reliability by consistency ratio.

3.10.2 Reliability

Reliability concerns the extent to which a measurement of a phenomenon provides stable and consist result. Reliability is also concerned with repeatability. For example, a scale or test is said to be reliable if repeat measurement made by it under constant conditions will give the same result (Taherdoost, 2017). Cronbach's alpha coefficient was used to measure the reliability of the questionnaire between each group and the mean of the whole groups of the questionnaire. The normal range of Cronbach's coefficient alpha value is between 0.0 and 1.0, and the higher values reflect a higher degree of internal consistency.it applied for the first two objectives, which are implementation of lean construction and benefits of implementing lean.

Table 3.3 the classification of Cronbach's Alpha Coefficient

Cronbach's Alpha Coefficient	Internal Consistency
≥ 0,9	Excellent
$0.9 \leq \alpha < 0.8$	Good
$0.8 \leq \alpha < 0.7$	Acceptable
$0.7 \leq \alpha < 0.6$	Questionable
$0.6 \leq \alpha < 0.5$	Poor
Below 0.5	Unacceptable

Reliability of data for the next two objectives, which are barriers of implementing and critical success factors of lean construction, was checked by Calculating of consistency ratio. For the validation of comparison, the consistency of the pairwise matrix (CI) should be checked by using $CR=CI/RI$, where *RI* is the random consistency index obtained from a randomly generated pairwise comparison from table 3.2.

For this study the Cronbach's alpha value is 0.844, it indicated that the internal consistency of the questionnaire is Good, implying the data's reliability.

Table 3.4 Reliability test result

Reliability Statistics

Cronbach's Alpha	N of Items
.844	17

3.11 Ethical consideration

The consideration of ethical issues in research is an important aspect of every researcher. According to Oyedolapo, (2014), the essential aspects of moral and ethical concerns for research include the use of other researchers work, confidentiality and integrity in collecting data, analyzing data and reporting and disseminating results and findings. Therefore, in this research the works of other researchers are properly cited. The research started after getting the respondents willingness, and the data obtained from the participants is maintained only for academic purpose.

Chapter 4

4. Result and Discussion

4.1 Introduction

This chapter focuses on the presentation and analysis of data obtained from the study's questionnaire processed using Microsoft excel and SPSS. The qualitative and quantitative research findings are outlined in tables, charts and text formats. Each result is prepared and discussed briefly to present the information about the sample size, response rate, types of organization and respondents educational status, background and working experience.it also includes the ranking of lean construction tools and principles implementation, benefits, barriers to implement and critical success factors for implementation in sidama regional government.

4.2 General information

The general respondent's information/demographic analysis involve all the possible detailed information about the response rate, position of respondents, educational background, and working experience. In order to attain this, the first sections of both questionnaires were mainly designed to provide background information about the respondents.

Table 4.1 General information of the study

		Frequency	Percent (%)
Rate of response	Received	58	74.36 %
	Not received	16	21.51 %
	Void	4	5.13 %
Position of respondents	Site Supervisor	9	15.6 %
	Project Manager	11	19.0 %
	Site Engineer	38	65.5 %
Educational status of respondents	MSC	18	31.0
	BSC	40	69.0
Work experience of respondents	<1 year	4	6.9
	11-15 years	4	6.9
	1-5 years	22	37.9
	6-10 years	28	48.3

4.2.1 Response rate

In this study a total of 78 questionnaires were distributed directly for project managers, site engineers and site supervisors, who are working on public construction projects owned by sidama regional government and executed by different contractors. From distributed questionnaire, 58 responses were received with 74.36% return rate, the other 16 (20.51%) questionnaire were not received and also 4 (5.13%) questionnaire were void or incorrect response.

4.2.2 Position of respondent

The respondents selected for this study are directly associated with building construction projects. According to their responses, the respondents work in different positions and have different professional backgrounds. The job positions of the respondents are project manager, site engineer, and site supervisors. As shown in table 4.1, the respondent's position illustrated that 65.5% of the respondents were site engineer, 19% were project manager, 12.1% were office engineer and also 3.4% were site supervisor. It is an advantage for the study that the majority of respondents were site engineer, because the objective concerns with site implementation practice of lean construction which mainly a close relationship with site engineers day-to-day work routine and the answers were accurate.

4.2.3 Educational status of respondents

This section discussed the educational background of respondents. Table 4.1 illustrates the level of education of respondents. From the total of 58 questionnaires analyzed, 40(69%) of the respondent had BSc and 18(31%) hold MSc degree. This revealed that population for study had adequate educational background and gave reliable response for the questionnaire.

4.2.4 Work experience of respondents

As discussed in section 4.2.2 the respondents were project managers, site engineers and site supervisors. Therefore, this section describes the respondents work experience in construction projects. The data in table 4.1 revealed that 28(48.3%) of the respondents have 6-10 years of experience, 22(37.9%) have 1-5 years of experience, 4(6.9%) of respondents have 11-15 and less than one (< 1) years' of working experience in construction industry. Most of the respondent are experienced and qualified to gives reliable data.

4.3 Implementation of Lean construction principles and tools

4.3.1 Implementation of Lean construction principles

Respondents were asked to what implementing lean construction principles in their construction projects. The received response analyzed using relative importance index and the variables are ranked and showed on table 4.2.

Based on the result obtained from the survey, respondents ranked 'pursue perfection (continuous improvement) with a RII value of 0.86 was ranked first. Continuous improvement in all its implication is done with a view to improving safety, efficiency and productivity on construction sites. The principle aims to always strive for perfection by delivering what the client expects: a continuous removal of waste or the avoidance of non-value-adding activities in construction projects. The study of Amirhossein Karimzadeh, (2015) said that any effort in continuous improvement will make the organization and project team a continuous learning system. With this mentality, even the project team's performance is considered as an effort in continuous improvement. In study of Ramaru Pretty, (2017) pursue perfection ranked first from other principles in adoption on construction projects.

The other principle which is called ‘create smooth flow in processes’ with RII value 0.74 was ranked second. Resources such as labor, material and construction equipment, and information flows are the basic units of analysis in lean construction. There are controllable and uncontrollable flows. Controllable flows are materials or instructions from the warehouse or management, respectively, and uncontrollable flows, such as the supplier’s provision of resources and design information (Mohammed Fadhil Dulaimi & caroline Tanamas, 2001). Also It concerns with a continuous flow in the construction process and value chain by focusing on the entire supply chain (Aziz & Hafez, 2013b).

Also ‘allowing customer (client) to pull’ was ranked third with RII value of 0.71. The principle identifies the real need to deliver the project to the client as soon as it is needed or on a specified project delivery date by eliminating non-value-adding processes on the construction site. Understanding and improving construction processes are essential to improving productivity (Wong & Ahmed, 2018).Using “pull” instead of “push” in the construction process means only produce what is specified at required time and quality and prepare for changes from client (Bosnich, 2019).

The study result showed that ‘map the value stream’ ranked fourth with RII value of 0.62. It concerns determining the current process of construction projects being undertaken on-site. This principle is the benchmark to identify waste and determine the ways to eliminate it before they affect the project’s quality, cost, and time. Low productivity is a chronic problem in the construction industry. One way to increase productivity is to reduce non-value-adding activities. Productivity improvements achieve higher cost savings with minimal investment. Value stream mapping has been used as a lean construction tool to help reduce non-value-adding activities in construction projects and increase productivity (Vikram & Rajput, 2018). Non value adding processes in construction site to be avoided

are overproduction, storage of unnecessary material, transport of labor and equipment above the required number and efficiency.

Identify customer value and fifth with RII value of 0.58. It related with specify the value according to the client's definition and needs and identify the value of the activities that are adding or generating value to the end product of project. The study by (Ramaru, 2017) in south Africa revealed that 'allowing customers to pull' ranked fourth (4^{th}).

Table 4.2 Relative importance index (RII) value and rank of lean principles

lean principle	RII	RANK
Identify customer value	0.58	5
Map the value stream	0.62	4
Create smooth flow in process	0.74	2
Allowing customer(client) to pull	0.71	3
Pursue perfection(continuous improvement)	0.86	1

4.3.2 Implementation of Lean construction tools

Lean construction is a new production philosophy that has the potential to bring innovative changes to the construction industry (Singh & Kumar, 2021). Lean tools designed to reduce both physical and non-physical wastes to improve project performance. In this research a total of twelve (12) lean tools are studied based on their functional usage.

According to respondents result illustrated on table 4.3, 'last planner system' which is described by 'Having master, phase & weekly work plan for your project' with RII value of 0.82 ranked first. followed by '5s' which means 'Keep the project site, material & equipment clean, tidy & orderly' with its RII value 0.78 ranked second, 'concurrent engineering' concerns with 'Execute different tasks parallel in your project 'had a RII value of 0.76 ranked third, the other lean tool 'just in time' described below by its function 'ordering of resources when they are only needed in your project' with RII value 0.68 ranked fourth. The fifth ranked lean tool which implemented in construction project were 'kaizen' or described as 'Evaluate the construction process in terms of time required,

resource used and resultant quality for continuous improvement' with RII value of 0.67. Daily huddle meeting ranked sixth with RII value 0.66, 'fail safe for quality' as described in the table 4.3 below 'constantly investigate potential safety and quality improvement practice' with RII value of 0.64 ranked seventh, also the study result shows visual management, prefabrication and first run studies ranked eighth, ninth and tenth with RII value of 0.63, 0.59 and 0.53 respectively. As can be seen on the table below 'six sigma which mean 'Examine the needs of the client in your project using facts, data and statistical analysis in organized way for improvement' ranked eleventh with RII value of 0.50 and kanban described as 'Exchange information on cards to purchase material, to control inventory and construction process' with RII value 0.47 ranked twelfth.

The top most significant lean construction tools are discussed below;

Last planner or described on table 4.3 below as 'Having master, phase & weekly work plan for your project' ranked first (1^{st}) with RII value of 0.82 by respondent. It is used for planning and coordination of projects and also for facilitating communication within project teams. The last planner system is considered an effective tool to control workflow and reduce project variability (Ahmed et al., 2021). It helps to deliver projects more safely, on-time with least cost and improve productivity. The study by (Hailu, 2020) revealed that the last planner system was a solution for poor planning problems, which cause waste on construction sites. It is an important tool for the construction management process and a monitor for planning efficiency to assist the smooth workflow variations, reducing the uncertainties in the construction process. According to Mohamed Saad Bajjou et al., (2017) study, the scheme of planning with the last planner system tools is includes master schedule, look-ahead planning, and weekly work plan. Master schedule is used to determine generally the main actors, the sequences of building as well as the milestones which should be accomplished during the step 'phase planning'. The objective is to

identify possible constraints related to each task. ‘Look-ahead planning’, schedule of two to eight weeks, which help to identify the constraints to be taken into account to avoid overruns of deadlines. Indeed, all contractors and subcontractors must check the availability of all necessary resources and conditions for the proper conduct of schedule tasks. ‘Weekly work plan’ is a weekly schedule containing only the tasks without constraints. So all stakeholders become responsible and engaged on the activities that will be executed. The last is ‘percentage of promises completed, which is an indicator that allows tracking the construction process by measuring the percentage of completed activities among those that have been scheduled (Milano, 2019). The study of (Adegbembo et al., 2016) revealed that last planner system ranked second (2^{nd}) most significant tool which implemented on construction site. Similarly (Babalola et al., 2018) study ranked fifth (5^{th}) in their study.

Last planner system offers an outline of how to control and plan construction project activities in an organized way. It includes four levels, which are master schedule, phase plan, weekly work plan and look-ahead plan. Master schedule is a timetable for a complete project with milestones to be achieved. It is designed based on the client’s project target standards, which are achieved by breaking down the project in to smaller pieces. Contractor’s project planning team do phase schedule in each phase. This level is more practical as compared to master schedule. This phase schedule was prepared before the construction project started. Look-ahead planning is a level, which places flow of work into attainable order. It helps the project manager to have control over activities to done in construction site. The weekly work plan is important because it covers weekly schedules, material need, safety concerns and construction methods. It helps in improving the way project is executed; it also strengthens the bond among employees by facilitating clear communication platform.

The project schedule was prepared and presented as seen below on figure 4.2. The project name with the task associated and duration it takes where displayed on the schedule. Also, the activities with their prerequisite presented on it to be completed as planned. This schedule and other project plan documents representing what 'should' be done on specified duration for each activity without compromise quality of work. Since 2016 G.C Hilton hotel and spa construction project started by sunshine construction plc, the project delayed for different reasons and the schedule is updated till now regarding the site condition.

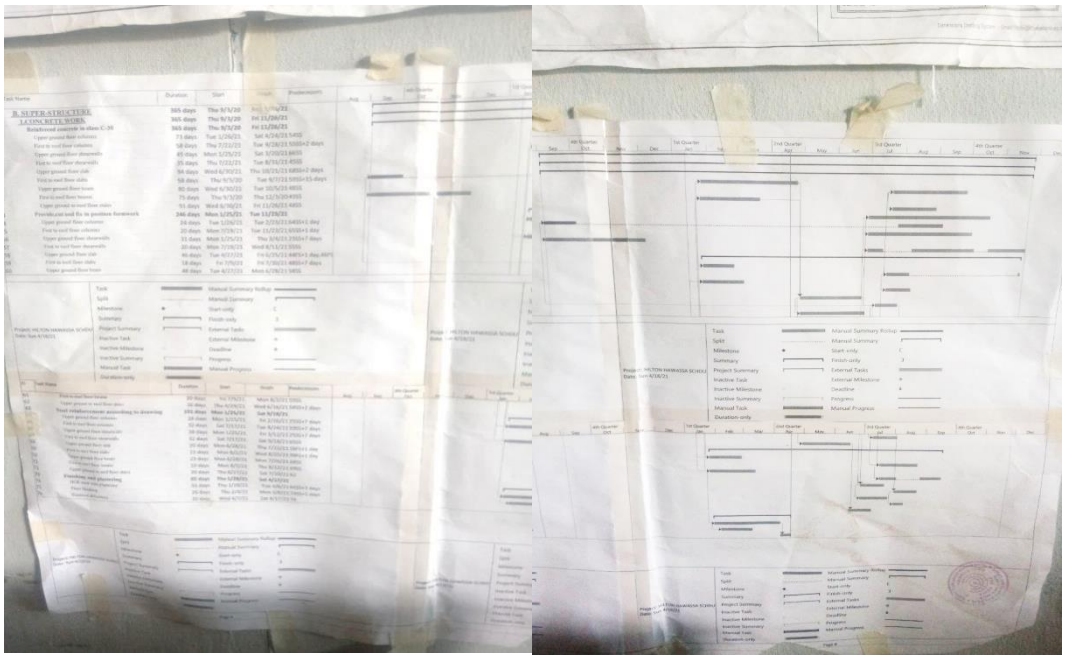

Figure 4.1 Master schedule (from project site)

5s or explained below as 'Keep the project site, material & equipment clean, tidy & orderly' ranked second (2^{nd}) with RII value of 0.78 by respondents. This indicates the tool is most frequently used for arranging tools, equipment, and materials according to usage and importance in construction projects. It is a workplace or construction site organization lean tool used for organizing and setting up the quality of the workplace. It is a tool for cleaning, sorting, and arranging the workplace by reducing damage to equipment or materials by improper storage. It also helps in improving productivity and efficiency by

eliminating waste and increasing the safety of personnel (Salunkhe, 2018; Singh & Kumar, 2021). According to Hailu, (2020) study, the 5s (sort, set in order, shine, standardize and sustain) tool is one of solution to overcome poor material handling and storage problems, which are most dominant source of waste on construction site. The tool also helps us to know what materials we have at hand to reduce excess inventory. The study of Singh & Kumar, (2021) revealed 5S ranked second(2^{nd}) most significant tool. Similarly the studies of (Ramaru, 2017) ranked sixth(6^{th}) and (Vimal Kumar & Ramasamy, 2016) ranked third(3^{rd}) in their study. *In the construction site the tools and equipment are cleaned after use and placed close work area to find easily. The construction site daily cleaned in order to control safety of workers and to facilitate smooth work flow area.*

5S is strategy for attaining workplace organization and cleanliness and it will improve quality, productivity and safety than any other lean tools. It is some rules for work place organization and in housekeeping which aim to organize each worker's work area for maximum efficiency and to reduce waste associated with the workplace organization to create a smooth and safe working environment. The five s (5s) are sort, set in order, shine, standardize and sustain.

The 5S tool which were observed and showed on figure in Hilton hotel and spa construction project are described as follow; they Sort frequently needed and lesser needed equipment, materials and tools on the appropriate place. So that frequently needed things are available nearby and as easy to find as possible relocate or get rid of unnecessary things. For the construction project concrete is the most frequently needed material, in order to eliminate stoppage of work due to lack of required amount needed they built concrete batching plant in construction site. The set-in-order applied by arranging essential materials, equipment and tools as accessible as possible to reduce the waste related to a worker's motion in locating or acquiring a needed thing. As shown on

below pictures, different tools and materials arranged for easy accessible by workers. The other shine observed as keeping work area, machine and tools clean in order to reduce the waste related to uncleanness and increase workers satisfaction. In construction site, the workers of sunshine construction properly keep the site clean everyday as shown on figure below and clean the tools and machines by washing or rubbing after they finishing their daily activities. The above those 3S are standardized and diffuse throughout the working place by means of clear procedures and clearly seen on each office of engineers working in construction project site. I observed the arrangements of documents on site engineers office as the same way materials and tools placed in store.

Figure 4.2 5S application in store

Figure 4.3 5S application in project site

Concurrent engineering or explained in table below as ‘Execute different tasks parallel in your project’ ranked third (3rd) with RII value of 0.76 by respondents response. It is a parallel execution of various tasks by multidisciplinary teams with the goal of obtaining most favorable projects concerning quality and productivity. The study of Aziz & Hafez, (2013) states that many enhancements can be accomplished by using concurrent engineering. Also many other tasks on construction site can be achieved through overlapping activities, splitting activities and reducing the transfer time between different activities. Concurrent engineering focusing on the team efforts, communication and information sharing are the keys for discovering new ideas. According to Nekouimehr, (2020) construction activities are regularly fragmented into sequential activities that they are referred to variant types of professionals, which result in a limitation on workflow and unintentionally increase project time. In the traditional procedures, each discipline works independently and contractor was the responsible person to facilitate this process. Need to

tackle those problem obliged contractors to adopt new strategies that concurrent engineering could be an effective tool. The study of Raaj & Kumar, (2019) revealed concurrent engineering ranked second (2^{nd}) most significant lean tool. *Different tasks in construction site could be done parallel to use the project schedule effectively as well as to reduce waste generated due to waiting.*

Just in time or explained in the table below 'ordering of resources when they are only needed in your project' was ranked fourth (4^{th}) with RII value of 0.68 according to respondents response. Just in time means to produce what is needed, when it is required and in how much quantity it is necessary. It is also the most developed and mostly used lean construction tool designed to eliminate the non-value adding activities and reduce inventories. According to W. Ahmad, (2019) just in time is based on the concept that stock on the site, which does not bring value to the client is considered as a source of waste. It means the material and equipment must be provided for construction when it is required or necessary. The study of Hailu, (2020) revealed that just in time can eliminate waiting time by delivering construction material on time. Generally wastes as a result of overproduction, transportation, unnecessary motion and via the production of defective part is also minimized by just in time. In the study of Adegbembo et al., (2016) the tool Ranked third. Similarly in the study of Meshref et al., (2022) it ranked second (2^{nd}) most significant tool. *For effective utilization of material and waste minimization, ordering materials when they are needed are a better way. Holding materials on store for long period of time makes the project unprofitable. For large projects producing some building materials are more advantageous and minimize waiting time of materials transported from source.*

Daily huddle meeting or daily site meeting was ranked fifth (5^{th}) with RII value of 0.67 depending on respondent's response. The tool provides a platform for the team members to share their views and to share what has been achieved at the same time, discuss problems

they are facing during the construction process. These are held to obtain the full involvement of employees in issue regarding the project and to encourage employees to solve problems together. J. G. Sarhan, (2000) states that with the daily huddle process, a short meeting is held initially every day as the lean construction model is followed. This way, team members will be able to convey the status of their work done the previous day or week, and importantly discuss any problems faced in completing tasks. The study of Raaj & Kumar, (2019) revealed that daily huddle meeting was ranked third. Similarly, in study of J. G. Sarhan, (2000) ranked sixth. *Site meeting regularly held one or two days per week if there is no urgent issues happened in construction site. This may not include the daily orientation of workers and day to day communication of project stakeholders. In the meeting the agendas and participants are different from meeting to meeting.*

Daily huddle meeting are meetings held to obtain the full involvement of employees in issues regarding the project and to encourage employees to solve problems together. These are includes short meetings generally conducted before start of or after the end of daily work activities. The construction Project team presented in Hilton hotel and spa construction site includes project manager, office engineer, site engineer and general Forman. Their meetings were held in construction site twice a week especially on Monday and Friday unless immediate issue would happen. But, every day for a few minutes there was an orientation about safety and site rules for workers before starting work. The discussions in the meetings were about identified potential problems that were takes place on the jobsite and on general construction site activities. This helped to enhance communication between project personnel and problem solving ability, the level of late-coming to site was reduced and the level of commitment of workers increased. In general it helped significantly to reduce waste in terms of the workforce.

Table 4.3 Relative importance index and rank of lean tools

Lean tools	Definition	RII	RANK
Last planner system	Having master, phase & weekly work plan for your project	0.82	1
5s	Keep the project site, material & equipment clean, tidy & orderly	0.78	2
Concurrent engineering	Execute different tasks parallel in your project	0.76	3
Just in time	ordering of resources when they are only needed in your project	0.68	4
Daily huddle meeting	Daily site meeting	0.67	5
Kaizen	Evaluate the construction process in terms of time required, resource used & resultant quality for continuous improvement	0.66	6
Fail safe for quality	Constantly investigate potential safety & quality improvement practice	0.64	7
Visual management	Having safety & warning signs in required areas at project site	0.63	8
Prefabrication	Using Prefabricated/precast elements	0.59	9
First run study	Redesign critical assignment including productivity studies in your project	0.53	10
Six sigma	Examine the needs of the client in your project using facts, data & statistical analysis in organized way for improvement	0.50	11
Kanban card	Exchange information on cards to purchase material, to control inventory & construction process	0.47	12

4.4 Benefits of lean construction

A total of twenty benefits of implementing lean construction were identified and respondents were asked to indicate their level of agreement using five point likert scales on the listed variables. Based on the received responses the factors were ranked as indicated in the table below. From the result showed on table 4.4 respondents ranked ‘increase

productivity' as the first and most influential benefits of implementing lean construction with the highest RII value of 0.87.while 'reducing waste and production cost' ranked second with RII value 0.81.the result obtained from table indicates 'eliminate all non-value adding steps' ranked third with RII value 0.76, 'pursue perfection by continuous improvement' ranked fourth with RII value of 0.67, 'reduce project time' ranked fifth with RII value of 0.66. Also the response illustrated that 'fewer defect and rework' and 'improving client satisfaction' together ranked the sixth with RII values of 0.65, 'will increase profit' ranked seventh with RII value 0.64, while the others are 'crating smooth work flow', 'improved employee morale and involvement' and 'better quality work' together and 'makes the projects easier to manage' ranked eighth, ninth and tenth with RII values of 0.63 and 0.62 respectively. The above are the top ten most important benefits of lean construction in sidama region projects according to respondents' response.

The top five most significant benefits of implementing lean construction are discussed below;

Increase productivity was ranked the first most significant benefits of implementing lean construction on construction projects with RII value of 0.87 based on participants' response. The best way of increasing productivity is increasing true efficiency, which concentrates on construction process by producing each structure based on specified quantity and quality requirement on contract document and by avoiding production of defective parts. The study of Enshassi & Zaiter, (2014) revealed that improving productivity in construction project is a great challenge facing the construction industry. As construction industry is ranked the most hazardous industries in world, improving safety in construction remains a priority. Increasing the safety of workers on construction site improve their efficiency and increase the productivity. The lean tools like last planner, visual management and 5s are used to improve safety of workers and improve construction

site to facilitate the smooth flow of materials, equipment's and man power. The study of Ahmed et al.,(2021) revealed that increase productivity ranked third (3rd).similarly Ayalew & Dakhli, (2016) ranked first (1st) in their study.

Reducing waste and production cost was ranked second (2nd) benefits of lean construction with RII value of 0.81 according to respondents response. According to Polat & Ballard, (2004) study the ordering of materials that do not fit in terms of quality, type and dimensions brings about material waste. Lean construction works to minimize waste as much as possible. Instead of throwing discarded materials into the trash, lean construction tries to find a way to reduce the project's waste of physical materials to save money. Waste categorized as over production, excess inventory and making defective product could be minimized or eliminated by using lean tools like just in time, concurrent engineering and 5s (sort, set in order, shine, standardize and sustain) (Erol, 2014; Hailu, 2020). Also lean reduce production cost of the construction process by making the process simplified and efficient. Ahmed et al., (2021) in their study argued lean construction is a very effective method which reduces the construction and life cycle cost of construction project definitely. The study of Akinradewo et al., (2018) revealed that reduce waste was ranked the first (1st) and the study of Ayalew & Dakhli, (2016) ranked second (2nd) most significant benefit of lean in their study. Also Oguntona et al., (2019) study revealed that reduce production cost ranked third (3rd).

Eliminate all non-value adding steps ranked the third (3rd) benefits of implementing lean construction on projects with RII value of 0.76 based on obtained response. Non-value adding activities are these activities also do not add value to the project but they should be eliminated as they are considered to be non-physical waste. They are categorized in to waiting, unnecessary transportation of material and equipment and rework (Elkherbawy, 2019). Those activities are eliminated by improving the scheduling method using last

planner, the material or equipment delay that cause waiting through just in time delivery and enhancing the relationship between contractor and suppliers. Lean construction provides efficient and effective communication process among stakeholders to create smooth workflow on construction site to avoid waiting and stoppage of work during execution of tasks. The study of Oyedolapo, (2014) states that construction process should not be seen as conversion activities but rather a process flow. Some benefits of adopting lean include the removal of non- value adding activities such as waiting, transporting and inspection of material. The study El-sawalhi et al., (2018) revealed that reduce non-value adding work was ranked first (1^{st}).

Pursue perfection by continuous improvement ranked the fourth (4^{th}) benefit of implementing lean construction with RII value of 0.67 according to response obtained from respondents. The study of Oyedolapo, (2014) defined continuous improvement as a culture of sustained improvement targeting the elimination of waste in all systems and processes of an organization. It involves everyone working together to make improvements without necessarily making huge capital investments. The study of Dr. Amade, (2000) states that continuous improvement is comprehensive and systematic approach to incremental and continuous improvement that depends on inventory reduction and the reduction of faulty parts. *Continuous improvement in all its implication is done with a view to improving safety, efficiency and productivity on construction sites*.

Reduce project time ranked the fifth (5^{th}) benefit of implementing lean construction with RII value of 0.66 based on response obtained from respondents. One of the biggest causes of productivity loss is the inefficient scheduling of workers. Techniques like last planner system minimize these issues by improving plan to actual ratio to reduce conflicts. As schedules are planned backward to meet the final deadlines, stakeholders can consider and address potential problems ahead of time to coordinate more effectively. Similarly reduce

total project duration or project time ranked fifth (5^{th}) in the study of (Ahmed et al., 2021). But in the study of Ayalew & Dakhli, (2016) it ranked the fourth (4^{th}) benefit of implementing lean construction.

Table 4.4 Benefits of implementing lean construction

Benefits of implementing lean construction	RII	RANK
Increase productivity	0.87	1
Reducing waste and production cost	0.81	2
Eliminates all non-value adding steps,	0.76	3
Pursue perfection by continuous improvement	0.67	4
Reduce project time	0.66	5
Fewer defect and rework	0.65	6
Improving client satisfaction	0.65	6
Will increase profit	0.64	7
Crating a smooth work flow	0.63	8
Improved employee morale and involvement	0.62	9
Better quality of work	0.62	9
Makes the projects easier to manage	0.61	10
Minimize double handling and movement of equipment and workers,	0.57	11
Improves process transparency and communication	0.57	12
Improve prediction of risk	0.56	13
Lower levels of inventory	0.56	13
Improve the quality of the environment	0.56	13
Construction site safety control improvement	0.54	14
Minimization of conflicts	0.52	15
Preventing pollution and emissions	0.49	16

4.5 Barriers to implement lean construction

One of the objectives of the study is to prioritize barriers to implement lean construction in sidama region projects. Analytical hierarchy process (AHP), which is a multi-criteria analysis approach helps decision makers to rank barriers based on pairwise comparison of each variables. In accordance to research objective raised, the present study uses a unique

set of twenty seven (27) lean implementation barriers in construction project, retrieved through exhaustive literature review. The selected barriers are categorized under seven groups namely; management related, awareness and educational related, financial related, cultural and human attitude related, technical related, government related and resource related barriers. The respondents are requested to prepare a pairwise comparison of those seven groups and twenty seven factors and their judgment analyzed with given scale. The geometric mean is calculated for pairwise comparison to aggregate respondents' responses. The aggregated comparison matrix for groups of main and sub-criteria is shown in table 4.5 and table 4.6 respectively.

Table 4.5 Aggregate comparison matrix of main criteria

Criteria (Barriers)	Management	Awareness	Financial	Government	Technical	Cultural	Resource	Criteria weight
Management related	0.3061	0.2381	0.2093	0.3521	0.2542	0.6000	0.1765	0.3052
Awareness related	0.0612	0.0476	0.0698	0.0141	0.0508	0.0400	0.0588	0.0489
Financial related	0.1020	0.0476	0.0698	0.0704	0.0508	0.0400	0.1765	0.0796
Government related	0.0612	0.2381	0.0698	0.0704	0.0847	0.0400	0.0588	0.0890
Technical Related	0.3061	0.2381	0.3488	0.2113	0.2542	0.1200	0.2941	0.2532
Cultural related	0.0612	0.1429	0.2093	0.2113	0.2542	0.1200	0.1765	0.1679
Resource related	0.1020	0.0476	0.0233	0.0704	0.0508	0.0400	0.0588	0.0561

The analysis result on table 4.5 revealed that management related barriers (0.3052) emerge as most critical one followed by technical related (0.2532), government related (0.1679) and cultural and human attitude related (0.0890) barriers. Financial related (0.0769),

resource related (0.0561) and awareness and educational related (0.0489) barriers hold fifth, sixth and seventh position respectively according to their criteria weight. The study not focused to prioritize the categories of barriers but to prioritize each barriers by their global weight to discuss the overall rank as follow.

The global priority weights result shown on table 4.6 below revealed that lack of top management support and commitment with global weight (0.1854) is the most significant barrier affecting lean implementation ranked first from overall barriers, followed by fragmentation and subcontracting nature of the industry with global weight (0.1215) ranked second and lack of government policies to encourage the use of lean with global weight (0.1051) ranked third. Also the other top barriers incomplete and inaccurate designs with global weight (0.0577) ranked fourth and lack of time to implement with global weight (0.0564) ranked fifth. The above are the top five most influential barriers of lean construction.

The top most significant barriers of implementing lean construction are discussed hereunder;-

Lack of top management support and commitment (MR1) was ranked the first barrier of implementing lean construction in sidama region projects with global weight of (0.1854) based on finding. Top management's support and commitment for lean practice is extremely importance in terms of successful application of lean in construction projects. When top management is hesitating towards adopting lean, some deficiencies might arise in lean implementation. The study (Gaikwad et al., 2020) agreed that lack of support and commitment also slow down the implementation process. For some managers the benefits are not clear and their training and experience is not sufficient to provide them with the ability to manage change in thinking, responsibility and roles arise from implementing lean (S Sarhan & Fox, 2013). Hailu, (2020) believes that top managers have to provide

sufficient time and resources to develop an effective plan and manage changes arising from the lean construction implementation process. similarly (Nwaki et al., 2021) pointed out that lack of management support and commitment is one of the key factors that impede lean construction. It is the responsibility of management to provide the enabling environment for implementation of lean concept. This will be possible when they invest in it, motivate the workforce by way of increasing their knowledge, skills and understanding of the concept. Also, they are responsible for the provision of the needed tools, equipment and technologies that drive lean construction on construction projects. The studies of (S Sarhan & Fox, 2013) and (Nwaki et al., 2021) ranked the second (2^{nd}) and also, (Ramaru, 2017) ranked fourth (4^{th}) most significant barrier.

Fragmentation and subcontracting nature of the industry (TR1) was ranked the second (2^{nd}) barrier of lean construction implementation with global weight of (0.1215) according to response. Participants of a project will feel less to agree to work and learn together to reach a common goal if there is fragmentation and subcontracting. Each of the participants will have their own background and approach, but share the goal of strongly finishing the project. Hence, establishment a clear path of communication between all of the parties is essential. Weak connection causes a harmful influence on the entire project, preventing effective synergy in the application of lean construction (Demirkesen et al., 2019; Saad Sarhan, 2015). Also Sarhan & Fox, (2013) believes Fragmentation and subcontracting in construction hinder the incentive for project participant to cooperate and learn together. In construction projects, contractors traditionally hire subcontractors. These subcontractors generally do not have contracts with client and may sometimes have to work with insufficient budgets. Because of this they may not deliver required tools, materials and workforce needed for lean implementation. The study of (S Sarhan & Fox, 2013) ranked fifth (5^{th}) barrier in their study.

Resistance to change the existing work culture (CR1) was ranked the third barrier of lean construction implementation with global weight of (0.1051) based of respondents answer. Those resistances of changing the work culture in construction organization or project arise either from management or from employees. With lean, the employees are exposed to techniques and tools which may alter their way of thinking and working but it helps in wastes reduction with enhanced productivity. The study of Hajj, (2018) point out that People do not accept the change because they feel a loss of control and excessive uncertainty when applying new concepts. Resistance from employees might be due to fear of loss of their job, if it was found that their job do not add value as lean construction is about eliminating non-value added activities and also they are unfamiliar with lean tools or its benefits (Mohamed Saad Bajjou et al., 2017). The study of Sayed et al., (2019) states that any change from good in the existing construction organization or project requires an investment in terms of time, resources and willingness to adopt and adapt. It noticed that managers are always afraid of their investment might not produce the expected results from lean. Both Oyedolapo, (2014) and Thakkar & Shah, (2021) studies ranked the first most significant barrier in their study and also Saad Sarhan, (2015) ranked second and Cano et al., (2015) ranked third in their study respectively.

Incomplete and inaccurate designs (TR2) were ranked the fourth barrier of lean construction implementation with global weight of (0.0577) according to respondents' response. Design and planning process are identified as major attributes of lean construction. Any ignorance to the importance of these could lead to harmful loss of time, cost and the overall process. As indicated in the studies of Hailu, (2020) and Sarhan & Fox, (2013) due to traditional contractual procedures, design and implementation of design are treated as separate products. This causes a conflict border between the two phases and creates lots waste such inaccurate designs and rework in design, final products with

significant variation from values specified in the design, and makes difficult to contractors due to design changes made by designers. Also Demirkesen et al., (2019) believes designing for lean is more challenging than traditional methods and this might lead to complexity in design, which makes design a barrier for lean projects. Nevertheless, it has to be considered that higher effort in design due to lean practices results into stable working processes on site since design and processes are aligned from the beginning. In contrast with this study findings, the study of Oke et al., (2019) ranked incomplete and inaccurate design barrier eleventh (11^{th}) and also Ahmed et al., (2021) ranked ninth (9^{th}) and Sarhan & Fox, (2013) ranked tenth (10^{th}) in their studies.

Influence of traditional management practice (MR2) was ranked the fifth (5^{th}) barrier of lean construction implementation in construction projects with global weight of (0.0564) based on respondents response. Construction companies are depend on traditional and non-progressive thinking about production and management must be considered a major obstacle to the useful performance of the lean construction principle. Also Devaki & Jayanthi, (2014) study believes that construction industry is huge and people are used to and are comfortable with the traditional style of management. So, do not want to change construction process is already working. But, the construction sector on the boom and resources depleting at a fast speed, it has a big role in waste generation and environment pollution. Changes in construction process and implementing lean principles and techniques will result in waste minimization. The study of Silva et al., (2021) states that due to fear of risk taker to implement new techniques, lack of knowledge on lean construction, thinking of new construction management practice requires additional time and cost and unfamiliarity with technologies makes the construction company under the influence of traditional management practice. The study of Gaikwad et al., (2020) ranked first (1^{st}), but in the study of (Hailu, 2020) ranked tenth (10^{th}).

Table 4.6 Barriers to lean implementation

Main criteria	Major criteria Weight	Sub criteria	Local Weigh t.	Global Weight	Percent (%)	Group Rank	Over all Rank
Management related	0.3052	MR1	0.6074	0.1854	18.54	1	1
		MR2	0.1849	0.0564	5.64	2	5
		MR3	0.1210	0.0369	3.69	3	9
		MR4	0.0866	0.0264	2.64	4	13
Awareness & education related	0.0489	AB1	0.5156	0.0252	2.52	1	14
		AB2	0.2331	0.0114	1.14	2	22
		AB3	0.1310	0.0064	0.64	3	26
		AB4	0.1203	0.0059	0.59	4	27
Financial related	0.0796	FR1	0.4741	0.0377	3.77	1	8
		FR2	0.2626	0.0209	2.09	2	17
		FR3	0.1614	0.0128	1.28	3	21
		FR4	0.1018	0.0081	0.81	4	24
Cultural & human related	0.1679	CR1	0.4992	0.0838	8.38	1	3
		CR2	0.1448	0.0243	2.43	3	15
		CR3	0.1644	0.0276	2.76	2	12
		CR4	0.1106	0.0186	1.86	4	18
		CR5	0.0810	0.0136	1.36	5	20
Technical related	0.2532	TR1	0.4797	0.1215	12.15	1	2
		TR2	0.2278	0.0577	5.77	2	4
		TR3	0.1557	0.0394	3.94	3	7
		TR4	0.1369	0.0347	3.47	4	10
Government related	0.0890	GR1	0.6259	0.0557	5.57	1	6
		GR2	0.2707	0.0241	2.41	2	16
		GR3	0.1033	0.0092	0.92	3	23
Resource related	0.0561	RR1	0.6051	0.0340	3.40	1	11
		RR2	0.2547	0.0143	1.43	2	19
		RR3	0.1402	0.0079	0.79	3	25

4.6 Critical success factors for lean implementation

One of the objectives of the study is to prioritize critical success factors to implement lean construction in sidama region projects. Analytical hierarchy process (AHP), which is a multi-criteria analysis approach helps decision makers to rank critical success factors based

on pairwise comparison of each variables. In accordance to research objective raised, the present study uses a unique set of sixteen (16) factors in construction project, retrieved through exhaustive literature review. The selected critical success factors were categorized as management and leadership, technical, workforce and resource and cultural and government related. The respondents are requested to prepare a pairwise comparison of those four groups and sixteen factors and their judgment analyzed with given scale. The geometric mean is calculated for pairwise comparison to aggregate respondents' responses. The aggregated comparison matrix for groups of main and sub-criteria is shown in table 4.7 an table 4.8 respectively.

Table 4.7 Aggregate comparison matrix of main criteria

CRITERIA	Management	Workforce	Technical	Cultural	Criteria Weight
Management	0.4268	0.6818	0.3000	0.3000	0.4272
Workforce	0.0854	0.1364	0.3000	0.3000	0.2054
Technical	0.4268	0.1364	0.3000	0.3000	0.2908
Cultural	0.0610	0.0455	0.1000	0.1000	0.0766

The major criteria weight analysis result shown on table 4.7 revealed that management and leadership related critical success factor ranked first (0.4272) emerge as most critical one followed by technical related (0.2908), workforce and resource related (0.2054) and cultural and governmental related (0.0766) critical success factors which holds second, third and fourth position respectively, according to their criteria weight. The study not focused to prioritize the categories of barriers but to prioritize each barriers by their global weight to discuss the overall rank as follow.

The global priority weights result shown on table 4.8 below revealed that management commitment and involvement with global weight (0.2136) is the most critical success factor for lean construction implementation ranked first from overall, followed by

understanding of technical requirement in lean with global weight (0.1887) ranked second and employee morale and motivation with global weight (0.1100) ranked third. Also strategy planning and technical capacity for lean implementation were ranked fourth and fifth with global weight of (0.1045) and (0.720). The above are the top five most critical success factors for lean construction implementation.

The top five most critical success factors for lean construction implementation were discussed below;

Management commitment and involvement (MF1) was ranked the first (1^{st}) most critical success factor with global weight of (0.2136) according to respondents answer. Management commitment and involvement is an effort of time and financial resources to lean program by managers and leaders in Construction Company. The study of (J. G. Sarhan, 2000) agreed that this factor is very crucial to the implementation of lean and it further important for strong leadership whereby clear vision, strategy and long term commitment are plays essential role to build an effective lean culture in an organization. Similarly the study of (Bashir et al., 2015) believes that the success of lean practice lies in their commitment and involvement to develop and implement an effective plan and adequately provide the required resources and support to manage changes arising from implementation. The study of Gaikwad et al., (2020) states that effective management can smooth the lean implementation process as well as can faster the process. The same with this study, (J. G. Sarhan, 2000), (Watfa & Sawalha, 2021) and (Gaikwad et al., 2020) ranked first (1^{st}) in their study and (Oguntona et al., 2019) ranked third.

Clear understanding of technical requirements in lean (TF1) was ranked the second (2^{nd}) critical success factor with global weight of (0.1887) based on respondents answer. Clarity in lean terms definition and identification of best practices are more important to lean implementation success. The study of Salem et al., (2005) indicated that the unfamiliarity

with or misunderstanding of lean concepts and tools were the greatest obstacle at the beginning of implementation, because some lean management tools come from manufacturing. The study of Demirkesen & Bayhan, (2019) states that a deeper understanding of the goals and techniques is key to successful lean implementation process, due to the time spent in repeating process. Hence, it is essential to review standards and requirements before implementation takes place. The study of (Bayhan et al., 2019) ranked first (1^{st}) in their study .

Employee morale and motivation (WF1) was ranked third (3^{rd}) critical success factor for lean implementation on construction projects with global weight of (0.110) according to response. In lean philosophy, employees are considered to be the core of the company and a key element in the lean system (Houti et al., 2019). They need to be encouraged and involved in the lean program to ensure success. Lean requires all employees to participate in the decision making by providing suggestions to improve the process. According to Watfa & Sawalha, (2021) study it is also vital to motivate and empower the participants by creating the right environment in which employees are recognized and encouraged, resulting in changing their attitude and overcoming their resistance to change. The study of Bashir et al., (2015) revealed that motivating and encourage employees to express their views on lean construction strategy enhance its implementation on ground. Similar with the study, also Watfa & Sawalha, (2021) ranked third and Oyedolapo, (2014) ranked fifth (5^{th}) in their study.

Strategy planning (MF2) was ranked the fourth (4^{th}) critical success factor for lean implementation with global weight of (0.1045) based on respondents response. It is important to put in place a lean implementation by determining the type of lean tools and techniques the company should to read according to their needs the scope of lean program. The strategy should also include human and financial resource allocation, hiring and

training plans and long term objectives. On the other hand planning is necessary to ensure successful implementation, planning involves establishing a structured methodology for the implementation, as well as developing a detailed cost and schedule estimation. The study of Demirkesen & Bayhan, (2020) revealed that making lean a company strategy enhances familiarity with lean practices and facilitates the implementation of lean. There is strong correlation between lean strategy and performance. The essential use of lean strategy is likely to yield enhanced performance in lean implementation. Strategy planning in the studies of (Watfa & Sawalha, 2021) ranked fifth and (Demirkesen & Bayhan, 2019) ranked sixth (6^{th}) .

Training of employees on lean tools and techniques (TF2) was ranked the fifth (5^{th}) critical success factor for lean implementation with global weight of (0.0720) according to obtained response. The organization could be engage their employees in learning process through training to acquire all the necessary knowledge and skills required to achieve a smooth implementation of lean construction. The study of Yunus et al., (2017) states that in order to ensure the success of lean thinking, employees in an organization need to be equipped with appropriate skills and knowledge. The lack of insufficient knowledge will become a resistance towards change. Failure in recognizing value-added and non-value added activities will also lead to waste and wasteful activity in construction process. Training of employees, in the studies of (Oguntona et al., 2019) ranked second (2^{nd}) and (Alarcon & Seguel, 2002) ranked third (3^{rd}).

Table 4.8 Critical success factors for lean implementation

Main criteria	Major criteria Weight	Sub criteria	Local Weight	Global Weight	Percent (%)	group Rank	Over all Rank
Management factors	0.4272	MF1	0.5001	0.2136	21.3640	1	1
		MF2	0.2446	0.1045	10.4476	2	4
		MF3	0.1434	0.0613	6.1252	3	6
		MF4	0.1119	0.0478	4.7794	4	7
Workforce factors	0.2054	WF1	0.5354	0.1100	10.9983	1	3
		WF2	0.1352	0.0278	2.7769	3	11
		WF3	0.1538	0.0316	3.1599	2	9
		WF4	0.0923	0.0190	1.8970	4	12
		WF5	0.0833	0.0171	1.7111	5	13
Technical factors	0.2908	TF1	0.6489	0.1887	18.8698	1	2
		TF2	0.2477	0.0720	7.2024	2	5
		TF3	0.1034	0.0301	3.0077	3	10
Cultural factors	0.0766	CF1	0.5517	0.0423	4.2262	1	8
		CF2	0.2144	0.0164	1.6427	2	14
		CF3	0.1341	0.0103	1.0269	3	15
		CF4	0.0999	0.0076	0.7650	4	16

Chapter 5

5. Conclusion and Recommendations

5.1 Conclusions

The construction industry is a major contributor to Ethiopian economy growth, both directly through its activities, and indirectly through the construction of infrastructure. To ensure improvement within the construction industry's performance its challenges should be known in order to find out solution or mitigation mechanism. The performance of the construction industry is hampered by waste which includes both physical wastes like materials and non-physical wastes like waiting and unnecessary movement on construction projects. So, this problem could be overcome by applying lean construction principles and tools on construction projects in order to eliminate waste and wasteful activities to add-value. Lean construction is a management philosophy focuses on eliminating waste and maximizing productivity through employee involvement and continuous improvement. Therefore, the principles and tools used, the benefits, the barriers to adopt and the critical success factor for lean construction implementation in sidama region projects are determined in this study. According to research findings, the following conclusions were reached;

1) The five principles and the twelve tools of lean construction were identified and the significance of each variable is determined by calculating the relative importance index value of the variables. From lean principles; pursue perfection (continuous improvement), create smooth flow in process, allowing client to pull, map the value stream and identify customer value ranked from first to fifth in descending order according to respondents answer. Also, from lean tools; last planner system, 5s, concurrent engineering, just in time and daily huddle meeting are the top five, which ranked from first to fifth in descending order of significance.

2) From literature a total of twenty selected benefits of implementing lean construction were identified and the significance of these variables is determined by calculating the relative importance index value of each variable. According to the result obtained, increase productivity, reducing waste and production cost, eliminate all non-value adding steps, pursue perfection by continuous improvement and reduce project time are the top five benefits in descending order of significance.
3) Seven groups of barriers to implement lean construction were identified from literature. Management, technical, cultural and human resource, government, financial, resource and awareness and education related are in descending order of significance. Also twenty-five factors that barrier implementation of lean construction were considered and categorized under those seven groups. Each factor is prioritized using analytical hierarchy process, which is a multi-criteria decision making method. Out of which, lack of management commitment and support, fragmentation and subcontracting nature of the industry, resistance to change the existing work culture, incomplete and inaccurate design and influence of traditional management practice are the top five factors in descending order of significance according to their global weight.
4) Four groups of critical success factors to implement lean construction were identified from literature. Management and leadership, technical, workforce and resource and cultural and governmental factors are in descending order of significance. Also, sixteen factors were considered and categorized under those groups. Each factor is prioritized using analytical hierarchy process, which is a multi-criteria decision making method. Out of which, management commitment and involvement, understanding of technical requirements in lean, employee morale and

motivation, strategy planning and training of employees are the five top critical success factors in descending order of significance according to their global weight.

5.2 Recommendation

This study has assessed the lean construction implementation in sidama region public projects. This has been achieved by investigating the lean construction principles and tools implemented, identifying the benefits of implementing, prioritizing the barriers to implement and critical success factors to implement lean. According to the research finding, the following recommendations were made as follow;

Contractor

1. Since managing both physical and non-physical waste is most significant management processes necessary to achieve project objectives by using lean construction to identify and analyze waste to improve productivity, minimize time and cost, improve quality and ensure client satisfaction.
2. Project managers should be committed and involved to change or modify the existing traditional management practices with lean management and encourage their employees for better implementation of lean construction tools and techniques.
3. Construction professionals should try to understand the lean construction tools and techniques and ready to encourage for implementation. Also they should close to and familiar with waste minimization and performance enhancement innovative ideas like lean.

Consultants

1. Should give attention to detail at design and planning stage to avoid inaccurate and inadequate designs, which hinders to implement lean construction on project sites.

2. Encourage those contractors which are not familiar with lean construction, to adopt it on their construction project.

Government

1. Encourage and promote innovative ways which minimize waste and improve lean implementation through inclusive in to policies.
2. Should facilitate the implementation lean construction by training stakeholders which participate on construction projects.

For further study

1. This research focus on only public building projects, the researcher recommends to assess the lean construction implementation on road projects.
2. Further study needs to be done on each type of lean technique/tools so that it is clear for the construction professionals for its implementation in the construction industry.

References

(MoUDC), M. of U. D. C. and C. (2012). *Ministry of urban development and construction*. *July*.

Abdelrazig, Y. E. (2015). *Using Lean Techniques to Reduce Waste and Improve*. *May*, 1–148. https://rc.library.uta.edu/uta-ir/bitstream/handle/10106/25028/ABDELRAZIG_uta_2502M_13057.pdf?sequence=1&isAllowed=y

Adegbembo, F. T., Bamisaye, O. P., & Aghimien, D. O. (2016). Assessment of lean construction practice in the Nigerian construction industry. *Joint International Conference (JIC) on 21st Century Human Habitat: Issues, Sustainability and Development*, *March*, 756–764.

Adekunle, O. A., Olufemi, M. L., & A., K. W. (2015). *Resources Conservation and Waste Management*. *4*(7), 20–31.

Ahmad, S., Wasim, S., Irfan, S., Gogoi, S., Srivastava, A., & Farheen, Z. (2019). *Qualitative v / s Quantitative Research Qualitative v / s . Quantitative Research- A Summarized Review*. *November*. https://doi.org/10.18410/jebmh/2019/587

Ahmad, W. (2019). *Application of Lean Principles and Performance Improvement of Construction Projects . Master Thesis Conceptual Formulation*.

Ahmed, S., Hossain, M. M., & Haq, I. (2021). Implementation of lean construction in the construction industry in Bangladesh: awareness, benefits and challenges. *International Journal of Building Pathology and Adaptation*, *39*(2), 368–406. https://doi.org/10.1108/IJBPA-04-2019-0037

Akhund, M. A., Memon, A. H., Memon, N. A., Ali, T. H., & khoso, A. R. (2019). Exploring Types of Waste Generated: A Study of Construction Industry of Pakistan. *MATEC Web of Conferences*, *266*, 05011. https://doi.org/10.1051/matecconf/201926605011

Akinradewo, O. I., Oke, A. E., Aigbavboa, C. O., & Ndalamba, M. (2018). Benefits of adopting lean construction technique in the South African construction industry. *Proceedings of the International Conference on Industrial Engineering and Operations Management*, *2018*(NOV), 1271–1277. https://doi.org/10.13140/RG.2.2.27044.01927

Akinradewo, O., Oke, A., Aigbavboa, C., & Ndalamba, M. (2018). *Benefits of Adopting Lean Construction Technique in the South African Construction Industry*. *Lc*, 2012–

2018.

Al-Aomar, R. (2012). Analysis of lean construction practices at Abu Dhabi construction industry. *Lean Construction Journal*, *2012*, 105–121.

Alarcón, L. F., Diethelm, S., Rojo, O., & Calderon, R. (2005). Assessing the impacts of implementing lean construction. *13th International Group for Lean Construction Conference: Proceedings*, 387–393.

Alarcon, L. F., & Seguel, L. (2002). Developing incentive strategies for implementation of Lean Construction. *10th Annual Conference of the International Group of Lean Construction*, 1–12.

Allu, E. L. A., & Emuze, F. (2018). Advancing lean implementation for improving sustainability in Sub-Saharan Africa: A literature review. *Sustainability (United States)*, *11*(3), 127–135. https://doi.org/10.1089/sus.2018.0003

Amade, B., Nnamdi Ononuju, C., Obodoh, D., & Ejimnkonye Okorie, C. (2019). Barriers to Lean Adoption for Construction Projects. *The Pacific Journal of Science and Technology-153*, *20*(1). http://www.akamaiuniversity.us/PJST.htm

Amirhossein Karimzadeh, E. (2015). *A comprehensive review on Lean Project Management, transformation & Implementation methods, and its utilization in the construction industry (Lean Construction)*. 86.

Ansah, R. H., Sorooshian, S., & Mustafa, S. Bin. (2016). Lean construction: An effective approach for project management. *ARPN Journal of Engineering and Applied Sciences*, *11*(3), 1607–1612.

Ashirwadam, J. (2014). *Communication Research Methods Methods of Data Analysis*. *August*.

Aslam, M., Gao, Z., & Smith, G. (2020). Framework for selection of lean construction tools based on lean objectives and functionalities. *International Journal of Construction Management*, *0*(0), 1–12. https://doi.org/10.1080/15623599.2020.1729933

Ayalew, T., & Dakhli, Z. (2016). The Future of Lean Construction in Ethiopian Construction Industry. *International Journal of Engineering Research & Technology*, *5*(02), 107–113.

Ayalew, T., Dakhli, Z., & Lafhaj, Z. (2018). Characterization of waste in Ethiopian building construction projects. *IGLC 2018 - Proceedings of the 26th Annual Conference of the International Group for Lean Construction: Evolving Lean*

Construction Towards Mature Production Management Across Cultures and Frontiers, *2*, 797–806. https://doi.org/10.24928/2018/0505

Ayman Ahmed, E. O., & Maha Ahmed, A.-Z. (2018). Lean Construction for Reducing Construction Waste in the Egyptian Construction Industry. *2nd Internatinal Conference "Sustainable Construction and Project Management - Sustainable Infrastructure and Transportation for Future Cities," February*.

Aziz, R. F., & Hafez, S. M. (2013a). Applying lean thinking in construction and performance improvement. *Alexandria Engineering Journal*, *52*(4), 679–695. https://doi.org/10.1016/j.aej.2013.04.008

Aziz, R. F., & Hafez, S. M. (2013b). Applying lean thinking in construction and performance improvement. *Alexandria Engineering Journal*, *52*(4), 679–695. https://doi.org/10.1016/j.aej.2013.04.008

Babalola, O. D., Ibem, E. O., & Ezema, I. C. (2018). Assessment of awareness and adoption of lean practices in the Nigerian building industry. *International Journal of Civil Engineering and Technology*, *9*(13), 1626–1640.

Bae, J., & Kim, Y. (2001). Sustainable Value on Construction Projects. *Journal of Green Building*, *3*(1), 156–167.

Bajjou, M. S., Chafi, A., Ennadi, A., & El Hammoumi, M. (2017). The practical relationships between lean construction tools and sustainable development: A literature review. *Journal of Engineering Science and Technology Review*, *10*(4), 170–177. https://doi.org/10.25103/jestr.104.20

Bajjou, Mohamed Saad, Chafi, A., & En-Nadi, A. (2017a). A comparative study between lean construction and the traditional production system. *International Journal of Engineering Research in Africa*, *29*, 118–132. https://doi.org/10.4028/www.scientific.net/JERA.29.118

Bajjou, Mohamed Saad, Chafi, A., & En-Nadi, A. (2017b). The potential effectiveness of lean construction tools in promoting safety on construction sites. *International Journal of Engineering Research in Africa*, *33*, 179–193. https://doi.org/10.4028/www.scientific.net/JERA.33.179

Ballard, G. (2016). Lean construction. *The Routledge Companion to Lean Management*, *1*(11), 271–285. https://doi.org/10.4324/9781315686899

Bashir, A. M., Suresh, S., Oloke, D. A., Proverbs, D. G., & Gameson, R. (2015). Overcoming the Challenges facing Lean Construction Practice in the UK Contracting

Organizations. *International Journal of Architecture, Engineering and Construction*, *4*(1). https://doi.org/10.7492/ijaec.2015.002

Bayhan, H. G., Demirkesen, S., & Jayamanne, E. (2019). Enablers and Barriers of Lean Implementation in Construction Projects. *IOP Conference Series: Materials Science and Engineering*, *471*(2), 0–9. https://doi.org/10.1088/1757-899X/471/2/022002

Belay, S., Goedert, J., Woldesenbet, A., & Rokooei, S. (2022). AHP based multi criteria decision analysis of success factors to enhance decision making in infrastructure construction projects. *Cogent Engineering*, *9*(1). https://doi.org/10.1080/23311916.2022.2043996

Bodkhe, M. A. Y., & Waghamare, P. A. P. (2016). *Investigation and Minimization of Construction Wastage Using Lean Technology in Construction*. *4*(3), 105–107.

Bosnich, T. (2019). *Applying lean construction principles to waste management and identifying minimisation opportunities to inform the industry*. *December*.

Cano, S., Delgado, J., Botero, L., & Rubiano, O. (2015). Barriers and success factors in lean construction implementation-survey in pilot context. *Proceedings of IGLC 23 - 23rd Annual Conference of the International Group for Lean Construction: Global Knowledge - Global Solutions*, *2015-Janua*(100), 631–641.

Casteel, A. (2017). *RESEARCH INSTRUMENTS FOR DATA COLLECTION*. 1–4.

Chhabra, A., & Rathore, N. (2011). *REVIEW OF DESIGN MANAGEMENT PROCESSES AND EFFICACY OF BUILDING INFORMATION MODELLING (BIM) WITH A VIEW TO EVOLVE A NEW CONCEPTUAL FRAMEWORK OF INTEGRATED*. 978–981.

CORVELLO, F. M., HERMOSILLA, J. L. G., AMARAL, C. S. T., GALATI, I. S., & SILVA, E. C. C. DA. (2020). *Prefabrication in Lean Construction context: limitations and challenges in the current scenario*. *November 2021*. https://doi.org/10.14488/ijcieom2020_full_0001_37285

Demirkesen, S., & Bayhan, H. G. (2019). Critical Success Factors of Lean Implementation in the Construction Industry. *IEEE Transactions on Engineering Management*, *PP*, 1–17. https://doi.org/10.1109/TEM.2019.2945018

Demirkesen, S., & Bayhan, H. G. (2020). A Lean Implementation Success Model for the Construction Industry. *EMJ - Engineering Management Journal*, *32*(3), 219–239. https://doi.org/10.1080/10429247.2020.1764834

Demirkesen, S., Wachter, N., Oprach, S., & Haghsheno, S. (2019). Identifying barriers in

lean implementation in the construction industry. *27th Annual Conference of the International Group for Lean Construction, IGLC 2019*, *3*, 157–168. https://doi.org/10.24928/2019/0151

Design, P. (2018). *BARRIERS AND SUCCESS FACTORS FOR DEVELOPING A LEAN CULTURE A case study at a Romanian contractor*. https://odr.chalmers.se/handle/20.500.12380/255902%0Ahttps://odr.chalmers.se/bitstream/20.500.12380/255902/1/255902.pdf

Devaki, M. P., & Jayanthi, R. (2014). *Barriers to Implementation of Lean Principles in*. *3*(5), 1189–1192.

Dodiya, P. (2020). *A Literature Review on Application of Lean Principles to Identify Performance Improvement of Building Construction*. *July*.

Doğan, S. Z., Çalğici, P. K., Arditi, D., & Günaydin, H. M. (2015). *CRITICAL SUCCESS FACTORS OF PARTNERING IN THE BUILDING DESIGN PROCESS*. 61–78. https://doi.org/10.4305/METU.JFA.2015.2.4

Dr. Amade, B. (2000). *AWARENESS, USE AND BENEFITS OF LEAN TECHNOLOGIES ON CONSTRUCTION PROJECTS IN NIGERIA*. *369*(1), 1689–1699. http://dx.doi.org/10.1016/j.jsames.2011.03.003%0Ahttps://doi.org/10.1016/j.gr.2017.08.001%0Ahttp://dx.doi.org/10.1016/j.precamres.2014.12.018%0Ahttp://dx.doi.org/10.1016/j.precamres.2011.08.005%0Ahttp://dx.doi.org/10.1080/00206814.2014.902757%0Ahttp://dx.

El-sawalhi, N. I., Jaber, B. M., & Shukri, A. Al. (2018). Towards lean and green thinking in construction projects at Gaza Strip. *Organization, Technology and Management in Construction: An International Journal*, *10*(1), 1827–1838. https://doi.org/10.2478/otmcj-2018-0011

Elkherbawy, A. (2019). *Lean Construction versus Project Management in road projects: Scheduling comparison*. *June*, 238. https://upcommons.upc.edu/handle/2117/183237?show=full

Enshassi, A., Saleh, N., & Sundermeier, M. (2019). *Barriers Hinder the Application of Lean Construction*. 77–88.

Enshassi, A., & Zaiter, M. A. (2014). Implementation of lean tools on safety in construction projects in palestine. *22nd Annual Conference of the International Group for Lean Construction: Understanding and Improving Project Based Production, IGLC 2014*, 1205–1218.

EROL, H. H. (2014). *Identifying the Effects of Lean Construction Principles on*. *June*.

Eze, R., S., O. P., E., & O.S, L. (2017). Assessment of materials waste in the construction industry: A view of Construction Operatives, Tradesmen and Artisans in Nigeria. *The International Journal of Engineering and Science*, *06*(04), 32–47. https://doi.org/10.9790/1813-0604013247

Fardhosseini, M. S., & Soltaninejad, M. (2021). *Qualitative Evaluation of 5S Application Considering the Experience of Electrical Construction Experts*. https://doi.org/10.3844/ajassp.2021.51.60

Farooqui, M. K. M., Seshagirirao, D. V., Vinitha, M. L., & Siva Kanna, V. (2019). Critical success factors for lean implementation within sme's in South India. *International Journal of Recent Technology and Engineering*, *8*(2 Special Issue 8), 922–927. https://doi.org/10.35940/ijrte.B1176.0882S819

Gaikwad, S. K., Paul, A., Moktadir, M. A., Paul, S. K., & Chowdhury, P. (2020). Analyzing barriers and strategies for implementing Lean Six Sigma in the context of Indian SMEs. *Benchmarking*, *27*(8), 2365–2399. https://doi.org/10.1108/BIJ-11-2019-0484

Genaidy, A., Luegring, M., Solomon, J., & Student, G. (2004). the Path From Lean Manufacturing To Lean Construction: Implementation and Evaluation of Lean Assembly. *12Th Annual Conference of the International Group for Lean Construction* , 1–14.

Gerasimos Siasos, I. (2017). The Benefits of Lean through an Analysis and Improvement of an Existing Production Line. *Material Science and Engineering with Advanced Research*, *2*(1), 15–24. https://doi.org/10.24218/msear.2017.23

Ghosh, S., Bhattacharjee, S., Pishdad-Bozorgi, P., & Ganapathy, R. (2014). A case study to examine environmental benefits of lean construction. *22nd Annual Conference of the International Group for Lean Construction: Understanding and Improving Project Based Production, IGLC 2014*, *1*(405), 133–144.

Gobind, B. (2015). *Research Methodology and Approaches*. *5*(3), 48–51. https://doi.org/10.9790/7388-05344851

Gulghane, A. A., & Khandve, P. V. (2015). Management for Construction Materials and Control of Construction Waste in Construction Industry: A Review. *Journal of Engineering Research and Applications Www.Ijera.Com ISSN*, *5*(41), 2248–962259. www.ijera.com

Hailu, S. A. (2020). *Waste Reduction in Building Construction Through Lean Construction Approach : A Preliminary Assessment of Current Practice in Bahir Dar* .

Hajj, C. El. (2018). *Notre Dame University-Louaize Faculty of Business Administration & Economics Graduate Division Barriers to the Implementation of Lean Management in the Lebanese Construction Industry for the Degree of the Master of Business Administration (M . B . A .) B.*

Halling, B. (2013). Lean Implementation: The Significance of People and Dualism. *Sustainable Operational Excellence*.

Henriques, P. G., De, P., & Silva, F. (2009). IMPLEMENTATION OF LEAN CONSTRUCTION PRINCIPLES IN PORTUGAL: "Adaptation of good practices from a Danish Case Study." *Joint International Symposium 2009- Construction Facing Worldwide Challenges (CIB)*, 396–405.

Hossain, M. A., Bissenova, A., & Kim, J. R. (2019). Investigation of wasteful activities using lean methodology: In perspective of kazakhstan's construction industry. *Buildings*, *9*(5). https://doi.org/10.3390/buildings9050113

Houti, M., El Abbadi, L., & Abouabdellah, A. (2019). Critical success factors for lean implementation "projection on SMEs". *Proceedings of the International Conference on Industrial Engineering and Operations Management*, *July*, 526–537.

HOWELL, G., & BALLARD, G. (2010). Implementing lean construction. *Lean Construction*, *May*, 111–126. https://doi.org/10.4324/9780203345825_implementing_lean_construction

Huaman-Orosco, C., & Erazo-Rondinel, A. A. (2021). An Exploratory Study of the Main Barriers to Lean Construction Implementation in Peru. *Proc. 29th Annual Conference of the International Group for Lean Construction (IGLC)*, 474–483. https://doi.org/10.24928/2021/0173

Ingle, A., & Waghmare, A. P. (2015). Advances in Construction: Lean Construction for Productivity enhancement and waste minimization. *International Journal of Engineering and Applied Sciences (IJEAS)*, *2*(11), 19–23. https://media.neliti.com/media/publications/257799-advances-in-construction-lean-constructi-26b89218.pdf

Israel, G. D. (2010). *Using Published Tables Using Formulas To Calculate A Sample Size Using A Census For Small Populations*.

Jacobs, G. F. (2010). *Review of Lean Construction Conference Proceedings (Msc)*.

Javkhedkar, A. (2006). Applying Lean Construction To Concrete Construction Projects. *A Master'S Project Report*, *December*, 1–40.

Jayaraman, V., Abdelhamid, T. S., & Ilozor, B. D. (2008). Assessment of uncertainty management approaches in construction organizations. *Proceedings of IGLC16: 16th Annual Conference of the International Group for Lean Construction*, 221–229.

Khaleel, T., & Al-Zubaidy, A. (2018). Major factors contributing to the construction waste generation in building projects of Iraq. *MATEC Web of Conferences*, *162*, 1–6. https://doi.org/10.1051/matecconf/201816202034

Khalid, F. (n.d.). *Validity & reliability*.

Kharade, A. V. (2019). *Lean Construction between theory and practice : A case study of the Irish Construction Industry*. *August*, 1–83.

Knotten, V., Lædre, O., & Hansen, G. K. (2017). *Building design management – key success factors*. *2007*(June). https://doi.org/10.1080/17452007.2017.1345718

Koohestani, K., Poshdar, M., & Gonzalez, V. A. (2020a). Finding the way to success in implementing lean construction in an unfavourable context. *IGLC 28 - 28th Annual Conference of the International Group for Lean Construction 2020*, 373–384. https://doi.org/10.24928/2020/0038

Koohestani, K., Poshdar, M., & Gonzalez, V. A. (2020b). Finding the way to success in implementing lean construction in an unfavourable context. *IGLC 28 - 28th Annual Conference of the International Group for Lean Construction 2020*, 373–384. https://doi.org/10.24928/2020/0038

Koskela, L. (2004). *Making-do the eighth category of waste*. 10. https://www.researchgate.net/publication/44389510_Making_do_-_the_eighth_category_of_waste

Lau, H. H., Whyte, A. A., & Law, P. L. (2008). Composition and characteristics of construction waste generated by residential housing project. *International Journal of Environmental Research*, *2*(3), 261–268.

Le Gratiet, G. C. (2017). *Implementation of lean construction tools on an on-going project : A case study on a tower project*. 79. https://projekter.aau.dk/projekter/files/260119027/Rapport.pdf

Lee, S. (2016). Application of AHP and Fuzzy AHP to Decision-Making Problems in Construction. *52nd ASC Annual International Conference Proceedings , 2004*.

Maske, N. B., & Valunjkar, S. (2020). Lean Construction Tool – A Literature Review.

International Research Journal of Engineering and Technology, *7*(10), 143–145.

Mengistu, D. G., & Mahesh, G. (2020). Challenges in developing the Ethiopian construction industry. *African Journal of Science, Technology, Innovation and Development*, *12*(4), 373–384. https://doi.org/10.1080/20421338.2019.1654252

Meshref, A. N., Elkasaby, E. A. A., & Ibrahim, A. (2022). Selecting Key Drivers for a Successful Lean Construction Implementation Using Simos' and WSM: The Case of Egypt. *Buildings*, *12*(5), 673. https://doi.org/10.3390/buildings12050673

Mhaske, M., Darade, M., Khare, P., Student, M. E., Scot, D. Y. P., Prof, A., Engineering, C., & Scot, D. Y. P. (2017). Construction waste minimization. *International Research Journal of Engineering and Technology(IRJET)*, *4*(7), 934–937. https://irjet.net/archives/V4/i7/IRJET-V4I7219.pdf

Milano, P. D. I. (2019). *Traditional and Lean Construction Management :*

Mohajan, H. K. (2017). Two Criteria for Good Measurements in Research: Validity and Reliability. *Annals of Spiru Haret University. Economic Series*, *17*(4), 59–82. https://doi.org/10.26458/1746

Mohamed, A. H. (2016). *Lean Construction as an innovative approach for minimising risks in Mega-Construction projects in the Kingdom of Saudi Arabia by A thesis submitted in partial fulfilment of the requirements for at the University of Salford*. *August*.

Mohammed Fadhil Dulaimi, & caroline Tanamas. (2001). The Principles and Applications of Lean Construction in Singapore. *Proceedings of the 9th International Group for Lean Construction ConferenceSingapore, March*, 1–14.

Mohd Arif, M., Nor Azmi, A. B., & Aini, J. (2019). The Effectiveness of Lean Construction Tools in the Malaysian Construction Industry Towards Contractor's Environmental Performance. *MATEC Web of Conferences*, *266*, 01022. https://doi.org/10.1051/matecconf/201926601022

Movaghar, E. M. (2016). *Identifying the Barriers of Implementing Lean Construction*. *September*. http://www.scopus.com/inward/record.url?eid=2-s2.0-69949090096&partnerID=tZOtx3y1

Nagapan, S., Abdul Rahman, I., & Asmi, A. (2012). Factors Contributing to Physical and Non-Physical Waste Generation in Construction Industry. *International Journal of Advances in Applied Sciences*, *1*(1). https://doi.org/10.11591/ijaas.v1i1.476

Nagapan, S., Rahman, I. A., & Asmi, A. (2011). *Factors Contributing to Physical and*

Non-Physical Waste Generation in Factors Contributing to Physical and Non-Physical Waste Generation in Construction Industry. *December*. https://doi.org/10.11591/ijaas.v1i1.476

Nekouimehr, E. (2020). *Ehsan Nekouimehr Master ' s thesis Assessment of maturity level of applying lean construction tools in construction industry*. *June*.

Nwaki, W., Eze, E., & Awodele, I. (2021). Major Barriers Assessment of Lean Construction Application in Construction Projects Delivery. *CSID Journal of Infrastructure Development*, *4*(1), 63. https://doi.org/10.32783/csid-jid.v4i1.206

Oguntona, O. A., Aigbavboa, C. O., & Mulongo, G. N. (2019). An assessment of lean construction practices in the construction industry. In *Advances in Intelligent Systems and Computing* (Vol. 788, Issue Lc). Springer International Publishing. https://doi.org/10.1007/978-3-319-94199-8_51

Oke, A., Akinradewo, O., Aigbavboa, C., & Ndalamba, M. (2019). Challenges to the implementation of lean construction practices in the South African construction industry. In *International Conference on Construction in the 21st Century* (Issue January). Springer International Publishing. https://doi.org/10.1007/978-3-319-94199-8

Ong, J., & Sui Pheng, L. (2021). *Lean Construction Implementation*. 45–74. https://doi.org/10.1007/978-981-15-8799-3_4

Oyedolapo, O. (2014). Implementation of the Lean Approach in Sustainable Construction : A Conceptual Framework, Lancashire, Central. *PhD. Thesis, April*, pp441.

Patel, J. P. and A. (2019). Effect of Physical Treatment on the Physicochemical, Rheological and Functional Properties of Yam Meal of the Cultivar "Ngumvu" From Dioscorea Alata L. of Congo. *International Journal of Recent Scientific Research*, *10*, 30693–30695. https://doi.org/10.24327/IJRSR

Polat, G., & Ballard, G. (2004). Waste in Turkish Construction: Need for Lean Construction Techniques. *Proceedings of the 12th Annual Conference of the International Group for Lean Construction*, 3–5.

Raaj, R., & Kumar, P. (2019a). An Analysis of Lean Construction Practices in Tamilnadu Construction Industry. *International Journal of Engineering Research & Technology (IJERT)*, *8*(05), 800–808. https://doi.org/10.15680/IJIRSET.2016.0509117

Raaj, R., & Kumar, P. (2019b). An Analysis of Lean Construction Practices in Tamilnadu Construction Industry. *International Journal of Engineering Research & Technology*

(IJERT), *8*(05), 800–808. https://www.ijert.org/research/an-analysis-of-lean-construction-practices-in-tamil-nadu-construction-industry-IJERTV8IS050569.pdf

Raghavan, N., Kalidindi, S., Mahalingam, A., Varghese, K., & Ayesha, A. (2014). Implementing lean concepts on indian construction sites: Organisational aspects and lessons learned. *22nd Annual Conference of the International Group for Lean Construction: Understanding and Improving Project Based Production, IGLC 2014*, 1181–1190.

Ramaru, P. (2017). *Assessment of Lean Concepts in the South African*. *0002*(August).

Rani, H. A. (2017). *Impact Factor (JCC): 2.9987 THE IMPACT OF CONSTRUCTION WASTE TO THE ENVIRONMENTAL ON PROJECT DEVELOPMENT IN ACEH*. *5*(04), 1–8. www.bestjournals.in

Ravikumar, M. M., Marimuthu, K., & Zubar, H. A. (2014). Application of AHP for lean implementation analysis in 6 MSMEs. *International Journal of Engineering and Technology*, *6*(2), 592–596.

Reinbold, A. (2017). *Benefits of Lean Construction for Affordable Housing Master thesis*. 92.

Roopa, S. (2012). *Questionnaire Designing for a Survey 1*. *46*(December), 273–277.

Saaty. (2002). *The Analytic Hierarchy Process (AHP) and the Analytic Network Process (ANP) for Decision Making Decision Making involves setting priorities and the AHP / ANP is the methodology for doing*. 1–109. https://www.stat.uchicago.edu/~lekheng/meetings/mathofranking/slides/saaty.pdf

Sakhare, V. D., & Patil, G. S. (2019). *Construction Equipment Monitoring : By Using Relative Important Indices (Rii) Analysis*. 261–263.

Salem, O., Solomon, J., Genaidy, A., & Luegring, M. (2005). Site implementation and assessment of lean construction techniques. *Lean Construction Journal*, *2*(2), 1–21.

Salem, O., Solomon, J., Genaidy, A., & Minkarah, I. (2006). Lean Construction: From Theory to Implementation. *Journal of Management in Engineering*, *22*(4), 168–175. https://doi.org/10.1061/(asce)0742-597x(2006)22:4(168)

Salunkhe, A. A. (2018). General overview of Lean Management in Construction Industry. *International Research Journal of Engineering and Technology*, *5*(7), 1999–2004. %0Awww.irjet.net

Sarhan, J. G. (2000). *a Pplication F Ramework for D Evelopment*. *160*, 160–167.

Sarhan, S, & Fox, a. (2013). Barriers to Implementing Lean Construction in the UK

Construction Industry. *The Built & Human Environment Review*, *6*, 1–17. http://www.tbher.org/index.php/tbher/article/view/81

Sarhan, Saad. (2015). *A Strategy for Overcoming Barriers to the Successful Implementation of Lean Construction in the UK A Strategy for Overcoming Barriers to the Successful Implementation of Lean Construction in the UK A dissertation submitted by School of Engineering*. *October 2011*. https://doi.org/10.13140/RG.2.1.2142.8640

Sariyildiz, S., & Veer, P. Van Der. (n.d.). *The role of ICT as a partner in Architectural Design Education*.

Sathe, S., & Allampallewar, S. B. (2017). *Application of Six Sigma in Construction*. 21839–21845. https://doi.org/10.15680/IJIRSET.2017.0611131

Sayed, A. Y. Al, Seth, D., & Hamouda, A. M. S. (2019). Prioritisation of lean construction barriers in Qatari context: A fuzzy AHP approach. *International Journal of Business Excellence*, *19*(4), 503–531. https://doi.org/10.1504/IJBEX.2019.103456

Shah, R. K., Al Shereiqi, K., & Borthwick, F. (2021a). A Study of Challenges and Benefits of Lean Construction (LC) Principles in Omani Construction Industry. *Journal of Construction Research*, *2*(2), 16–29. https://doi.org/10.30564/jcr.v2i2.2760

Shah, R. K., Al Shereiqi, K., & Borthwick, F. (2021b). A Study of Challenges and Benefits of Lean Construction (LC) Principles in Omani Construction Industry. *Journal of Construction Research*, *2*(2). https://doi.org/10.30564/jcr.v2i2.2760

Shaik Md Sami Pasha, B. H. N. (2019). An Analysis of Lean Construction Practices in Tamilnadu Construction Industry. *International Journal of Engineering Research & Technology (IJERT)*, *8*(05), 800–808. https://doi.org/10.15680/IJIRSET.2016.0509117

Shankari, R. S., Ambika, D., & Kavithra, S. S. (2017). A Review On Waste Material Minimization In Construction Industry. *International Research Journal of Engineering and Technology(IRJET)*, *4*(1). https://irjet.net/archives/V4/i1/IRJET-V4I1235.pdf

Shaqour, E. N. (2022a). The impact of adopting lean construction in Egypt : Level of knowledge , application , and benefits. *Ain Shams Engineering Journal*, *13*(2), 101551. https://doi.org/10.1016/j.asej.2021.07.005

Shaqour, E. N. (2022b). The impact of adopting lean construction in Egypt: Level of knowledge, application, and benefits. *Ain Shams Engineering Journal*, *13*(2), 101551.

https://doi.org/10.1016/j.asej.2021.07.005

Shlu, A. (2017). *minimizing wasteby lean thinking*.

Silva, N., Carlos, L., & Brito, B. De. (2021). *BARRIERS TO IMPLEMENTING LEAN CONSTRUCTION PRACTICES IN*. *11*, 48386–48392.

Singh, S., & Kumar, K. (2021). A study of lean construction and visual management tools through cluster analysis. *Ain Shams Engineering Journal*, *12*(1), 1153–1162. https://doi.org/10.1016/j.asej.2020.04.019

Taherdoost, H. (2017). *Decision Making Using the Analytic Hierarchy Process (AHP); A Step by Step Approach*. *2*, 244–246.

Teka, F. (2018). *A STUDY ON THE MANAGEMENT PRACTICE AND MINIMIZATION OF WASTE ON*.

Thakkar, H., & Shah, V. A. (2021). Barriers To Implementation of Lean Construction Techniques in Gujarat Construction Industry. *International Journal of Engineering Technologies and Management Research*, *8*(4), 17–24. https://doi.org/10.29121/ijetmr.v8.i4.2021.905

Verma, A., Angalekar, S. S., & Khandare, M. (2017). Ijesrt International Journal of Engineering Sciences & Research Technology Application of Lean Construction Tool (L.P.S) To Improve Labour Productivity At Construction Site. © *International Journal of Engineering Sciences & Research Technology*, *287*(6), 287–301. http://www.ijesrt.com

Vikram, A., & Rajput, S. S. (2018). Application of Lean Construction Principles in Affordable Housing in India : a Review. *Journal of Emerging Technologies and Innovative Research*, *5*(12), 508–513.

Vimal Kumar, U., & Ramasamy, G. (2016). A critical study of various lean techniques in practice and developing a framework for different construction building projects. *International Journal of Chemical Sciences*, *14*, 175–187.

Wandahl, S. (2014). Lean Construction with or without Lean - Challenges of implementing Lean construction. *22nd Annual Conference of the International Group for Lean Construction: Understanding and Improving Project Based Production, IGLC 2014, January 2014*, 97–108.

Watfa, M., & Sawalha, M. (2021). Critical Success Factors for Lean Construction: An Empirical Study in the UAE. *Lean Construction Journal*, *2021*, 1–17. www.leanconstructionjournal.orgWatfawww.leanconstructionjournal.org

Wellman, J. L. (2011). Improving Project Performance. *Improving Project Performance*. https://doi.org/10.1007/978-1-137-51237-6

Wong, L. S., & Ahmed, M. E. A. M. (2018). A critical review of lean construction for cost reduction in complex projects. *Jordan Journal of Civil Engineering*, *12*(4), 707–720.

Yahya, M. A., & Mohamad, M. I. (2009). The significance of lean principles to achieve rapid construction. *National Postgraduate Conference on Engineering and Science*, 643–653.

Yunus, R., Noor, S. R. M., Abdullah, A. H., Nagapan, S., Hamid, A. R. A., Tajudin, S. A. A., & Jusof, S. R. M. (2017). Critical Success Factors for Lean Thinking in the Application of Industrialised Building System (IBS). *IOP Conference Series: Materials Science and Engineering*, *226*(1). https://doi.org/10.1088/1757-899X/226/1/012045

Zohrabi, M. (2013). Mixed method research: Instruments, validity, reliability and reporting findings. *Theory and Practice in Language Studies*, *3*(2), 254–262. https://doi.org/10.4304/tpls.3.2.254-262

APPENDICES

Appendix-1; Questionnaire

Hawassa University

Institute of Technology

Faculty of Civil Engineering and Built Environment

Dear respondent I am working on masters of Science degree in civil engineering (specialization on Construction Technology and Management) at Hawassa University, school of graduate studies. The questionnaire prepared to obtain necessary data to **"Assessment of lean construction practice in Ethiopian; the case of sidama region**''. Your response is highly valuable and contributory to the outcome of the research. Therefore you are kindly requested to fill this questionnaire. All the information gathered will be kept strictly confidential and will be used only for academic research and analysis without mentioning the names of individuals companies involved. I would like to extend my gratitude for taking your precious time to respond to this questionnaire. If you have any inquiry please contact through the following addresses;

Name; Muluken fikadu

MSc. Student at Hawassa University, faculty of civil engineering and built environment

Phone- 0953997095

Email- mulefikadu951@gmail.com

NB; Lean construction is a production management-based project delivery system emphasizing the reliable and speedy delivery of value. The goal is to build the project while maximizing value, minimizing waste, and to achieve perfection.

Instructions: This research is conducted for academic purposes, so please try to fill it carefully and truthfully. For each of the questions, please **tick [□]** in the provided box which you believe is the most suitable answer using the given scale.

SECTION 1; GENERAL INFORMATION

1. Name of organization (optional)_____
2. Grade of company_____
3. Current project site location_____
4. Your working company

   Contractor □ Consultant □

5. Your current Position

Project manager □ Site engineer □ Forman □

Site supervisor □ Office engineer □

If other specify_____

6. Your Educational status

PhD □ MSc □

BSc □ Diploma □

If other specify_____

7. Your educational background

   Civil engineering □

   CoTM □

   If other specify_____

8. Your Work experience in construction industry

< 1 year □ 1-5 years □ 6-10 years □

11-15 years □ >16 years □

SECTION A: Implementation of Lean Construction Tools & Principles

This portion of questionnaire explores the implementation of lean construction in sidama region construction projects. Please **indicate [×] your answe**r using the following likert scale;1=Never; 2=Almost never ; 3 = Sometimes; 4 =Always; 5=Always

9. To what extent do you **implement** the following lean tools and principles?

Lean principles & tools	1=Never	2=Almost never	3=Sometimes	4=Almost always	5=Always
Lean principles	1	2	3	4	5
Identify customer value	1	2	3	4	5
Map the value stream	1	2	3	4	5
Create smooth flow in process	1	2	3	4	5
Allowing customer(client) to pull	1	2	3	4	5
Pursue perfection(continuous improvement)	1	2	3	4	5
Lean tools function	1	2	3	4	5
Daily site meeting	1	2	3	4	5
Using Prefabricated/precast elements	1	2	3	4	5
Execute different tasks parallel in your project	1	2	3	4	5
ordering of resources when they are only needed in your project	1	2	3	4	5
Keep the project site, material & equipment clean, tidy & orderly	1	2	3	4	5
Having safety & warning signs in required areas at project site	1	2	3	4	5
Constantly investigate potential safety & quality improvement practice	1	2	3	4	5
Having master, phase & weekly work plan for your project	1	2	3	4	5
Redesign critical assignment including productivity studies in your project	1	2	3	4	5
Exchange information on cards to purchase material, to control inventory & construction process	1	2	3	4	5
Examine the needs of the client in your project using facts, data & statistical analysis in organized way for improvement	1	2	3	4	5
Evaluate the construction process in terms of time required, resource used & resultant quality for continuous improvement	1	2	3	4	5

SECTION B; Benefits of implementing lean construction (LC) in the construction industry

This portion of questionnaire explores the benefits of implementing lean construction (LC) in sidama region construction industry. Please **indicate [×] your answe**r using the following likert scale; .1 = strongly disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = strongly agree

10. To what extent do you agree that the following are the benefits of implementing LC?

Benefits of implementing lean construction	1=strongly disagree	2=Disagree	3=Neutral	4=Agree	5=strongly agree
Crating a smooth work flow	1	2	3	4	5
makes the projects easier to manage	1	2	3	4	5
Fewer defect and rework	1	2	3	4	5
increase productivity,	1	2	3	4	5
improve prediction of risk	1	2	3	4	5
will increase profit	1	2	3	4	5
Reducing waste and production cost	1	2	3	4	5
preventing pollution and emissions	1	2	3	4	5
improve the quality of the environment	1	2	3	4	5
minimization of conflicts	1	2	3	4	5
improving client satisfaction	1	2	3	4	5
lower levels of inventory	1	2	3	4	5
Pursue perfection by continuous improvement	1	2	3	4	5
Construction site safety control improvement	1	2	3	4	5
improved employee morale and involvement	1	2	3	4	5
Better quality of work	1	2	3	4	5
eliminates all non-value adding steps,	1	2	3	4	5
Minimize double handling and movement of equipment and workers,	1	2	3	4	5
Improves process transparency and communication	1	2	3	4	5
Reduce project time	1	2	3	4	5

SECTION C; BARRIERS TO THE ADOPTION OF LEAN CONCEPTS

This section of the questionnaire assesses the barriers to the adoption of lean concepts for construction projects. Please indicate your answer using the following AHP scales pairwise comparison. Please **indicate [□□] your answer**.

11. To what extent do you agree the following are barriers to implement lean construction?

Code	Criteria	9=Extremely important	7=Very strongly	5=Strongly important	3=Moderately	1=Equally important	3=Moderately	5=Strongly important	7=Very strongly	9=Extremely important	Criteria
3.1 Management related barriers											
Lack of top management support and commitment	9	7	5	3	1	3	5	7	9		Lack of time to implement
Lack of top management support and commitment	9	7	5	3	1	3	5	7	9		Lack of transparency
Lack of top management support and commitment	9	7	5	3	1	3	5	7	9		Influence of traditional management practice
Lack of time to implement	9	7	5	3	1	3	5	7	9		Lack of transparency
Lack of time to implement	9	7	5	3	1	3	5	7	9		Influence of traditional management practice
Lack of transparency	9	7	5	3	1	3	5	7	9		Influence of traditional management practice
3.2 Awareness and educational related barriers											
Lack adequate lean awareness & knowledge	9	7	5	3	1	3	5	7	9		Misconception about lean
Lack adequate lean awareness & knowledge	9	7	5	3	1	3	5	7	9		Lack of collaboration between academicians & construction industry
Lack adequate lean awareness	9	7	5	3	1	3	5	7	9		Low educational background of

& knowledge										labors
Misconception about lean	9	7	5	3	1	3	5	7	9	Lack of collaboration between academicians & construction industry
Misconception about lean	9	7	5	3	1	3	5	7	9	Low educational background of labors
Lack of collaboration between academicians & construction industry	9	7	5	3	1	3	5	7	9	Low educational background of labors
3.3 Financial related barriers										
High implementation cost	9	7	5	3	1	3	5	7	9	Absence of incentives and motivation
High implementation cost	9	7	5	3	1	3	5	7	9	Unstable market condition and inflation
High implementation cost	9	7	5	3	1	3	5	7	9	Corruption
Absence of incentives and motivation	9	7	5	3	1	3	5	7	9	Unstable market condition and inflation
Absence of incentives and motivation	9	7	5	3	1	3	5	7	9	Corruption
Unstable market condition and inflation	9	7	5	3	1	3	5	7	9	Corruption
3.4 Cultural and human attitude related barriers										
Resistance to change the existing work culture	9	7	5	3	1	3	5	7	9	Fear of blame and unfamiliar practice for implementing
Resistance to change the existing work culture	9	7	5	3	1	3	5	7	9	Lack of employee cooperation
Resistance to change the	9	7	5	3	1	3	5	7	9	Waste accepted as unavoidable

existing work culture										
Resistance to change the existing work culture	9	7	5	3	1	3	5	7	9	Poor housekeeping
Fear of blame and unfamiliar practice for implementing										Lack of employee cooperation
Fear of blame and unfamiliar practice for implementing										Waste accepted as unavoidable
Fear of blame and unfamiliar practice for implementing										Poor housekeeping
Lack of employee cooperation										Waste accepted as unavoidable
Lack of employee cooperation										Poor housekeeping
Waste accepted as unavoidable										Poor housekeeping
3.5 Technical related barriers										
Fragmentation and subcontracting nature of the industry	9	7	5	3	1	3	5	7	9	Incomplete and inaccurate designs
Fragmentation and subcontracting nature of the industry	9	7	5	3	1	3	5	7	9	Limited of using prefabricated structures
Fragmentation and subcontracting nature of the industry	9	7	5	3	1	3	5	7	9	Lack of technical skills about lean
Incomplete and inaccurate designs	9	7	5	3	1	3	5	7	9	Limited of using prefabricated structures
Incomplete and inaccurate designs	9	7	5	3	1	3	5	7	9	Lack of technical skills about lean

Limited of using prefabricated structures	9	7	5	3	1	3	5	7	9	Lack of technical skills about lean
3.6 Government related barriers										
Lack of government policies to encourage the use of lean	9	7	5	3	1	3	5	7	9	Government bureaucracy and instability
Lack of government policies to encourage the use of lean	9	7	5	3	1	3	5	7	9	Enforcement of laws on waste management
Government bureaucracy and instability	9	7	5	3	1	3	5	7	9	Enforcement of laws on waste management
3.7 Resource related barriers										
Lack or inadequate resource	9	7	5	3	1	3	5	7	9	Lack of long term relationship with supplier
Lack or inadequate resource	9	7	5	3	1	3	5	7	9	Inefficiency in resource planning
Lack of long term relationship with supplier	9	7	5	3	1	3	5	7	9	Inefficiency in resource planning

SECTION D: CRITICAL SUCCESS FACTORS (STRATEGIES) TO IMPROVING LEAN IMPLEMENTATION IN CONSTRUCTION INDUSTRY

This section of the questionnaire explores the critical success factors of improving lean implementation in construction industry. Please indicate **[×]** your answer using AHP scale pairwise comparison.

12.To what extent do you agree the following are critical success factors to implement lean?

Criteria	**9=Extremely important factor**	**7=Very strongly important factor**	**5=Strongly important factor**	**3=Moderately important factor**	**1=Equally important factor**	**3=Moderately important factor**	**5=Strongly important factor**	**7=Very strongly important factor**	**9=Extremely important factor**	Criteria
4.1 Management & leadership factors										
Management commitment and involvement	9	7	5	3	1	3	5	7	9	Strategy planning
Management commitment and involvement	9	7	5	3	1	3	5	7	9	Creating awareness
Management commitment and involvement	9	7	5	3	1	3	5	7	9	Training and education
Strategy planning	9	7	5	3	1	3	5	7	9	Creating awareness
Strategy planning	9	7	5	3	1	3	5	7	9	Training and education
Creating awareness	9	7	5	3	1	3	5	7	9	Training and education
4.2 Workforce and resource factors										
Employee morale and motivation	9	7	5	3	1	3	5	7	9	Existence of clear roles in lean
Employee morale and motivation	9	7	5	3	1	3	5	7	9	Availability of resource for lean

Employee morale and motivation	9	7	5	3	1	3	5	7	9	Good supplier & customer relationship
Employee morale and motivation	9	7	5	3	1	3	5	7	9	Technology adoption & infrastructure
Existence of clear roles in lean	9	7	5	3	1	3	5	7	9	Availability of resource for lean
Existence of clear roles in lean	9	7	5	3	1	3	5	7	9	Good supplier & customer relationship
Existence of clear roles in lean	9	7	5	3	1	3	5	7	9	Technology adoption & infrastructure
Availability of resource for lean	9	7	5	3	1	3	5	7	9	Good supplier & customer relationship
Availability of resource for lean	9	7	5	3	1	3	5	7	9	Technology adoption & infrastructure
Good supplier & customer relationship	9	7	5	3	1	3	5	7	9	Technology adoption & infrastructure
4.3 Technical factors										
Understanding of technical requirement in lean	9	7	5	3	1	3	5	7	9	Technical capacity for lean implementation
Understanding of technical requirement in lean	9	7	5	3	1	3	5	7	9	Availability of lean tools and techniques
Availability of lean tools and techniques	9	7	5	3	1	3	5	7	9	Technical capacity for lean implementation
4.4 Cultural and governmental factors										
Changing organizational culture	9	7	5	3	1	3	5	7	9	Adoption of continuous improvement
Changing organizational culture	9	7	5	3	1	3	5	7	9	Adopting lean culture

Changing organizational culture	9	7	5	3	1	3	5	7	9	Supportive nature of governmental regulation
Adoption of continuous improvement	9	7	5	3	1	3	5	7	9	Adopting lean culture
Adoption of continuous improvement	9	7	5	3	1	3	5	7	9	Supportive nature of governmental regulation
Adopting lean culture	9	7	5	3	1	3	5	7	9	Supportive nature of governmental regulation

Appedix-2; Interview questions

1. What techniques do you used to minimize waste and wasteful activities in the site
2. What are Benefits of applying lean tools
3. What are the Obstacles to improve construction projects in-terms of safety, material management, site arrangement and planning
4. What are strategies to use new construction management techniques
5. Do have quality audit culture? How it looks like?
6. What are the effects of subcontracting and incomplete design in-terms of waste minimization?
7. What is the Influence of traditional management style to implement new management methods?

Checklist for Case Study

Name of project……..

Project location……

Lean tools	Yes	No
1. Last planner system		
➢ having master, phase and weekly work plan		
2. 5S (sort, set in order, shine, standardize, sustain)		
➢ Arrange materials and equipment properly		
➢ Clean equipment used during construction		
3. Just in time		
➢ Avoiding excess inventory in construction site		
➢ Ordering materials only when they are needed		
4. Concurrent engineering		
➢ Execute different activities in parallel		
5. Fail safe for quality		
➢ Check the quality of work and safety of environment in every moment		
6. Visual management		
➢ Placing safety and notice sign boards in construction site		
7. Daily site meeting		