An Evaluation on Factors Affecting Construction Labor Productivity and their Management Solutions in Adama, Ethiopia.

Lewam Kinfe Gebreyesus

A Thesis Submitted to the Department of Civil Engineering School of Civil Engineering and Architecture in Partial Fulfillment of the Requirement for the Degree of Master's in Construction Engineering and Management.

Office of Graduate Studies

Adama Science and Technology University

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DECLARATION

I hereby declare that this MSc Thesis entitled "**An Evaluation on Factors Affecting Construction Labor Productivity and their Management Solutions in Adama, Ethiopia.**" is my original work and has not been presented for a degree in any other university. All sources of material used for this thesis have been duly acknowledged through citation.

Lewam Kinfe Gebreyesus	____________________	____________________
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APPROVAL PAGE OF ADVISOR

I, the advisor of the thesis entitled, "**An Evaluation on Factors Affecting Construction Labor Productivity and their Management Solutions in Adama, Ethiopia.**" and developed Lewam Kinfe Gebreyesus, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, members of the Board of Reviewers of the thesis by Lewam Kinfe Gebreyesus have read and evaluated the thesis entitled "**An Evaluation on Factors Affecting Construction Labor Productivity and their Management Solutions in Adama, Ethiopia.**" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Civil Engineering (Specialization in Construction Engineering and Management).

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
BC	Building Contractor
CLP	Construction Labor Productivity
CQS	Craftsman Questionnaire Sampling
CW	Criteria Weight
DI	Disruption Index
EQ	Equation
FDS	Foreman Delay Survey
FAHP	Fuzzy Analytic Hierarchy Process
FTOPSIS	Fuzzy Technique for the Order of Preference by Similarity to the Ideal Solution
GDP	Gross Domestic Product
GW	Global Weight
LW	Local Weight
MCDM	Multi Criteria Decision Making
PFP	Partial Factor Productivity
PMI	Project Management Index
PPE	Personal Protective Equipment
PR	Performance Ratio
RII	Relative Importance Index
TFN	Triangular Fuzzy Number
TFP	Total Factor Productivity
TOPSIS	Technique for the Order of Preference by Similarity to the Ideal Solution
WHs	Work Hours

ABSTRACT

The construction industry has significant strategic importance to the nation's economic, social, and infrastructure development. Despite many technological advances, the industry continues to be labor-intensive. In most countries, labor represents 30% to 50% of the construction project's overall cost. However, poor construction labor productivity is one of the significant issues in the industry. Moreover, there is a study gap in evaluated solutions to mitigate the shortcomings in the study area. Therefore, the main aim of the current research is to study management practices to overcome factors affecting construction labor productivity in Adama, Ethiopia. Descriptive and explanatory research combined with quantitative research approaches is adopted to address the research objectives. Ongoing multistory building construction projects are the population of this study. Currently there are thirty-four ongoing multistory building construction projects and census samples were used since the population is manageable to be studied entirely in terms of cost and time. The primary data were gathered from the resident engineers, site engineers and project managers through questionnaire and secondary data from past studies. Before and after the data collection, the reliability of questioner and validity of the collected data were checked, respectively. The data analysis is conducted in three phases by Excel. In the first phase, shortage of construction material, old and inefficient equipment, poor site management, lack of safety tools, poor planning and scheduling, incomplete facilities, payment delay, lack of inspiration of workers, delay in decision making, shortage of tools and equipment, poor quality of materials, confined working space, low labor wage, lack of skilled labor and violation of safety precautions are determined the most significant factors affecting construction labor productivity through relative importance index, and Pareto principle. The most significant factors are weighted through the Fuzzy Analytical Hierarchical Process in the second phase. From the final phase, through Fuzzy Technique for the Order of Preference by Similarity to the Ideal Solution, stable organizational structure, coordination between all stakeholders, proper site administration, regular and effective communication, proper project financing, enhancing leadership and decision making of supervisors, short interval plan, project completion plan, effective supervision and quality control and hold regular meetings with labors are determined the most significant management practices to overcome factors affecting construction labor productivity. Finally, it recommends to take construction labor productivity issues into consideration and implement the determined management solutions.

Key words*: Construction Labors, Construction Labor Productivity, Management Practices.*

CHAPTER ONE-INTRODUCTION

1.1 Introduction

Construction productivity is the relationship between the output produced and one or more associated inputs devoted to the production process. CLP is an effective indicator of the efficiency of the industry's activities. Poor CLP has been a serious concern in many countries, wherever most construction work remains manual. It occurs when there is a gap between the baseline productivity and actual average production rates. Several factors contribute to labor productivity loss in construction. This chapter discusses the background of the study, statement of the problem, objectives of the study, research questions, significance of the study, scope and limitation of the study, and organization of the study.

1.2 Background of the Study

The construction industry is an industry with significant strategic importance in any country's economic, social, and infrastructure development. Its productivity level significantly affects a nation's economic growth and contributes to Gross Domestic Product (GDP) (Mahat et al., 2019). Elazzazy (2020) argued that the construction industry constitutes approximately 10% of the national income of developed countries. However, its economic contribution is more significant in developing countries than the developed ones. Major construction projects account for 10% of GDP and approximately 50% of the fixed wealth invested in developing countries. The construction industry's development in these countries lags far behind other sectors compared to developed countries (Elazzazy, 2020).

A study by Cheng & Darsa (2021) stated that the construction industry in Ethiopia is booming. It is one of the largest sources of employment in the country, with millions of Ethiopians engaged in full and part-time jobs in the construction industry. Accordingly, the construction industry's contribution to the GDP of Ethiopia has increased considerably, from 9% in 2015/2016 to 18% in 2017/2018. Currently, numerous projects are under construction, and the government has allocated billions of dollars to the sector.

Labor is an essential asset to the construction industry since construction projects are designed, assembled, installed, constructed, tested, and commissioned by of professionals including engineers, trade workers, and general laborers, in the context of changing weather, socio-economic, and legal conditions (Zhao & Dungan, 2018). In most countries, labor costs range from 30% to 50% of the total construction project cost, implying that labor productivity is critical to the efficiency and success of construction operations (Gunduz & Abu-Hijleh, 2020). Despite major technological developments, construction remains a labor-intensive business (Ghate & Minde, 2016). Similarly, Hemalatha & Priyanth (2018) stated that most construction work is done manually with limited help from equipment in developing countries.

Construction productivity and labor productivity are two essential terms influencing the construction firm's profit and loss. Elazzazy (2020) defined construction productivity as the relationship between the output produced and one or more associated inputs devoted to the production process. According to Agrawal & Halder (2020), labor productivity measures how efficiently a system utilizes its human resources to produce output from input. Researchers argue that construction productivity mainly depends upon labor effort and performance. For instance, Rao et al. (2015) stated that construction productivity strongly depends on labor productivity. It is one of the most critical aspects of every construction company's performance and market competitiveness and a key to long-term growth (Singh & Rana, 2020).

To overcome the CLP barriers, one must identify and recognize the primary factors causing them (Johari & Jha, 2020). Determining various factors that impact labor productivity is crucial in forming a strategy to help construction companies reduce costs and time delays, thus improving overall project performance (Sebastian & Raghavan, 2015). After that, it is required to implement various labor productivity improvement strategies to reduce the level of influencing labor productivity factors and consequently improve productivity (Kazerooni et al., 2021). Overcoming these labor productivity factors provides high productivity and improvement in the construction industry's performance. According to Dey et al. (2017), the advantages of maximization of labor productivity in construction include increased output rate, reduction of overall cost, maintaining the planned production rate, and maintaining high-quality standards.

1.3 Statement of the Problem

Construction industry is facing many challenges and one of the most significant is low productivity (Hamza et al., 2019). Productivity, or lack thereof, is one of the construction industry’s most prevalent problems (Palop & Piqueras, 2016). Moreover, poor worker performance is a recurring issue in the construction sector worldwide, according to Johari & Jha (2020). Similarly, Abdel-H & Mohamed (2020) indicated that poor labor productivity has been a serious concern in many countries, wherever most construction work remains manual. It occurs when there is a gap between the baseline productivity and actual average production rates. It is always one of the causes of cost and time overruns in construction projects. Abdel-H & Mohamed (2020) revealed that the project loss cost and time due to poor labor productivity is 19% for each activity in Egypt.

In Ethiopia, the construction industry is also suffering from low labor productivity. As per the study by Ashebir et al. (2020), poor labor productivity adversely affects the success of organizations engaged in the Ethiopian construction industry. Similarly, Yadeta (2019) revealed that CLP is one of the significant risks among the top risks of construction projects in the Ethiopian construction industry. Consequently, construction projects are not often delivered on time and within budget, and reworking is required to satisfy customers' needs (Mengistu et al., 2016). As per studies by Mengistu et al. (2016) and Ashebir et al. (2020), delays in decision making, material shortages, payment delays, changing orders, poor labor experience, equipment shortages, site accidents, lack of inspiration to the work, and shortage of periodic meetings with labor are common top factors impacting CLP in Ethiopia.

As Ashebir et al. (2020) indicated, there should be a measured effort by the management or participants to have effective improvement strategies in labor productivity, and every shortcoming should be analyzed and corrected for the success of construction projects. Although a large number of management strategies have been proposed to improve productivity, the effectiveness of these strategies is not evaluated based on their actual contributions. As a result, the construction authorities and industry practitioners cannot find and implement the most effective management strategies (Hwang et al., 2020). Therefore, this study evaluates factors affecting CLP and its management solutions.

1.4 Objectives of the Study

1.4.1 General Objective

The main objective of this research is to evaluate the factors affecting construction labor productivity and their management solutions in Adama, Ethiopia.

1.4.2 Specific Objectives

The specific objectives of this study are to:

- Explore the determinant factors affecting CLP
- Prioritize the significant factors affecting CLP.
- Determine management practices that have the potential to overcome significant factors affecting CLP.
- Develop a framework to overcome factors affecting CLP.

1.5 Research Questions

The following questions raised and addressed in this study,

- Which factors are affecting CLP most significantly?
- What are the priorities of the significant factors affecting CLP?
- Which management practices should be implemented to overcome significant factors affecting CLP?
- What is the suitable means to overcome factors affecting CLP?

1.6 Significance of the Study

Since labor is a major driving force in any construction project and shares the high cost, efficient labor productivity is a significant criterion in ensuring project success. Furthermore, efficient production is essential for ensuring project success (Abdul et al., 2019). Therefore, this study focused on the determinant factors affecting CLP and management practices to overcome the factors affecting CLP.

The determined factors affecting CLP will help individuals or groups responsible for successfully completing construction projects have a better and deeper understanding of the current factors affecting CLP. As Mengistu et al. (2016) indicated, knowing the affecting factors is a way to determine the required resources to execute the project's activities in conformity with the specifications contracted time of the project. Moreover, determining various factors that impact labor productivity is crucial to form a strategy to help construction companies reduce costs and time delays, thus improving overall project performance.

The management practices revealed in this study will help stakeholders make decisions to maximize labor resource utilization and increase construction project productivity. Increased labor productivity will bring higher financial returns to the construction company and more satisfied customers. It determines the means for better labor productivity. It will assist industry experts in decision-making to address CLP problems. Overall, the findings study will contribute to forming policies and strategies for a better CLP. Furthermore, it will be helpful for future researchers to measure the productivity rate before and after the implementation of effective management practices.

1.7 Scope of the Study

The study attempted to determine factors affecting CLP and mitigation solutions for better CLP. The overall scope of the research is presented in the sub-sections below. It includes the thematic, spatial, and temporal scope of the study separately.

1.7.1 Thematic Scope

This research focused on labor productivity in the construction industry. It explores the determinant factors affecting CLP, prioritizes the significant factors affecting CLP, determines management practices that have the potential to overcome significant factors affecting CLP and finally, develops a framework to overcome factors affecting CLP. In this research, the actual productivity rate difference before and after implementing effective management practices is not measured due to time and cost constraints.

1.7.2 Spatial Scope

This study is conducted in Adama city, Ethiopia. It is carried out on active building construction projects in the city to reveal various negative factors affecting the CLP and solutions to mitigate the barriers.

1.7.3 Temporal Scope

Labors who execute construction activities, including trade workers and general labors, are the main focus of this study. Therefore, collecting the data from the relevant respondents and decision makers for primary data took two months, from the beginning of March 2022 till the end of April 2022. Similarly, for secondary data, it took a month, May 2022.

1.8 Limitation of the Study

In this research, the actual productivity rate difference before and after management practice implementation is not measured due to time and cost constraints. Therefore, time and cost are the study's main limitations. It recommended that future researchers to measure the effectiveness of the best management solutions on the actual productivity rate before and after their implementation.

1.9 Organization of the Study

The research is organized into five main chapters. The first chapter is an introduction, and it covers basic research information. Chapter two reviews the literature on the title and related topics. The third chapter illustrates the methodology used in the research. The analysis of the findings and discussion based on those results are presented in the fourth chapter. The last chapter consists of the conclusions and recommendations.

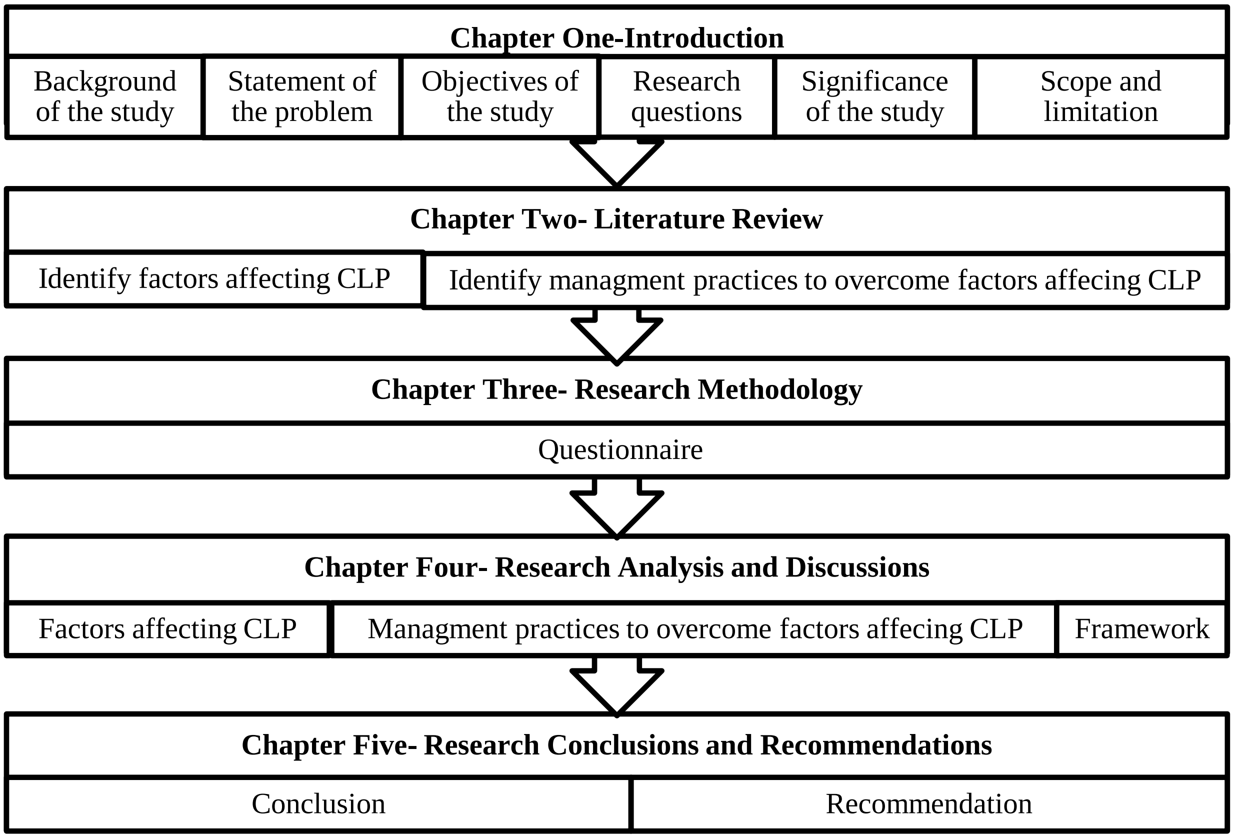

Figure 1.1 Organization of the Research

CHAPTER TWO - LITERATURE REVIEW

2.1 Introduction

Construction projects are complicated and dynamic processes involving numerous custom-crafted components and systems. These are designed and engineered, assembled, installed, constructed, tested, and commissioned by a consortium of professionals, including engineers, trade workers, and general laborers, in changing weather, socio-economic, and legal conditions. Labors can be defined as individuals or groups of people involved in a construction project to carry out the work according to their expertise and skills and are assigned to work based on the plans of the project owner.

Labor productivity remains one of the essential means to assess the overall performance of construction projects since it is a fundamental input to achieving the highest level of productivity. Furthermore, it is the determinant of the efficiency of construction resources, where labor productivity is the most significant factor that affects the overall performance of the porn work of any organization. Therefore, this chapter reviews the literature on the subject, such as the construction labors, CLP and its measurement, factors affecting it, and management practices to mitigate CLP barriers.

2.2 Construction Labor Productivity and Measurement

2.2.1 Construction Labor

Labors are individuals or groups of people involved in a construction project to carry out the work based on their expertise and skills and are assigned to work based on the plans of the project owner (Nurhendi et al., 2019). Labor is a fundamental input to any construction project to achieve the highest level of productivity. In building construction, various construction workers are involved, directly and indirectly. Palop & Piqueras (2016) identified workers involved in all construction projects. Table 2.1 shows the workers who participate in building construction projects in different activities.

Table 2.1 Main construction trades descriptions (Source :Palop & Piqueras (2016))

No.	Trade Name	General Definition
1	Bar Bender and Fixer	To cut, bend and fix reinforcement steel bars according to drawings and bending schedules.
2	Concrete and Grouting Worker	To mix, place, and compact concrete using vibrating machines; to carry out curing, leveling, and smoothening of concrete.
3	Leveler	To read and interpret drawings; set up job lines and levels and prepare templates.
4	Scaffolder	To erect and dismantle bamboo scaffolding required in construction, repair or decoration work, and other forms of structures.
5	Construction Goods Vehicle Driver	To drive vehicles to transport construction materials, building debris, or excavated materials within, into, or out of construction sites.
6	Cement Sand Mortar Worker	To mix cement and sand to create mortar and place it in different structures; to carry out curing, leveling, and smoothening.
7	Metal-steel Worker	To fit, assemble, weld, and forge metal and steel parts; to install non-structural metalwork; to operate metal-working machines. To cut or join structural steel sections, steel water mains and steel gas mains by an electric arc, oxyacetylene flame, or other welding processes.
8	Curtain Wall and Glass Panes Installer	To measure, cut, and fix glass panes with silicone plastic or beads; to grind or round edges of glass panes.
9	Painter and Decorator	To prepare surfaces, fittings and fixtures of buildings and other structures for painting and decorating.
10	Welder	Specializes in fusing materials together. The materials to be joined can be metals (such as steel, aluminum, brass, stainless steel, etc.) or varieties of plastic or polymer.
11	Marble Worker	To set out, measure, cut, and set marble slabs, granite slabs, or similar stones on walls, floors, or other surfaces; to grind and polish marble, granite, or similar stones.
12	Window Frame Installer	To combine and install windows frames of different materials.
13	Prestressing Operative	To introduce internal stresses into (as a structural beam) to counteract the stresses that will result from the applied load (as in incorporating cables under tension in concrete).
14	Floor Layer	To prepare or fit the floor base and sometimes install the coverings.

No.	Trade Name	General Definition
15	Rigger / Metal Formwork Erector	To set up lifting apparatus and equipment for lifting and lowering of materials; to fix and dismantle large panel metal formwork.
16	Construction Plant Mechanic	To fit, assemble, erect, install, maintain and repair mechanical plants and equipment, including emergency generators.
17	Electrical Fitter	To fit, assemble, install, test, commission, maintain.
18	Electronic Equipment Mechanic	Electronics technicians help design, develop, test, manufacture, install, and repair electrical and electronic equipment. They may be employed in product evaluation and testing, using measuring and diagnostic devices to adjust, test, and repair equipment.
19	Refrigeration Ventilation Mechanic	To research electrical and mechanical engineering problems related to refrigeration/air-conditioning/ventilation systems.
20	Fire Service Mechanic	To perform technical tasks, either independently or under the direction of a qualified engineer, contributory to design, development, manufacture, installation, operation, maintenance and repair of fire services systems, equipment, and fire extinguishers.
21	Lift and Escalator Mechanic	To install, adjust, maintain and repair lifts.
22	Piling Operative Worker	To set up piling rigs for driven or bored piles works, with basic knowledge of method, hand signals, and geology-related to piling.
23	Waterproofing Worker	To protect structural integrity by making the building waterproofed.
24	Gas Installer	To install, commission, maintain and repair domestic and non-domestic gas appliances, gas utilization systems, and gas flow controls and meters connected to gas cylinders or gas supply points.

2.2.2 Productivity

Bamfo et al. (2019) define productivity as the ratio of the quantity of output to that of input. The concept of productivity is closely related to the quality of input, output, and process (Singh & Rana, 2020). Productivity generally measures how efficiently a system uses resources to produce output (Agrawal & Halder, 2020). According to Palop & Piqueras (2016), it can be shown in the form of an equation as follows:

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}} \quad \text{[Eq 2.1]}$$

The concept of productivity is distinguished from profitability, performance, efficiency, and effectiveness. The relationship between performance, profitability, productivity, effectiveness, and efficiency is presented in figure 2.1.

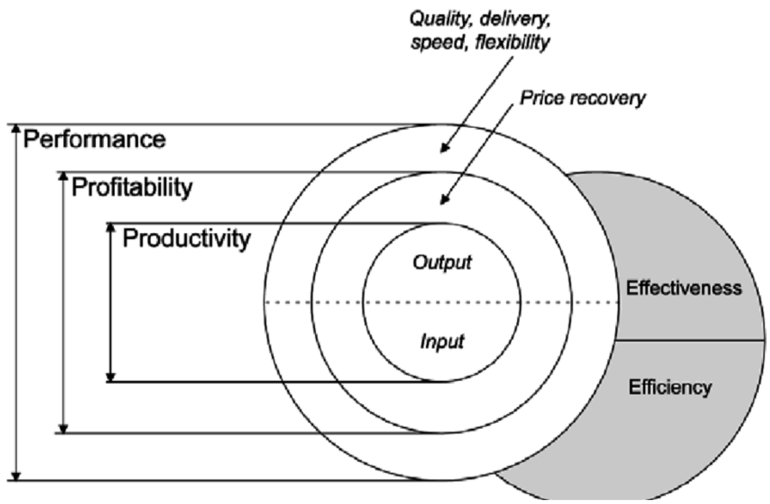

Figure 2.1 Triple-P model (source: Tangen (2005))

Profitability is the overriding goal for the success and growth of any business. It is the ratio between revenue and cost (Bamfo et al., 2019). Since profitability is an outcome or a result and not a participant in the processes like productivity, a result does not affect the operations strongly. However, it can improve the entire process and allow it to perform correctly (Elazzazy, 2020). Bamfo et al. (2019) state that "profitability" includes a productivity component. Profitability is strongly influenced by the prices a company spends on its input and receives for its output. While productivity is a more precise idea relating to the output-to-input ratio, performance is a term that encompasses nearly any objective of competition and manufacturing excellence, such as cost, flexibility, speed, dependability, and quality (Bamfo et al., 2019).

Tangen (2005) defined efficiency as the minimum resource level theoretically required to run the desired operations in a given system compared to how many resources are utilized. The same author also defined effectiveness as the ability to attain the desired objective or the degree to which desired results are achieved. According to Bamfo et al. (2019), the combination of high values of both efficiency and effectiveness in the transformation process leads to increased productivity. Thus, it is conceivable for an efficient system to be ineffective, and it is also possible for an effective system to be inefficient.

2.2.3 Construction Labor Productivity, CLP

There is no consensus about the exact definition of productivity for construction labor (Agrawal & Halder, 2020). It has been defined in many ways. For instance, Bamfo A. et al. (2019) expressed productivity as the ratio of output quantity to input. According to Zhao & Dungan (2018), productivity is the ratio between work effort, labor hours, and the measure of completed work. Elazzazy (2020) defined productivity as a measure of how efficiently a system uses its resources to produce output from input.

According to Rao et al. (2015), labor productivity is a subdomain of overall construction productivity. Therefore, construction productivity is significantly dependent on labor productivity, as construction is a labor-intensive industry. Therefore, CLP is one of the most critical factors affecting the construction industry's overall performance. Hemalatha & Priyanth (2018) stated that CLP is an effective indicator of the efficiency of the industry's activities.

2.2.4 Construction Labor Productivity Measurement

CLP measurement is very crucial for the success of construction projects. It determines the required resources to execute the activities of the projects and the required duration, which conforms with the specifications of the contracted time of the project. Once labor productivity is measured, the effect of any factor or combination of factors can be assessed by comparing labor productivity values before and after the factor was in place (Rojas, 2008). Accordingly, it allows contractors to start looking for the root causes of the problem and increases the chances of improving performance by implementing corrective actions early on. Moreover, a new managerial approach's impact on productivity can be determined by measuring labor productivity before and after the new approach is implemented.

To determine the appropriate output measurement method, the selection criteria set by Song & AbduRizk (2008) include three criteria. The first criterion is the high correlation with the labor hours and must be quantifiable. Secondly, the measurement should be independent of productivity-influencing factors, such as site conditions and labor skills. Finally, the measurement should be easy to track and cost effective to implement.

Different measures of productivity serve different purposes. Palop & Piqueras (2016) note that there is no single, industry-wide measurement technique for work measurement in construction, various measuring applications are available, each with its definition of productivity. In addition, the measurement is difficult because of the industry's heterogeneity of inputs and outputs and the need to measure input and output service quality (Palop & Piqueras, 2016). Similarly, productivity in the construction industry can be measured at different levels for different purposes. Ayele & Fayek (2019), construction productivity measurement can be computed at activity, project, and industry levels.

The intent of measuring labor productivity at the company level is to determine the overall performance of a contracting organization (Rojas, 2008). Activity level productivity measures are the most commonly used in the construction industry. It measures individual construction activities' performance, such as concrete placing, steel erection, etc. (Ayele & Fayek, 2019). Accordingly, project-level productivity measures consider the performance related to a collection of activities required to construct a particular facility. However, its measurement is much more complicated because it deals with multiple tasks that constitute a single project. It is tough to unify all construction activities' inputs and outputs (Elazzazy, 2020). Industry-level productivity measures the amount of output produced per unit of input; it provides a measure of industrial efficiency. Industry-level productivity measures represent an overall assessment of the state of productivity in the industry sector (Ayele & Fayek, 2019).

Construction workers' activities on construction sites can be classified into three groups: Productive, Contributory, and Unproductive. Sebastian & Raghavan (2015) defined and categorized the activities. Productive or direct six category related to the construction process that alters the output, such as mason laying dick, labor mixing materials, electrician pulling wire, and welder welding pipe. Contributory/support works are activities that indirectly impact the output but are commonly needed in operation, including tradespeople getting material, traveling to work locations, and taking instructions under contributory work. Unproductive work is idle or doing activities unrelated to the job, including personal breaks, waiting for equipment to be fixed, waiting for more instructions, late starts, or early departure.

Singh & Rana (2020) pointed out that individuals often perform labor productivity estimates using analytical techniques and personal judgment. The work hour estimates are usually obtained through direct interaction with a scheduler, site manager, or related subcontractors who are knowledgeable enough to reflect a project's actual conditions and constituent activities. As per Zhao & Dungan (2018), contractors often rely on proprietary or commercially available data and their previous performance on other projects, with appropriate adjustments to consider project-specific factors to determine the associated hours for the quantity of work performed.

2.2.4.1 Construction Labor Productivity Measurement Tools and Interpreting Techniques

Standard techniques for productivity measurement and obtaining information about workers' time spent on productive, contributory, and non-productive activities include direct observation, time study, activity sampling, field rating, five-minute rating, Forman delay survey, craftsman questionnaire sampling, and recording methods.

I. Direct Observation

Direct observation is one of the continuous observation methods. As per Chavan & Salunkhe (2016), researchers observe workers' activities throughout the workday and identify tool time and non-tool time activities. The authors declared this method to be tedious and time-wasting. Nevertheless, the data collected is accurate and precise, and the collection of length and pattern of time of each work task is among the benefits of direct observation. The drawbacks are that the observer can manage only a maximum of five workers in a crew (Chavan & Salunkhe, 2016).

II. Time Study

A time study technique is not simply the timing of an operation but a process designed to develop a standard time or output for any construction operation, regardless of the observed rate (Chavan & Salunkhe, 2016). Accordingly, time study involves timing to discover how long operations are taking, rating to assess the worker being observed against a norm, and building up time standards by allowing for appropriate relaxation and contingency allowances. In addition, as per Rojas (2008), time studies are used to collect information about the duration of the different tasks that make up a construction operation or process.

These studies are task-based rather than worker-based. Data-gathering forms are prepared to collect the information, and they will be specific for each construction operation or process (Rojas, 2008). As per Kisi (2015), the main advantage of time studies is that they are very cost-effective and easy to use. They require a stopwatch and an interval timer that can record a specified sequence of events. However, the major drawback is that it can be helpful only if the activity involves a few workers or machines (Kisi, 2015).

III. Activity Sampling

Chavan & Salunkhe (2016) defined activity sampling as any measurement technique for which observations are non-continuous. The observations represent a sampling of the total activity. Similarly, Bamfo et al. (2019) defined it as a technique in which numerous instantaneous observations are made throughout workers, machines, or processes. This technique is applied by undertaking many instantaneous observations concerning labor, equipment, and activities at a particular time. Each observation records the events that occurred at that moment. Hence, the percentage of observations carried out for a specific activity or a delay is considered a measurement of the percentage time for activity or delay (Elazzazy, 2020). There are three primary methods for activity sampling: productivity ratings/work sampling, field ratings, and five-minute ratings (Rojas, 2008).

A. Productivity Ratings/Work Sampling

Work sampling is also known as ratio survey, observation ratio, snap reading method, and random observation method. Statistical sampling theory is applied because the amount of time spent collecting data has to be limited. Therefore, the primary aim work sampling is to observe an operation for a limited time and, from the observations, infer how productive the operation is. Classify the worker's activity as, productive (direct work), semi-productive or supportive (preparatory work, tools, and equipment, material handling), or non-productive (waiting, traveling, and personal). Accordingly, to adopt this approach, first develop a data collection form that will facilitate calculating the observations on site.

Then, take random observations of workers involved in a given operation in the field. The observation should indicate the workers' activity mode, i.e., productive, non-productive, or semi-productive. In doing so, record all observations on the form by entering a checkmark under the appropriate mode of activity observed. Finally, add all the checkmarks under each mode and calculate the percentage of each activity. The productive work category should typically be over 30%.

$$\text{Percentage Productive} = \frac{\text{Total observations}}{\text{observations marked as productive}} * 100\% \qquad \text{[Eq. 2.2]}$$

$$\text{Percentage Semi} - \text{productive} = \frac{\text{Total observations}}{\text{observations marked as semi}-\text{productive}} * 100\% \qquad \text{[Eq. 2.3]}$$

$$\text{Percentage Unproductive} = \frac{\text{Total observations}}{\text{observations marked as unproductive}} * 100\% \qquad \text{[Eq. 2.4]}$$

For work sampling to be adequate, the observer must make many observations, a number determined from statistical sampling theory, a number derived from a sampling error of 5%, and a level of confidence of 95%. Where, N is the sample size, Z is the number of standard deviations defining the confidence intervals, P is the estimated probability of observing a worker doing a particular activity, and L is the accuracy limit.

$$N = \frac{\mathrm{Z2}*\mathrm{P}*(1-\mathrm{P})}{L2} \qquad \text{[Eq. 2.5]}$$

The benefits of the work sampling technique stated by Oglesby et al. (1989) cited by Kisi (2015) include simplicity of the procedure, no special equipment is required to conduct the study, results are available quickly, less exact but often helpful, preliminary results can be reported soon after the start of the study, and it is a relatively inexpensive and valuable technique for studying non-repetitive, noncyclical activities in which complete methods and frequency descriptions are not easy to quantify. The drawbacks of work sampling technique include: not being economical for studying a single worker or machine, not being well-suited for sampling short-cycle jobs, and the difficulty of obtaining data that provides sufficient indicators about individual differences, accordingly.

B. Field Rating

Field rating roughly estimates a construction operation's activity level. It categorizes the observed worker as working or nonworking and uses the "working" fraction to measure effectiveness. To collect a random sample, an observer on site watches the workers. Once the sample is collected, the field rating will be calculated as the total observations in the working category divided by the total number of observations, plus 10% to account for foreman and supervisory activity. The number should be roughly over 60% for a job to be satisfactory.

$$\text{Field rating} = \frac{\text{Total observations of working}}{\text{Total number of observations}} + 10\% \qquad \text{[Eq. 2.6]}$$

A field rating system is a straightforward and quick rating system in which samples are selected randomly, and estimation efficiency is based on the total number of observations (Kisi, 2015). However, the main drawback of field rating system is that there is no correct way to categorize the multitude of activities for productivity rating purposes (Oglesby et al. (1989), cited in Kisi (2015)). The method does not tell the analyzer anything about the sources of problems or inefficiencies.

C. Five-Minute Rating

The five-minute rating technique is not based on statistical sampling theory. It relies on simply observing an operation for a short time. The observation does not result in a large enough sample to support work sampling. It is not considered as statistically valid as field or productivity ratings. This technique is seen more as a shortcut to determine if further evaluation of a particular construction operation is required (Rojas, 2008). The procedure used to implement the 5-minute rating technique starts with identifying the crew members to be observed and structuring a form, with the crew noted in the column headings and time of observation listed in the rows of the first column.

Observe the crews as they are working. For the observation interval, determine whether the crew member has been active for over half the interval. If so, mark the observation cell with an "x"; if not, leave the cell empty. Then add the "x" observations for the table and divide the sum by the total number of observations.

$$\text{Effectiveness } = \frac{\text{Observed effective}}{\text{Total observations}} * 100\% \qquad \text{[Eq. 2.7]}$$

According to (Kisi, 2015). The advantage of this technique is that, since the workers will not know whether they are being watched, they will not react to the observer's presence The method provides some insight into the crew's effectiveness and can identify areas where more observation is required.

IV. Forman Delay Survey

The Foreman Delay Survey (FDS) relies on a questionnaire to be filled out by the foreman at the end of a working day according to a particular survey schedule. The objective of this technique is to identify the reasons for delays and the extent of them. In a delayed survey, foremen are asked to report any delays more significant than a specified time experienced during the day (Chavan & Salunkhe, 2016). FDS starts with a questionnaire distributed to the foreman to be filled out. Once the form has been filled out, the information is extracted in percentages, and action is taken to ensure that sources of delays are appropriately dealt with. After that, the survey results are converted from total person-hours lost into equivalent percentages and reported on a form. Finally, the information on the report sheet will identify concerns that the foremen have with the operation.

FDS measures only losses due to delay and rework and does not facilitate other parameter measurements helpful in determining the efficiency of activities (Kisi, 2015). However, it is a relatively low-cost method for analyzing the sources of delays during construction and is easily stylized and implemented.

V. Craftsman Questionnaire Sampling

Craftsman Questionnaire Sampling (CQS) is a questionnaire-oriented technique attempting to address issues and concerns related to a craftsman's productivity and motivation. CQS provides information regarding the sources of delays in the amount of rework performed and creates a participatory atmosphere on-site (Chavan & Salunkhe, 2016). Accordingly, in performing CQS, the administrator of CQS walks around the field and randomly selects craftsmen to answer the questionnaires.

Because of the random selection and the determination of the activities, the craftsmen are involved in the immediate post. After craftsmen and foremen fill out the questionnaires, the administrator repeats the cycle until he gets an adequate sample size (Chavan & Salunkhe, 2016). Once the questionnaires have been collected, the results are compiled, and the statistics are reported to all concerned.

VI. Photography and Video Studies

Photographic studies use a camera or video camera to capture time-lapse pictures of a construction operation. Time-lapse refers to taking still pictures at selected intervals (Rojas, 2008). Accordingly, the interval can vary from 1 to 10 seconds. However, intervals of 1,4 and greater than 4 seconds are usually used to keep track of hand movements, study the overall body or equipment movements and refer to the operation's proceeding ratings, respectively. Generally, time-lapse photography takes single pictures at intervals of one, two, three, or four seconds for extended periods (Chavan & Salunkhe, 2016). Video studies refer to using a video camera to capture real-time video of a construction operation. Digital video cameras and video processing software can allow real-time video to be recorded and time-lapse pictures from the same event to be extracted (Rojas, 2008).

2.2.4.2 Construction Labor Productivity Approaches

Several productivity measures are commonly used. Choosing between them usually depends on the purpose of the productivity measurement and data availability (Rao et al., 2015). Chavan & Salunkhe (2016) identified two types of productivity measurements: partial factor productivity and total factor productivity.

I. Total/Multifactor Productivity (TFP)

Total factor productivity considers outputs and all inputs and measures the output of a group of inputs, or total inputs used. According to Shoar & Banaitis (2019), this measure has a direct relation with total output and a reverse relation with the summation of inputs. Input resources often include labor, equipment, materials, energy, and capital.

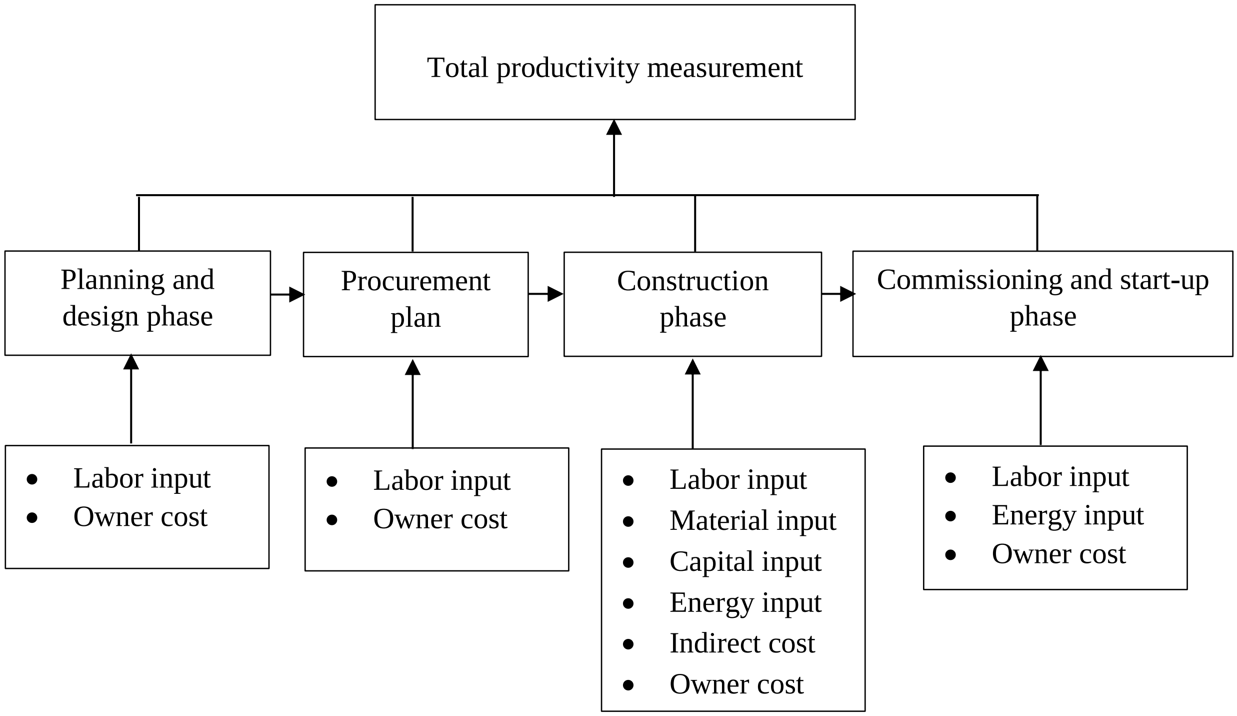

Figure 2.2 Total productivity measurement framework (source: Ayele & Fayek (2019))

Figure 2.2 shows that the consideration of input quantification for total productivity measurement starts at the planning and design stage. In addition, the other expense input is further grouped into construction project indirect and owner costs (Ayele & Fayek, 2019). Of the most frequently used TFP measures, capital-labor TFP relies on a value-added output concept. In contrast, the capital-labor energy-materials TFP relies on a particular measure of gross output.

As per Jarkas & Horner (2015), the drawbacks of total factor productivity measures include difficulties in accurately determining and measuring all the input resources used to achieve the output and impracticality, especially for researchers to monitor or assess the impacts of selected individual output factors. In other words, it has limited diagnostic value.

$$\text{TPF} = \frac{\text{Total output}}{\sum(\text{labor+capital+equipment+material+energy})} \qquad \text{[Eq. 2.8]}$$

II. Single/ Partial Factor Productivity (PFP)

Single/ Partial factor productivity is where outputs and single or selected inputs are considered. It is the output ratio to one class of input (Chavan & Salunkhe, 2016). This measure relates directly to the outputs and reverses the relation with a single or selected set of inputs. The complex nature of the construction process and the interaction of its activities make partial factor productivity measurement a popular option since effective control systems monitor each input separately (Jarkas & Horner, 2015).

$$\text{Capital productivity} = \frac{\text{Installed quantity(output)}}{\text{capital input}} \qquad \text{[Eq. 2.9]}$$

$$\text{Equipment productivity} = \frac{\text{Installed quantity(output)}}{\text{Equipment hours (input)}} \qquad \text{[Eq. 2.10]}$$

$$\text{Labor productivity} = \frac{\text{Installed quantity(output)}}{\text{Labor work hours (input)}} \qquad \text{[Eq. 2.11]}$$

PFP measures are most commonly used to measure labor productivity in construction. It is defined as the ratio of labor output to input; the output depends on the installed quantities, and labor input depends on labor work hours (Shoar & Banaitis, 2019).

$$\text{Average labor productivity} = \frac{\text{output}}{\text{labor employed}} \qquad \text{[Eq. 2.12]}$$

$$\text{Formwork labor productivity} = \frac{\text{Output quantity (m2)}}{\text{Man−hour (mh)}} \qquad \text{[Eq. 2.13]}$$

$$\text{Rebar installation labor productivity} = \frac{\text{Output quantity (Kg)}}{\text{Man−hour (mh)}} \qquad \text{[Eq. 2.14]}$$

$$\text{Concreteing labor productivity} = \frac{\text{Output quantity (m3)}}{\text{Man−hour (mh)}} \qquad \text{[Eq. 2.15]}$$

Kharmale & Arjita (2015) defined benchmarking as an analytical and systematic tool extensively deployed to measure, compare and eventually increase the construction industry's productivity level in a different project, corporate, and activity levels. Benchmarking examines the best-in-class performance for a specific activity, project, or industry (Thomas, 2015). The following definitions and equations are elements of the benchmarking labor productivity mentioned by Kharmale & Arjita (2015) and Thomas (2015).

Total work hours are the sum of daily working hours in each project. While, the sum of the quantities of completed activities daily in each project is total quantities. The cumulative productivity measures the inclusive effort necessary to install the work, calculated as:

$$\text{Cumulative productivity } (\text{m}^2/\text{hr}) = \frac{\text{Total quantities completed } (\text{m}^2)}{\text{Total work hrs (hrs)}} \qquad \text{[Eq. 2.16]}$$

Baseline productivity: the highest performance rate a contractor can achieve for a specific design under certain circumstances. Calculating the baseline productivity starts by selecting *n* reporting periods with the highest production (quantities). *n* is 10% of the total reporting periods, but not less than 5%. Then organize a baseline subset that contains n rows where the output is highest. The baseline subset contains the work hours and quantities for each n reporting period identified in the first step. Finally, Sum the work hours and quantities in the baseline subset and, using (Eq.2.16), compute the productivity by dividing the baseline subset quantities into the baseline subset work hours.

An abnormal workday is defined as any workday where the daily productivity statistic value is below LCL; thus, abnormal workdays refer to days with significantly below average/cumulative productivity. Similarly, Disruption index (DI) measures the variability within a single project. It measures the extent to which the project experienced abnormal workdays. DI is calculated by using eq 2.17

$$\text{DI} = \frac{\text{Number of abnormal (Disrupted) workdays}}{\text{Total number of workdays}} \qquad \text{[Eq. 2.17]}$$

Performance ratio (PR) is calculated by dividing the actual cumulative productivity by the baseline productivity. Project management index (PMI) is a parameter (dimensionless) that reflects the project management contribution to the cumulative labor performance of the project.

$$\text{PR} = \frac{\text{Cumulative productivity (W}-\text{hr/unit)}}{\text{Expected baseline productivity (W}-\text{hr/unit)}} \qquad \text{[Eq. 2.18]}$$

$$\text{PMI} = \frac{\text{Baseline productivity (W}-\text{hr/unit)}-\text{Cumulative productivity (W}-\text{hr/unit)}}{\text{Expected baseline productivity (W}-\text{hr/unit)}} \qquad \text{[Eq. 2.19]}$$

According to Sebastian & Raghavan (2015), variability in productivity is a determinant of the performance of a construction project. well-performing projects exhibit lower variability when compared to projects that perform poorly. High variability of productivity is a strong indicator of poor labor performance. When evaluating more than a few projects, a numerical measure of variability is probably necessary.

$$\text{Variation} = \frac{\Sigma\sqrt{(\text{Actual Productivity} - \text{baseline productivity})\wedge 2}}{\text{n}} \qquad \text{[Eq. 2.20]}$$

$$\text{Coefficient of Variation} = \frac{\text{Variation} * 100}{\text{Baseline productivity}} \qquad \text{[Eq. 2.21]}$$

2.3 CLP Improvement

Hemalatha & Priyanth (2018) described productivity improvement as the art of doing the right things for better worth and making it a part of a continuous process in construction. According to Kharmale & Arjita (2015), enhancing the labor productivity of construction activities is advantageous for the economy of any country at micro and macro levels because the higher level of productivity facilitates utilizing the available resources more efficiently. It also assists the industry in enhancing overall performance and, in so doing, improves the contribution to the growth of the national economy (Ghodrati et al., 2018).

The presence of human resources with high productivity at each stage of a project plays a significant role in the project's success. Any improvement in labor productivity increases the output rate, reduces overall cost, maintains the planned production rate, and maintains high-quality standards (Dey et al., 2017). Similarly, Singh & Rana (2020) noted that improved productivity reduces the unit cost of projects and gives the overall best performance of projects. Construction companies may gain an advantage over their competitors by improving productivity to build projects at lower costs. Furthermore, overcoming barriers and improvement leads to significant profits for the industry and its clients (Ghodrati et al., 2018). However, numerous factors affect labor productivity, and the identification and evaluation of factors impacting CLP used to prepare a strategy to reduce inefficiencies and improve the effectiveness of project performance (Chavan & Salunkhe, 2016).

Similarly, Durdyev et al. (2018) noted that addressing the factors influencing labor productivity is crucial for improving the productivity performance of the construction sector.

CLP barriers can be mitigated by implementing different management practices, management is the application of knowledge, skills, tools, and techniques to project activities to meet project requirements. It is accomplished through processes using project management knowledge, skills, tools, and techniques that receive input and generate output. (Project Management Institute, 2013). Accordingly, project management is accomplished through the appropriate application and integration of logically grouped project management processes, categorized into five process groups. These five process groups are initiating, planning, executing, monitoring and controlling, and closing.

Previous research determined the impacts of different management practices on improving labor productivity. Ghodrati et al. (2018) studied the effectiveness of various management strategies. They revealed that construction projects with high implementation levels of the investigated management strategies have better labor productivity than those with low-level implementation. A study by Shan et al. (2016) on the effectiveness of management practice in improving CLP revealed that CLP positively correlates to implementing the various management programs on the sampled construction projects.

2.4 Factors Affecting CLP

Numerous factors affect labor productivity. According to Agrawal & Halder (2020), some factors are external, such as inclement weather and political unrest. Some might be internal to the worker, including the worker's ability in a team, personal mindset, and dedication to work. The same study stated that some factors could be controlled or improved by providing sufficient training to the workers on using tools and machinery. Some might be out of control, like rain and high wind. Some factors are objective, such as crew size, which has a numerical measure. In contrast, other factors are subjective, such as the complexity of the task, which does not have a well-defined measurement (Ebrahimi et al., 2021). The following table shows different factors negatively affecting CLP in different countries.

Table 2.2 Factors affecting CLP in different countries.

Country	**Source**	**Top factors affecting productivity CLP**
Jordan	Ghanim (2016)	Poor planning and scheduling, material shortage of project site, equipment shortage, lack of skilled labor, poor site management, rework due to construction error, old and inefficient equipment, lack of supervisors' experience, payment delay to the suppliers causing the stoppage of material delivery to site, slow response of consultant's staff attending inspection work.
Iran	Shoar & Banaitis (2019)	Improper project financing, unrealistic schedule, inflation in the cost of execution, rework, extreme weather conditions, lack of training, lack of equipment.
Pakistan	Irfan et al. (2020)	Shortage of skilled labor, payment delay by the owner to contractor, unrealistic scheduling and expectation of labors performance, clarity of technical specification, and delay in wages payment to labors.
Qatar	Gunduz & Abu-Hijleh (2020)	Poor labor supervision, delays in payments, poor work environment, low skilled labor, and bad weather conditions.
India	Dixit et al. (2019)	Contractual disputes, scope clarity of the project, design capability and frequent, design changes, rework.
Vietnam	Hai & Nguyen (2019)	Worker's experience, labor discipline; pay forms, quality of construction materials, ability to organize production, quality of tools and tools, organization of construction supervision.
Malaysia	Durdyev et al. (2018)	Inadequate supply or high cost of resources: workers, materials, machinery, and money, level of skill and experience of the workforce, level of motivation/commitment of the workforce, supervision, performance monitoring and control, competencies of the project manager, unrealistic deadline for project completion set by the client.
Egypt	Montaser et al. (2018)	Lack of materials and lack of inventory at the project site by purchasing department procurement department, lack of skilled and specialized labor, high prices of materials continuously, slow delivery and abstract work, lack of coordination between consultants (public and private), slow adoption of both graphics and materials, poor supervision of operations, traffic equipment.

Country	Source	Top factors affecting productivity CLP
Libya	Almamlook et al. (2020)	Lack of labor supervision, experience and skill of labor, construction technology, coordination among design disciplines, errors in design drawings, delay in responding to requests for information, rework, lack of incentive scheme, working overtime and lack of leadership.
Nigeria	Adagba et al. (2021)	Conflict with project stakeholders, the skill of labor, financial crisis, government policies, cultural conditions and customs of the community at the project site, amount of variation/change of orders during execution, shortage of experienced labor, level of co-ordination among design disciplines, compatibility and consistency among contract document.
Ethiopia	Eba (2019)	Increase of material price/fluctuation/, effect of bad weather (rain, wind, high/low), absence of safety training & program, lack of safety tools and accidents during construction, lack of motivation, and shortage of materials
	Ashebir et al. (2020)	Delays in decision making, material shortages, payment delays, changing orders by the client/consultant, poor labor experience, equipment shortages, site accidents, lack of inspiration to the work, poor workmanship, and shortage of periodic meetings with labor.

Factors affecting CLP can be categorized into eight major categories: management related factors, technical related factors, financial related factors, labor related factors, material related factors, equipment and tools related factors, safety and health related factors and project environment and external related factors.

2.4.1 Management Related Factors

The management related factors affecting CLP include poor control and supervision, poor planning and scheduling, poor site management, delay in decision making, inspection delay, lack of providing incentives, lack of training to labor, crew size and composition, misunderstanding between labor and superintendent, delay in responding to information, lack of periodic meetings with labors, contractual dispute, insufficient coordination among parties, lack of supervisors' experience and unclear instruction to labors.

Agarwal et al. (2016) mentioned that labor supervision involves a supervisor, foreman, and the boss of a group of laborers or workers. The main task of any manager is to plan, direct and control. Any management problems reduce the output of laborers. A study by Mengistu et al. (2016) stated that labor productivity increases with an increasing number of man-hours per day in which the field supervisor would contact the crews. The same study revealed that proper monitoring and supervision of laborers while working is vital to any organization because both can extend project time and cost.

The term "sequence of work" is crucial for completing the project on time. Therefore, management at different levels concerns with scheduling and planning. Unrealistic schedules are mainly determined by the skills and experience of the management team in planning and scheduling (Shoar & Banait, 2019). Mengistu et al. (2016) revealed that the compression of schedules affects labor productivity by adverse outcomes of lower labor productivity rates and higher project costs. Similarly, Dilawer (2014) indicated that employees working with heavy workloads or target work create a loss in the quality of work and increase the need for reworking. Moreover, Tiredness and speed cause inefficiency and poor quality as a result.

Poor site management is a management related factor affecting CLP (Dey et al., 2017). According to Palop & Piqueras (2016), poor site management was responsible for much time wasted on a job. Various materials are stored in one place to protect them from rain or other problem. The study by Agarwal et al. (2016) suggested that the storage location be very near the working area so that workers could take the materials easily to the construction site.

2.4.2 Technical Related Factors

Technical related factors affecting CLP include incomplete and inaccurate drawing, variation/ change of orders during execution, lack of clarity of technical specifications, rework, lack of compatibility among contract documents, the complexity of the design and project, and improper construction method. Palop & Piqueras (2016) revealed that changes to specifications and drawings/ designer errors and omissions are among the most significant factors affecting CLP since it requires additional time for adjustments of resources to meet the change.

Accordingly, incomplete drawings or drawings contain errors are difficult to find until the construction contractor finds them well after the construction phase has started. Similarly, productivity decline when drawings or specifications are erroneous, ambiguous, unclear, etc. (Rashid, 2015).

As per Mengistu et al. (2016), the low quality of completed portions of the construction project causes redoing of work. It impacts the production rate and decreases the output of the laborers. Therefore, work redone was one of the worst issues leading to poor productivity. It was found that the amount of time spent on rework was between 4.9–7.7 man-hours per week, while laborers spent an average of 14.3% of their time redoing work (Mengistu et al., 2016).

2.4.3 Finance Related Factors

Payment delays, low labor wages, inflation in the cost of execution (high cost of resources: workers, materials, machinery, and money), and improper project financing are finance related factors affecting CLP.

A study by Shoar & Banaitis (2019) stated that improper project financing is one of the leading causes that can directly lead to delayed salary payment and unavailability of materials since payment is essential for supplying the raw materials to complete the work successfully. Agarwal et al. (2016), when the suppliers deliver the materials on time or late, and the project owner is at a loss in any other work, the lack of money on the owner or contractor causes a delay in payment. Due to the result, improper financing reduces CLP.

2.4.4 Labor Related Factors

Lack of skilled and specialized labor, lack of motivation of workers, bad labor characteristics, late arrival, early quit, unscheduled break, misunderstanding among labors, communication barrier, the poor economic condition of workers, increase in laborer’s age, physical fitness of labor, labor absenteeism, physical fatigue and labor personal problems are labor related factors affecting CLP. Aptitude is the potential to demonstrate the ability to perform a certain kind of work at a certain level (Johari & Jha, 2020). The physical aptitude of the workers impacts performance more than mental aptitude, and clerical perception harms performance.

Accordingly, a worker with a higher aptitude delivered better productivity output with higher efficiency and concluded that aptitude is an important performance indicator of any construction worker. Thus, to enhance labor productivity, contractors must ensure the availability of high-aptitude workers on site.

According to Mengistu et al. (2016), motivation is essential since non-motivated employees can negatively affect their work. To solve this issue, friction on the job, substandard output quality, a high turnover of employees, absenteeism, tardiness, and many other disciplinary problems should be avoided (Mengistu et al., 2016).

2.4.5 Material Related Factors

The identified material related factors affecting CLP are the shortage of construction materials, slow adoption of materials, poor quality of construction materials, and the unsuitability of material storage location.

According to many researchers, material shortages are material-related factors affecting CLP. This is because work cannot be done progressively or to the required quality without material (Mengistu et al., 2016). A study by Ghanim (2016) revealed that material shortages significantly impact the productivity of construction activities. Workers often spend their time unproductive work due to unavailability or shortage of the required materials. Similarly, Manoharan (2017) revealed that material shortage is a significant factor affecting CLP.

Manoharan (2017), time spent waiting for material arrival reduces the quantity of work expected during a given man-hour period. Thus, it is affecting the overall productivity of labors in construction work. Similarly, Dilawer (2014) noted that delayed procurement of materials and delivery to the site would create idle man-hours and eventually affect labor productivity.

2.4.6 Equipment and Tools Related Factors

According to previous studies, the equipment and tools-related factors affecting CLP include shortages of tools and equipment, old and inefficient equipment, waiting for equipment to arrive, and poor quality of tools.

Previous studies revealed that a shortage of equipment and tools affects CLP. It is caused by insufficient quantity or quality of tools and equipment to meet the project's needs. For instance, suppose tools or construction equipment are unavailable at the right location and time. In that case, labor productivity suffers as they may be unable to proceed with the work orderly and consistently (Dilawer, 2014). Similarly, Ghanim (2016) and Manoharan (2017) confirmed that the shortage of this item causes major idle time since laborers cannot progress their work as they need the minimum number of equipment to work effectively.

Old and inefficient equipment and the quality of tools affect the productivity of construction labors. According to Ghanim (2016), old equipment usually causes frequent breakdowns due to poor maintenance and lack of regular service. Poorly maintained equipment leads to failures causing the projects to be delayed (Manoharan, 2017).

2.4.7 Safety and Health Related Factors

Site accidents, lack of safety tools (PPE), absence of safety training & program, violation of safety precautions, insufficient lighting, and hazardous work area are safety and health related factors affecting CLP.

The construction safety on the site is a crucial factor in the workers' productivity. Therefore, construction projects must avoid hazardous endeavors that may cause work-related injuries and accidents (Ashebir et al., 2020). Accordingly, Site accidents are one of the top factors affecting labor productivity. In addition, laborer's carelessness, ignorance, negligence, and lack of attention cause an unsafe working environment leading to site accidents; when laborer's are injured, they delay the rest of the gang (Eba, 2019).

2.4.8 Project Environment and External Related Factors

Previous researches revealed a number of project environment and external factors affecting CLP. Project location, confined working space, incomplete facilities, restricted site access, culture or customs of the community, religious and other holidays, extreme weather conditions, government policies and political instability are among project environment and external related factors.

Weather conditions are necessary for properly completing any construction project. Extreme weather conditions have a negative effect on CLP. It generally depends on the country's geography, location, and construction project location (Shoar & Banaitis, 2019). Psychologically, workers tend to become restless and irritable in hot weather (Dey et al., 2017).

A study conducted in China by Li et al. (2016) revealed that high-temperature environments decreases labor productivity, with direct work time reduced by 0.57% and idle time increasing by 0.74% when the temperature increased by one-degree centigrade. Furthermore, the percentage of direct work time increased by 0.33% when the workers experienced high temperature increased by one year and decreased by 0.72% when the worker’s age increased by one year (Li et al., 2016). The overall result of the study shows that high-temperature environments impose heat stress on the human body and decrease labor productivity in the construction industry.

According to Rashid (2015), if a work site is remote, CLP suffers because labor, equipment, and materials may not be on-site when and as needed to support efficient prosecution of the work. In addition, CLP losses may occur when access to the work area is delayed or late. The contractor is required to do more work in a shorter period, resulting in overmanning, dilution of supervision, and lack of coordination of the trades.

2.5 Management Practices to Overcome Factors Affecting CLP

Previous research determined the effectiveness of various management strategies. They revealed that construction projects with high implementation levels of the investigated management strategies have better labor productivity than those with low-level implementation. For instance, Patkure & Kulkarni (2018) conducted a comparative study before and after implementing solutions to improve CLP management practices. After the implementation of solutions, it was observed that labor productivity increased, and it was found that labor productivity for site 1 increased by 83.82% and for site 2 by 88%.

Management practices to overcome CLP affecting factors are categorized into preconstruction, construction method and site, human resources, construction materials, equipment and tools, safety and health, and stakeholders’ management practices.

2.5.1 Preconstruction Management Practices

Use of software in planning work packages, appointed experienced designer, well-defined scope of work, complete and approval of construction drawing before the commencement of construction, realistic work schedule, collaborative procurement, project start-up plan, project completion plan, short interval plan, and fulfill regulatory requirement are preconstruction management practices to overcome factors affecting CLP and improve CLP.

It should be confirmed that the design for all construction phases is adequate. The schedule should be completed before actual construction begins and relevant phases are mobilized (Nasir, 2013). The scope of work should be clear and well-defined for all project team members. In a study by Gurmu & Aibinu (2018), the well-defined scope of work is one of the most effective management practices for improving labor productivity. Things to consider for properly defining the scope of work include a clear description of the project goals, a clear description of the owner's vision for the facility, the basic requirements of the project, and the timeframe of all the work involved to produce the project's deliverables (Nasir, 2013).

A construction work package is an executable construction deliverable that describes a specific scope of work and should include a budget and schedule that can be compared with actual performance (Nasir, 2013). Preparing manageable construction work packages is one factor that positively influences labor productivity (Gurmu & Aibinu, 2018).

2.5.2 Construction Method and Site Management Practices

For better CLP, there is a real need to assemble the knowledge of good site construction management practices in one place and add new practices as the need arises (Thomas & Ellis, 2017). A study by Ghodrati et al. (2018) suggested that project managers can improve CP in their projects by using a suitable construction method that is in synergy with the available technology, material, and equipment. Proper site administration, providing necessary site facilities, proper construction site layout, dynamic site layout plan, site security plan, traffic control plan, and adoption of advanced technologies are construction methods and site management practices to overcome CLP factors.

Poor site management could result from poor labor management, poor communication between laborers and managers, poor communication between construction parties, poor material management, lack of site manager experience, and lack of labor experience (Ibrahim, 2013). Effective site layout contributes to a safer job, reduced job costs, and reduced double-handling of materials (Thomas & Ellis, 2017).

Advanced construction technology adopted by Ghodrati et al. (2018) includes lean construction, industrialization, prefabrication, modularization, work packaging, and constructability. Additionally, big data, building information modeling, augmented reality, laser scanning, artificial intelligence techniques, off-site manufacture, automation, and productivity indicators are found effective in the study Ghasemi & Chong (2020).

2.5.3 Human Resource Management Practices

Rao et al. (2015) note that construction activities rely only on human resources, so effective use of each activity and proper labor management are crucial. A structured human resource management program should be employed during the construction phases, and good management practice should be maintained for the employees through frequent visits to the work areas, during which the managers should show sincere interest in the workforce and the work to create better relationships and improve labor productivity (Dilawer, 2014). Detailed workforce plan, hiring skilled workers, training of workers, incentive/bones, increase labors wage/salary, timely payment, proper arrangement of labors, clear delegation of responsibility worker’s participation in decision making and skill assessment and evaluation are identified human resource management practices to overcome factors affecting CLP and improve CLP.

It is significant for the construction industry to deploy suitable training programs to leverage workers' skills and safety awareness (Kazerooni et al., 2021). According to Johari & Jha (2020),, the purpose of training workers is to ultimately boost productivity. The trainers must also focus on enhancing their physical abilities to enhance their overall aptitude and improving workers' mental abilities during training because a worker with a higher aptitude delivers better productivity output with higher efficiency (Johari & Jha, 2020).

Dilawer (2014), since construction projects involve many people, all with different personalities, cultures, nationalities, and levels of understanding, communication can be difficult, and misunderstandings can arise. Therefore, formal and informal structure of effective communication is essential in the work area, and with effective communication. Accordingly, it is possible to avoid communication problems by giving guidelines for effective communication of messages, allowing people the freedom to organize some work, and treating people as essential individuals.

Johari & Jha (2020) mentioned that higher motivation keeps workers enthusiastic about their jobs to increase the retention rate of workers at a site. Therefore, the practice of conducting regular motivational activities at a site needs to be adhered to by site personnel. Motivational practices include communication, extrinsic rewards, intrinsic rewards, and positive reinforcement. Gyamfi et al. (2020) researched motivational strategies for improving labor productivity in construction companies. Empowerment, quality of life, and monetary incentive have significant relationships with motivation. Effective use of such techniques could assist construction industry practitioners in enhancing craftsmen's performance (Gyamfi et al., 2020).

2.5.4 Materials Management Practices

Caldas et al. (2015) defined materials management as an integrated process comprising the people, organizations, technology, and procedures used to identify effectively, quantify, acquire, expedite, inspect, transport, receive, store, and preserve materials across the life cycle of a project. As per Gurmu & Ongkowijoyo (2020), implementing suitable construction materials management practices can improve productivity in construction projects. Materials management practices to overcome factors affecting CLP include procurement plans for materials on time, just-in-time materials delivery, proper materials handling systems, long-lead materials identification, materials status database, post receipt preservation and maintenance, and on-site materials tracking.

Materials that require a long-lead time are necessary for critical project activities and affect the design and construction schedule, so it is essential to plan, identify, and track critical and long-lead materials and plan for their timely procurement at the construction site (Nasir, 2013). Also, proper handling of materials is critical in increasing labor productivity.

Procurement plans for materials include guidelines, requirements, or systems for purchasing, expediting, and delivery of materials for the project. Issues to consider are coordinating materials procurement schedule with the construction schedule, facilitating a purchasing system that has the capability of allowing field purchase of consumables, developing a list of authorized suppliers, and requiring the fabricator/vendor to take back all cribbing, packaging, and shipping aids when they leave (Nasir, 2013).

2.5.5 Equipment and Tools Management Practices

Effective tools and equipment management practices improve CLP (Nasir, 2013). Construction equipment procurement plans, providing tools and equipment on time, just-in-time equipment, equipment productivity analysis, and equipment maintenance are the equipment management practices to improve CLP.

Nasir (2013), procurement procedures and plans are required for construction machinery, including guidelines, requirements, or systems for purchasing or renting, expediting, and delivery of construction machinery and equipment for the project. According to the study, issues to consider during procurement procedures and plans include: will the construction machinery be purchased, rented, or leased? Coordinate the construction machinery procurement schedule with the construction schedule, develop a list of authorized suppliers, and coordinate with equipment logistics to determine the required dates for required rental machinery.

According to Nasir (2013), issues to consider in construction machinery productivity analyses include measuring the utilization time of construction machinery and equipment, measuring delays due to unavailability of construction machinery and machinery used adjusting to the construction schedule, and contingency plans available when the schedule changes.

Timely maintenance is among equipment and tools management practices to improve CLP. It is critical for keeping the machinery in good working condition. It ensures that the equipment can perform optimally without breaking down and availability, when needed, since properly managing routine and scheduled maintenance minimizes project impact due to machinery downtime/failure accordingly.

2.5.6 Safety and Health Management Practices

Previous studies confirmed that it is possible to improve safety and productivity simultaneously on construc-tion projects. In the study by Shan et al. (2016) and Gurmu & Aibinu (2018), safety management programs consistently correlate positively with better labor productivity. Safety and health plan, assign safety engineer, safety and health training, implement safe work method statement, provide hygienic site conditions, toolbox safety meetings, frequent housekeeping, keep workplace safety signs facility, proper maintained PPE, effective site communication and anticipating problems and planning for them in advance are the safety and health management to improve CLP.

Mengistu et al. (2016) suggested that initial project planning should consider seasonal weather conditions. Flexibility should be built into the work schedule to allow for downtime during inclement weather. The same author recommended special consideration for crews working in non-ideal weather conditions. Since the work environment directly affects the workers' performance, the construction company has to secure the needed facilities, such as clean restrooms and spacious rest and food areas. Moreover, the companies should maintain proper ventilation and lighting conditions and control the contamination levels as much as possible (Gunduz & Abu-Hijleh, 2020).

The managers in the construction industry should develop a deeper appreciation of the safety factors which exhibit a significant effect on labor productivity. It demands continuous monitoring of measures such as the number of injuries/ accidents, strikes, clean-up and repair costs, loss of production, legal issues, and the development of control measures to limit the recurrence of such incidences (Kazerooni et al., 2021). Generally, every measure should be taken to make the workplace hygienic, including proper sanitary facilities, drinking water facilities, dining and recreation room, and good housekeeping (Dilawer, 2014). The organization should conduct safety induction courses for each employee and arrange regular safety meetings for all the workers and accordingly introduce strict compliance of using the right PPE (Personal Protective Equipment), proper signboards, barricades, and right tools or equipment to reduce the employee’s exposure to hazards at the work area, accordingly.

2.5.7 Stakeholders Management Practices

Construction projects involve stakeholders, and these stakeholders are affected by or affect the project's activities directly or indirectly. Previous studies confirmed that proper stakeholder management is crucial to improving the project's overall performance, including labor productivity. Coordination between stakeholders, regular and adequate communication on construction status, enhancing supervisor leadership and decision making, effective supervision and quality control, proper project financing, and stable organizational structure are stakeholder management practices determined by different studies to improve CLP.

Enhancing leadership and decision-making for the supervisors is one of the effective management practices determined by previous studies. As Palop & Piqueras (2016) stated, proper management of construction projects requires knowledge of modern management techniques, and familiarity with general management knowledge and particular knowledge domains is indispensable. It involves setting priorities for improvements, providing cost-efficient and easy-to-use methods, promoting a supportive labor-management relationship, and cutting costs while increasing profits accordingly.

A study conducted by Dixit (2021) determined that coordination between all stakeholders is the top management practice affecting construction productivity to control the issues of low pro-ductivity. Similarly, regular and effective communication on construction status with the project stakeholders is determined as the fourth top management practice implemented by practitioners to improve productivity. It has the most vital relationship with labor productivity in Ghodrati et al. (2018) study. Additionally, Gurmu (2020) stated that the organizational structure could change depending on the phases of the construction project; however, the key personnel should not leave the site.

2.6 Best experiences in developed and developing countries

In this subsection, best management practices to improve CLP both in developed and developing countries are discussed: Canada, New Zealand, Indonesia, Malaysia, and Ghana.

A study by Kazerooni et al. (2021) revealed Canada's most effective CLP improvement strategies. Developing clear instructions about the equipment used to transport materials, providing clear instructions to craftspeople on how to complete tasks before their execution, applying preventive maintenance to heating and air-conditioning systems to make sure they are in working order, performing project team activities, training laborers to achieve the latest concrete-pouring techniques, hold regular meetings with laborers about schedule and remaining tasks, and hire cheap labor for daily housekeeping tasks are the most effective solutions.

Ghodrati et al. (2018) revealed the effectiveness of a set of implemented management strategies in New Zealand, including incentive programs, labor management, training, communication, supervision, planning, resource scheduling, use of advanced construction methods, and management of construction in improving CLP. Similarly, Gurmu & Aibinu (2018) revealed the well-defined scope of work, safety and health policy, safety and health plan, hazard analysis, long lead materials identification, task safety analysis, and toolbox safety meetings are the top seven practices to enhance CLP in Australia.

In Malaysia, strategies for improving CLP effective management and supervision, viable construction practices, sufficient reward system, continuous training and development of the workforce, use of a balanced scorecard to measure the effect of training, creating a safe and friendly working condition, creating job security and satisfaction, proper communication and dissemination of information, setting precise goals, use of modern equipment and machines, close monitoring of laborers, permanent employment for laborers and employment of qualified and competent labors Yusof et al. (2018).

According to Akomah et al. (2020), Coordination among team members, provision of the right environment for workers to work, good communication channels, proper motivation, setting targets for the workforce, improving health and safety, satisfying the welfare needs of workers, a good relationship between supervisor and workforce, proper site layout, proper material handling, clear guidelines and approach to work, correction of bad behavior that negatively influences productivity, avoidance of material shortage and appreciating the efforts and contribution of the workforce are the solutions to improve CLP in Ghana.

2.8 Summary of Literature Review and Research Gap

Previous studies related to CLP are reviewed in the above sections. Section 2.8.1 summarized the discussions of previous studies. The identified research gap from previous studies is also discussed in section 2.8.2.

2.8.1 Summary of Literature Review

Generally, productivity can be defined as a measure of how efficiently a system uses its resources to produce output from input. There are various techniques to measure productivity, such as direct observation, time study, activity sampling, Forman delay survey, craftsman questionnaire sampling, and recording methods. Numerous factors affect CLP. Identifying and evaluating factors affecting CLP is a critical issue in preparing a strategy that reduces inefficiencies and improves the effectiveness of project performance. As table 2.3 show, sixty-two that factors affecting CLP are identified and categorized into eight major categories.

Table 2.3 Summary of Literature Review

Factors affecting CLP	
Management related factors	**Sources**
Poor planning and scheduling	Shoar & Banaitis (2019),Mengistu et al. (2016),Ghanim (2016), Chaturvedi et al.(2016), Gerges et al.(2016).
Poor control and supervision	Montaser et al. (2018),Gunduz & Abu-Hijleh (2020), Durdyev et al. (2018) Mengistu et al., (2016).
Lack of supervisors' experience	Ghanim (2016), Durdyev et al (2018), Agrawal (2019)
Inspection delay	Adagba et al. (2021), Ashebir et al. (2020)
Delay in decision making	Ashebir et al. (2020), Ghanim (2016)
Delay in responding to information	Adagba et al. (2021).
Poor site management	Mengistu et al. (2016), Hai & Nguyen, (2019),
Unclear instruction to labors	Dey et al. (2017), Montaser et al. (2018).
Lack of periodic meetings with labors	Ashebir et al. (2020), Gerges et al.(2016),
Lack of providing incentive	Agarwal et al.(2016) ,Gerges et al. (2016).
Lack of training to labor	Shoar & Banaitis (2019), Gerges et al. (2016), Ashebir et al. (2020), Dixit et al.(2019).
Crew size and composition	Gunduz & Abu-Hijleh (2020).
Contractual dispute	Dixit et al. (2019), Adagba et al. (2021).
Insufficient coordination among parties	Bitamba & An (2020), Ghanim (2016).
Misunderstanding between labor and superintendent	Shoar & Banaitis (2019), Agrawal (2019), Ashebir et al. (2020), Akomah et al. (2020).

Technical related factors	**Sources**
Rework	Ghanim (2016), Shoar & Banaitis (2019),Dey et al. (2017), Dixit et al. (2019).
Variation/ change of orders during execution	Adagba et al. (2021), Ashebir et al. (2020), Dey et al. (2017)Agrawal (2019), Dixit et al. (2019).
Complexity of the design and project	Adagba et al. (2021), Ashebir et al. (2020), Bitamba & An (2020), Ghanim (2016), Agarwal et al. (2016).
Lack of compatibility among contract documents	Adagba et al. (2021), Dixit et al. (2019), Agarwal et al (2016), Irfan et al. (2020).
Incomplete and Inaccurate drawing	Bitamba & An (2020), Manoharan (2017), Adagba et al. (2021), Montaser et al. (2018).
Lack of clarity of technical specifications	Ghanim (2016), Manoharan (2017), Adagba et al. (2021), Montaser et al. (2018), Agrawal (2019).
Improper construction method	Montaser et al. (2018), Akomah et al. (2020).
Finance related factors	**Sources**
Inflation in the cost of execution	Adagba et al. (2021), Shoar & Banaitis (2019), Montaser et al. (2018), Durdyev et al. (2018),Eba (2019).
Improper project financing	Shoar & Banaitis (2019), Dey et al. (2017).
Payment delay	Irfan et al. (2020), Ashebir et al. (2020), Gunduz & Abu-Hijleh (2020), Mengistu et al. (2016), Ghanim (2016), Agrawal (2019).
Low labor wage	Irfan et al. (2020), Ghanim (2016).
Labor related factors	**Sources**
Lack of skilled and specialized labor	Dixit et al. (2019), Adagba et al. (2021), Ghanim (2016), Gunduz & Abu-Hijleh (2020), Durdyev et al. (2018),
Lack of motivation of workers	Ashebir et al. (2020), Durdyev et al. (2018), Eba (2019),
Bad labor characteristics	Hai & Nguyen (2019) ,Mengistu et al. (2016), Agrawal (2019)
Late arrival, early quit, unscheduled break	Agarwal et al. (2016).
Misunderstanding among labors	Ghanim (2016), Ashebir et al. (2020), Gerges et al. (2016), Akomah et al. (2020).
Communication/ Language Barrier	Chaturvedi et al. (2016).
Poor economic condition of workers	Adagba et al. (2021), Agrawal (2019), Ashebir et al. (2020)
Increase in laborer's age	Adagba et al. (2021), Gerges et al. (2016).
Physical fitness of labor	Dey et al. (2017).
Labor absenteeism	Adagba et al. (2021), Bitamba & An (2020), ,Agrawal,(2019), Akomah et al. (2020).
Physical fatigue	Adagba et al. (2021), Shoar & Banaitis (2019), Agrawal (2019), Ashebir et al. (2020).
Labor personal problems	Adagba et al. (2021), Ghanim (2016), Agrawal (2019), Gerges et al. (2016) Akomah et al. (2020).
Drug abuse and alcoholism	Adagba et al. (2021), Eba (2019).

Material related factors	**Sources**
Shortage of construction material	Ashebir et al. (2020), Ghanim (2016), Montaser et al. (2018), Mengistu et al. (2016), Manoharan (2017)
Slow adoption of materials	Manoharan (2017), Gerges et al. (2016), Montaser et al. (2018), Akomah et al. (2020).
Poor quality of construction materials	Hai & Nguyen (2019), Ashebir et al. (2020), Akomah et al. (2020).
Unsuitability of material storage location	Gunduz & Abu-Hijleh (2020), Ghanim (2016), Agarwal et al. (2016), Ashebir et al. (2020).
Equipment and tools related factors	**Sources**
Shortage of tools and Equipment	Ghanim (2016), Shoar & Banaitis (2019), Mengistu et al. (2016), Eba (2019), Sebastian & Raghavan (2015)
Waiting for equipment to arrive	Gerges et al. (2016).
Old and inefficient equipment	Ghanim (2016), Ashebir et al. (2020), Dixit et al. (2019).
Poor quality of tools	Hai & Nguyen (2019).
Safety and health related factors	**Sources**
Site accident	Mengistu et al. (2016), Eba (2019), Ashebir et al. (2020)
Lack of safety tools (PPE)	Eba (2019), Montaser et al. (2018).
Absence of safety training & program	Eba, (2019).
Violation of safety precautions	Mengistu et al. (2016), Ashebir et al. (2020).
Insufficient lighting	Eba (2019), Gerges et al. (2016), Akomah et al. (2020).
Hazardous work area	Gunduz & Abu-Hijleh (2020), Adagba et al. (2021), Gerges et al. (2016), Agrawal (2019).
Project environment and external related factor	**Sources**
Project location	Eba (2019), Agrawal (2019).
Confined working space	Adagba et al. (2021), Ghanim (2016).
Incomplete facilities	Eba (2019), Gerges et al. (2016) Akomah et al. (2020).
Restricted site access	Agarwal et al. (2016), Gerges et al. (2016).
Culture/ customs of community	Adagba et al. (2021).
Religious and other holidays	Adagba et al. (2021), Eba (2019).
Extreme weather conditions	Shoar & Banaitis (2019), Gunduz & Abu-Hijleh (2020), Eba (2019), Agrawal (2019), Adagba et al. (2021).
Government policies	Adagba et al. (2021), Gerges et al. (2016), Ashebir et al. (2020), Akomah et al. (2020).
Political instability	Shoar & Banaitis (2019), Agrawal (2019), Eba (2019).

The advantages of overcoming CLP barriers include the increased rate of output, reduction of overall cost, maintaining the planned rate of production, maintaining high-quality standards, etc. Enhancing the labor productivity of construction activities would immensely be advantageous for the economy of any country at the micro and macro levels. The table below summarizes the management practices to overcome factors affecting CLP.

Table 2.4 Management practices to overcome factors affecting CLP

Management practices to overcome factors affecting CLP	
Preconstruction management	**Sources**
Use of software in planning work packages	Gurmu & Aibinu (2018).
Appointed experienced designer	Patkure & Kulkarni (2018).
Well-Defined scope of work	Gurmu &Aibinu (2018), Sivaraj & Vidivelli (2018).
Complete and approved drawing	Ghodrati et al. (2018), Agrawal & Halder (2020).
Realistic work schedule	Ghodrati et al.(2018), Gurmu & Aibinu (2018),
Collaborative procurement	Mahat et al. (2019), Ghodrati et al. (2018).
Project start-up plan	Gurmu & Aibinu (2018).
Project completion plan	Gurmu & Aibinu (2018), Sivaraj & Vidivelli (2018).
Short interval plan	AbuHamra & Enshassi (2015), Gurmu & Aibinu (2018)
Fulfill regulatory requirement	Gurmu & Aibinu (2018).
Construction method and Site management	**Sources**
Proper site administration	Agrawal & Halder (2020).
Providing necessary site facilities	Sivaraj & Vidivelli (2018), Ghodrati et al. (2018).
Proper construction site layout	Akomah et al. (2020), Chdhry (2015).
Dynamic site layout plan	Gurmu & Aibinu (2018), Hwang et al.(2020).
Site security plan	Gurmu & Aibinu (2018).
Traffic control plan	Gurmu & Aibinu (2018).
Adoption of advanced technologies	Hwang et al.,(2020), Gurmu & Aibinu (2018)
Detailed workforce plan	Ghodrati et al. (2018).
Hiring skilled workers	Dilawer (2014).
Effective supervision and quality control	Yusof et al (2018), Gurmu & Aibinu (2018)
Human resource management	**Sources**
Training of workers	Dixit (2021), Agrawal & Halder (2020)
Incentive/bones	Ghodrati et al. (2018), Agrawal & Halder (2020), Gyamfi et al. (2020), Johari & Jha (2020)
Increase labors wage/salary	Sivaraj & Vidivelli (2018), Kazerooni et al. (2021), Ghodrati et al. (2018).
Timely payment	Dixit (2021), Agrawal & Halder (2020).
Proper arrangement of labors	Agrawal & Halder (2020)
Clear delegation of responsibility	Ghodrati et al. (2018), Gurmu & Ongkowijoyo (2020), Sivaraj & Vidivelli (2018),Kazerooni et al. (2021),
Worker's participation in decision making	Sivaraj & Vidivelli (2018).
Skill assessment and evaluation	Gurmu & Ongkowijoyo (2020).
Correct bad labor characteristics	Akomah et al. (2020), Sivaraj & Vidivelli (2018).
Team building	Shan et al (2016), Kazerooni et al (2021).
Good communication	Ghodrati et al. (2018), Agrawal & Halder (2020).
Good relation between labor and superintendents	Sivaraj & Vidivelli (2018), Akomah et al. (2020).

Human resource management	**Sources**
Shift-based working hours	Agrawal & Halder (2020), Ghodrati et al. (2018).
Hold regular meetings with labors about schedule and remaining tasks	Kazerooni et al. (2021), Ghodrati et al. (2018), Agrawal & Halder (2020).
Giving workers breaks time and & day off for holidays	AbuHamra & Enshassi (2015).
Materials management	**Sources**
Procurement plans for materials	Gurmu (2020), Ghodrati et al. (2018).
Providing materials on time	Ghodrati et al. (2018), Gurmu (2020).
Just-in-time materials delivery	Hwang et al. (2020).
Proper materials handling systems	Akomah et al. (2020), Dilawer (2014).
Long-lead materials identification	Gurmu (2020).
Materials status database	Gurmu (2020), Hwang et al. (2020).
Post receipt preservation and maintenance	Gurmu (2020), Hwang et al. (2020).
On-site materials tracking	Gurmu (2020), Agrawal & Halder (2020).
Equipment and tools Management	**Sources**
Equipment procurement plans	Gurmu & Aibinu (2018), Ghodrati et al. (2018).
Providing tools and equipment on time	Ghodrati et al. (2018).
Just-in-time equipment	Hwang et al. (2020).
Equipment maintenance	Gurmu & Aibinu (2018).
Equipment productivity analysis	Gurmu & Aibinu (2018).
Safety and health management	**Sources**
Safety and health plan	Gurmu & Aibinu (2018), Hwang et al.(2020).
Assign safety engineer	AbuHamra & Enshassi, (2015).
Safety and health training	Gurmu & Aibinu (2018), AbuHamra & Enshassi (2015).
Implement safe work method statement	Gurmu & Aibinu (2018).
Provide hygienic site conditions	Agrawal & Halder (2020), Sivaraj & Vidivelli (2018).
Toolbox safety meetings	Gurmu & Aibinu (2018).
Frequent housekeeping	Gurmu & Aibinu (2018), Kazerooni et al. (2021) AbuHamra & Enshassi (2015), Hwang et al. (2020).
Keep workplace safety signs facility	AbuHamra & Enshassi (2015).
Proper maintained PPE	Agrawal & Halder (2020), Dilawer (2014).
Effective site communication	Ghodrati et al. (2018), Ghodrati et al. (2018).
Anticipating problems and planning for them in advance	Ghodrati et al. (2018).
Stakeholders' management	**Sources**
Coordination between stakeholders	Dixit (2021), Sivaraj & Vidivelli (2018)
Regular and effective communication on construction status	Ghodrati et al. (2018), Agrawal & Halder (2020) , Hwang et al. (2020)
Enhancing leadership and decision making for the supervisors	Ghodrati et al. (2018).
Proper project financing	Agrawal & Halder (2020), Dixit (2021).
Stable organizational structure	Gurmu & Aibinu (2018), Hwang et al. (2020).

2.8.2 Research Gap

As discussed in the above sections, poor CLP is a concern in many countries. Therefore, many studies have been undertaken in several countries, including Ethiopia, to investigate factors affecting CLP. Research by Mengistu et al. (2016) and Ashebir et al. (2020) determined the top factors affecting labor productivity on construction projects in Bale and Wolita Zone, respectively. The researchers only recommended ways to improve CLP. Eba (2019) determined methods to improve CLP through the respondent's suggestions for building construction projects. However, the researcher could not find a study that evaluated improvement strategies and practices in the study area. Table 2.5 provides the research gap in the study area by presenting the methodology, source of data and study area of previous research conducted in the related title.

Table 2.5 Research gap

Title	**Source**	**Study Area**	**Source of data**	**Methodology**
Statistical analysis of the effectiveness of management programs in improving CLP on large industrial projects.	Shan et al. (2016)	Austin, United States	Questionnaire	Benchmarking Median
Prioritizing CLP improvement strategies.	Kazerooni et al. (2021)	Edmonton, Canada	Questionnaire	F-TOPSIS, F-AHP, Fuzzy Cognitive Maps
Survey of management practices enhancing labor productivity in multi-story building construction projects.	Gurmu & Aibinu (2018)	Victoria, Australia	Questionnaire Interviews	RII, data reduction
Role of management strategies in improving CLP.	Ghodrati et al. (2018)	Auckland, New Zealand	Interviews	Mean score
Practical solutions for improvement in CLP.	Patkure & Kulkarni (2018)	Islampur, India	Questionnaire Observation	RII, Case study
Identification and mitigation of factors affecting CLP.	Dey et al. (2017)	Chennai, India	Questionnaire	RII

Title	Source	Study Area	Source of data	Methodology
Improving labor productivity in Ghanaian building construction projects.	Akomah et al. (2020)	Ghana	Questionnaire	Means Score Standard deviations, Factor analysis
Assessment of factors affecting CLP on road projects.	Mengistu et al. (2016)	Bale, Ethiopia	Questionnaire	RII
A study on factors affecting CLP.	Ashebir et al. (2020)	Wolita, Ethiopia	Questionnaire	RII
Investigation of factors affecting CLP in building projects.	Eba (2019)	Oromia, Ethiopia	Questionnaire	RII

The researcher identified a study gap in this topic, geography and methodology are the main gaps. Geography-wise, although various research has been conducted on related topics, there is a study gap in evaluating management practices to overcome factors affecting CLP in this area. Therefore, this study first determines the negative factors affecting CLP in Adama, Ethiopia, since the main objective is to overcome the significant factors affecting CLP. Determining factors in this area was crucial because, as Chavan & Salunkhe (2016) mentioned, factors such as environmental, material, safety, quality, project, manpower, time, motivation, and leadership have different effects on labor productivity depending on the project location. After that, it evaluates various management practices based on their potential to overcome the CLP barriers and consequently improve productivity.

As table 2.4 implies, Kazerooni et al. (2021) adopted an approach relatively similar to the current one. However, the main differences besides the study area are the criteria and sub-criteria used in the research. The current research uses the factors affecting CLP as the criteria to overcome factors affecting CLP. While, Kazerooni et al. (2021) use the impact on CLP, implementation feasibility, workers' adaption, and implementation risk as criteria.

CHAPTER THREE - RESEARCH METHODOLOGY

3.1 Introduction

This chapter discusses the methods used to achieve the objectives of the study. It describes the study area, research design, population of the study, sample size distribution, sampling technique, source of data, data collection instrument, data analysis techniques, validity and reliability of the research, and ethical considerations.

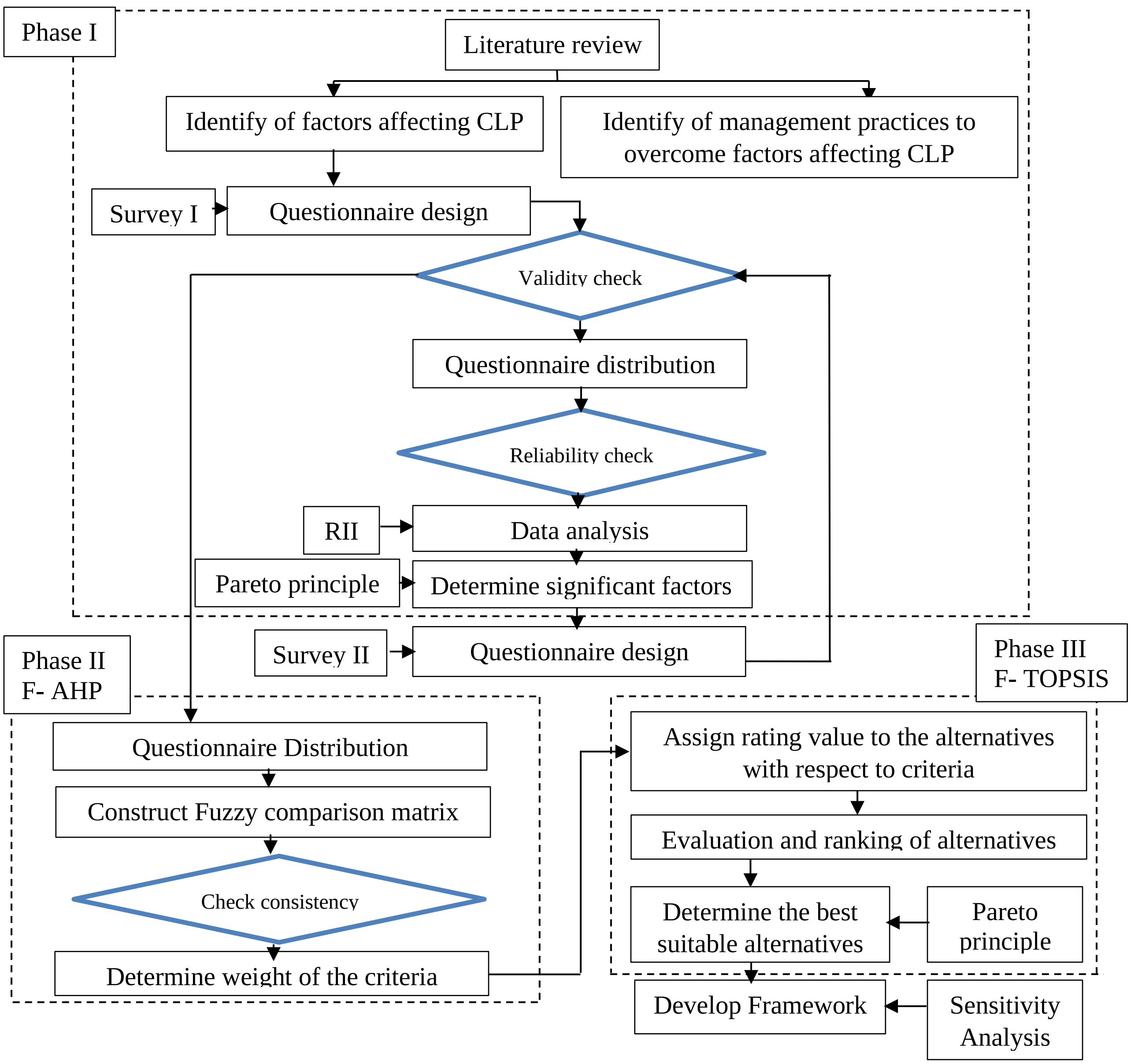

Figure 3.1 Research methodology

As figure 3.1 presents, this research was conducted in three phases. In the first phase, an extensive list of factors that affect CLP was prepared through a literature review. A questionnaire survey was conducted to determine the most significant factors affecting CLP, which is the study's first objective. For the second and third phases, another questionnaire survey was prepared similarly to the first phase and distributed to the same respondents who participated in the first questionnaire. The purpose of this survey was to achieve the second and third objectives of this study. Phase II was conducted through F-AHP to determine the weight of the significant factors. Phase III was conducted through F-TOPSIS to determine effective management practices to overcome the most significant factors affecting CLP.

3.2 Study Area

The study area is Adama city, located in Ethiopia's Oromia national, regional state, east Showa zone, 99 km from the capital city, Addis Ababa. Adama city is located at 8.54° N and 39.27° E. It is one of the reform cities in the region and consists of fourteen urban and four rural kebeles. With an area of 29.86 square kilometers and a population density of 7,374.82/ km2, all are urban inhabitants (Rage Faye, 2021). Figure 3.2 shows the study area.

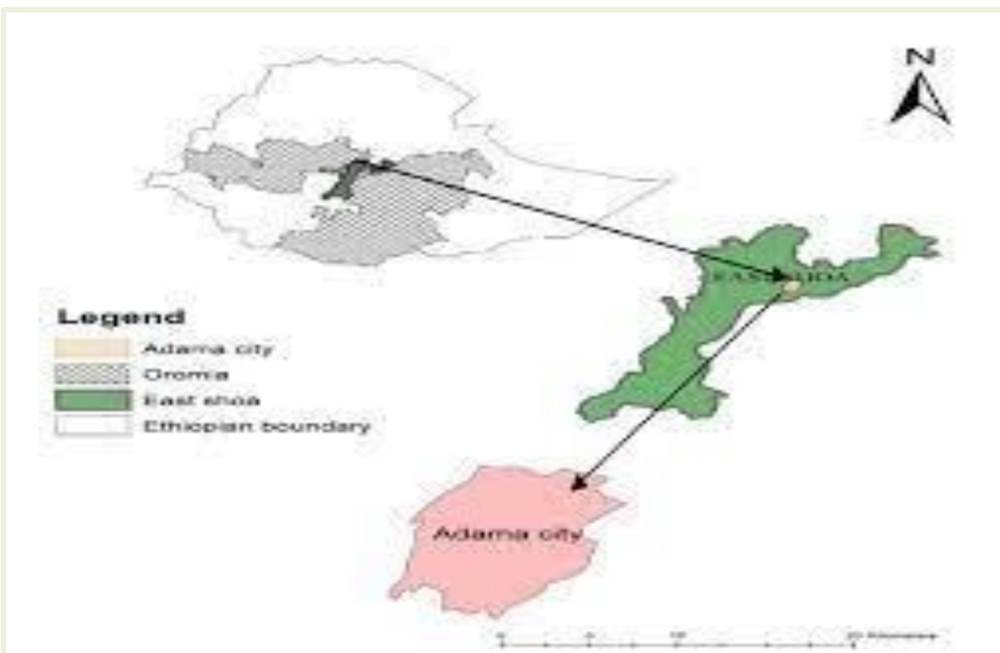

Figure 3.2 Map of the study area

3.3 Research Design

The research follows positivism philosophical standpoint following the deduction process. Positivism is an objective analysis and interprets tangible social reality, assuming that the researcher is independent of and neither affects nor is affected by the research subject. Positivism tends to focus on facts, look for causality and reduce phenomena to their simplest elements for formulating (testing) hypotheses (Richard & Anita, 2015). The deduction process looks for ideas in texts (journal articles, books, etc.) and through communication with colleagues, experts, etc.

This study is both descriptive and explanatory research with quantitative research approach to address the research objectives. According to Richard & Anita (2015), descriptive analysis systematically identifies and records a phenomenon, process, or system. The author also stated that such identification and recording will be done from a particular perspective and often for a specific purpose. Descriptive approach adopted to analyze factors affecting CLP, first objective of the study.

The purpose of the study is to explore a new universe, one that has not been studied earlier, called explanatory (Inaam, 2016). It answers a question or explains a specific issue/phenomenon (Richard & Anita, 2015)As in exploratory studies, propositions/hypotheses are used. Here, as the situation is known better, theory can be used to develop the hypotheses the research will test. Also, this could be a follow-on from an exploratory study that has produced testing hypotheses. Therefore, this approach analyzes the management practice to overcome the factors affecting CLP.

This research used a quantitative approach to achieve the research objectives specified in the above section. Quantitative research focuses on objectivity and is appropriate when there is a possibility of collecting quantifiable measures of variables and inferences from the population samples (Queirós et al., 2017). The same author acknowledges that quantitative research approaches adopt structured procedures and formal instruments for data collection. A quantitative research approach was adopted in this study to determine factors affecting CLP and improvement practices numerically.

3.4 Population of the Study

The target population of this study is ongoing building construction projects in Adama city. According to the Adama Construction Authority, there are thirty-four ongoing multi-story building construction projects in the city. The public sector owns one of the projects, and the private sectors own the rest. Since the total population is manageable in terms of cost and time to address the specified objectives, a Census survey was adopted in this study. As Kothari (2004) stated, a complete enumeration of all items in the population is known as a census inquiry. It can be presumed that in such an inquiry when all items are covered, no element of chance is left, and the highest accuracy is obtained. Therefore, thirty-four active multistory building construction projects in Adama city were studied.

3.5 Source of Data

To obtain the desired data, primary and secondary data sources were used to achieve all the specified objectives of this research. The data gathered from the sources are discussed in the sections below.

3.5.1 Primary Data

Primary data is the data gathered by the researcher. A book by Wilson (2014) categorizes questionnaire surveys, interviewing techniques, focus groups, and participant observation under primary data collection forms. Therefore, the primary data source for this research is the major component of this study through questionnaire surveys.

3.5.2 Secondary Data

According to Wilson (2014) secondary data is defined as information already collected by someone else and is available for the researcher to use. It provides the researcher with contextual material for the research. Historical records, textbooks, reviews, and articles that analyze or discuss ideas, events, criticisms, or commentary are categorized under secondary data. This study uses textbooks, reviews, articles, and discussion ideas to strengthen the results obtained from this research.

3.6 Data Collection Instrument

The data collected in this study was carried out by survey methods, using questionnaires to collect primary data. According to Queirós et al. (2017),a questionnaire survey allows obtaining information about a given phenomenon through the formulation of questions that reflect the perceptions and behaviors of a group of individuals. This research used a questionnaire survey with closed-ended questions. The questionnaire is designed based on the reviews made from various literature. It ensures to address the study's objectives, and different sections categorize it. The questionnaires were designed and distributed to the site engineers, resident engineers and project managers. Yusof et al. (2018) indicated that site professionals and labors have a mutual relationship on-site and track their daily activity. Therefore, they are the most suitable respondents to investigate labor challenges and improve their output.

This study has three phases. Two questionnaire surveys were conducted separately to achieve the research objectives. For survey I, the questionnaire was built from three sections covering the study's main questions. The first section relates demographic information about respondents and companies' profiles. The second section contained 62 identified factors and categorized them into eight categories according to their interrelated concepts. Experts were asked to indicate the effect of factors on CLP using a 5-point Likert scale representing "1" Very low effect, "2" Low effect, "3" Moderate effect, "4" High effect, "5" Very high effect to determine the significant factors affecting CLP.

Similar to the first questioner, the first section of the questionnaire II aims to gather general information about the firm and its respondents. The second section is prepared to conduct F-AHP to weight the fifteen most significant factors affecting CLP determined in phase one. In this section, respondents weight the factors through pair-wise comparison representing “$\tilde{1}$” Equally Important, “$\tilde{3}$” Weak Important, “$\tilde{5}$” Strong Important, “$\tilde{7}$” Very strong Important, and “$\tilde{9}$ ” Extremely strong Important. The third section prepared to rate alternative solutions through F-TOPSIS. It consisted of sixty-five identified management practices to overcome factors affecting CLP. Experts were asked to rate management practices based on their potential to overcome each barrier, representing “VH” Very High, “H” High, “M” Medium, “L” Low, and “VL” Very Low.

3.7 Data Analysis Techniques

The collected data were analyzed using Excel software, a widely used statistical program. In this research, excel was used to analyze the data from the respondents, RII, F-AHP, and F-TOPSIS.

3.7.1 Relative Importance Index

Data from the first questionnaire survey was analyzed using RII to determine significant factors affecting CLP. Relative importance index technique formula (Gerges et al., 2016).

$$\text{RII}\ (\%) = \frac{(\,5(\text{n5}) + 4(\text{n4}) + 3(\text{n3}) + 2(\text{n2}) + \text{n1}\,)}{5(\text{n1} + \text{n2} + \text{n3} + \text{n4} + \text{n5})} * 100 \qquad \text{[Eq. 3.1]}$$

Where n1, n2, n3, n4, and n5 are the total number of respondents select "“1” Very low effect, “2” Low effect, “3” Moderate effect, “4” High effect, “5” Very high effect.

3.7.2 Pareto Principle

The Pareto principle was discovered by an Italian economist named Vilfredo Pareto, who observed how the vast majority of wealth (80%) was owned by relatively few of the population (20%). The Pareto analysis aims to identify the critical 20% of causes and to solve them as a priority. It is also known as the 80/20 rule. 80% of the problems are due to 20% of the causes. It also assists in distinguishing the “vital few” from the “useful many” and is widely used in education, construction, finance, medicine, and management (Al-Salahi et al., 2020). According to Bojan et al. (2015), the Pareto principle can be implemented in different aspects of projects. For example, 20% of tasks take 80% of the project time, 20% of the project team works on 80% of tasks, and 20% take 80% of the project budget.

Many researchers have used the Pareto principle to determine critical factors for different studies. For instance, Serdar D. & Syuhaida (2012) determined 20% of the factors causing 80% of the on-site productivity problems in the New Zealand construction industry. Similarly, Gupta et al. (2017) adopted the Pareto principle to determine the top 20% of barriers in developing a roadmap to overcome barriers to energy efficiency in buildings using MCDM. El-Barteek et al. (2013) used the Pareto principle, and only the top 20% of the factors significantly influenced CLP.

3.7.3 Multi - Criteria Decision Making, MCDM

According to Belhadi et al. (2017), the MCDM approach is the best way to solve the problem under the study by prioritizing the barriers and suggesting the most efficient solutions. This research adopted hybrid methods of MCDM. Hybrid MCDM helps the decision makers understand and concentrate more on the high criteria rank and provides the best alternatives in different problems and situations (Sirisawat & Kiatcharoenpol, 2018). Although the AHP method can be used for decision-making, integrating other decision support tools, such as TOPSIS, improves the decision-making process. This hybrid method has conducted various types of research in different areas.

Various research on different areas has been conducted using this hybrid method. For instance, Kazerooni et al. (2021) integrated AHP and F-TOPSIS to rank the CLP improvement strategies meeting the specified criteria. F-AHP was utilized to get weights of the criteria of barriers. At the same time, F-TOPSIS prioritizes the solutions suggested for enhancing CLP. Similarly, Patil & Kant (2014) identify and rank the solutions of knowledge management adoption in the supply chain to overcome its barriers

3.7.3.1 Fuzzy sets

According to Patil & Kant (2014), decision making is very difficult in a vague and uncertain environment. This vagueness and uncertainty can be handled using the fuzzy set theory proposed by Zadeh (1965). In particular, tackling the ambiguities in linguistic estimation is a beneficial way to convert these linguistic terms into fuzzy numbers. In practice, fuzzy numbers can represent linguistic values, and the TFN is commonly used. A character tilde ‘‘~’’ is placed above a symbol if the symbol represents a fuzzy set (Patil & Kant, 2014).

In the application of hybrid MCDM, fuzzy AHP and TOPSIS are used and consist of four levels.

Level 1- Gola–overcome factors affecting CLP
Level 2 - Criteria-Groups of factors affecting CLP
Level 3 - Sub- Criteria-factors affecting CLP
Level 4 -Solution- Management practices to overcome factors affecting CLP

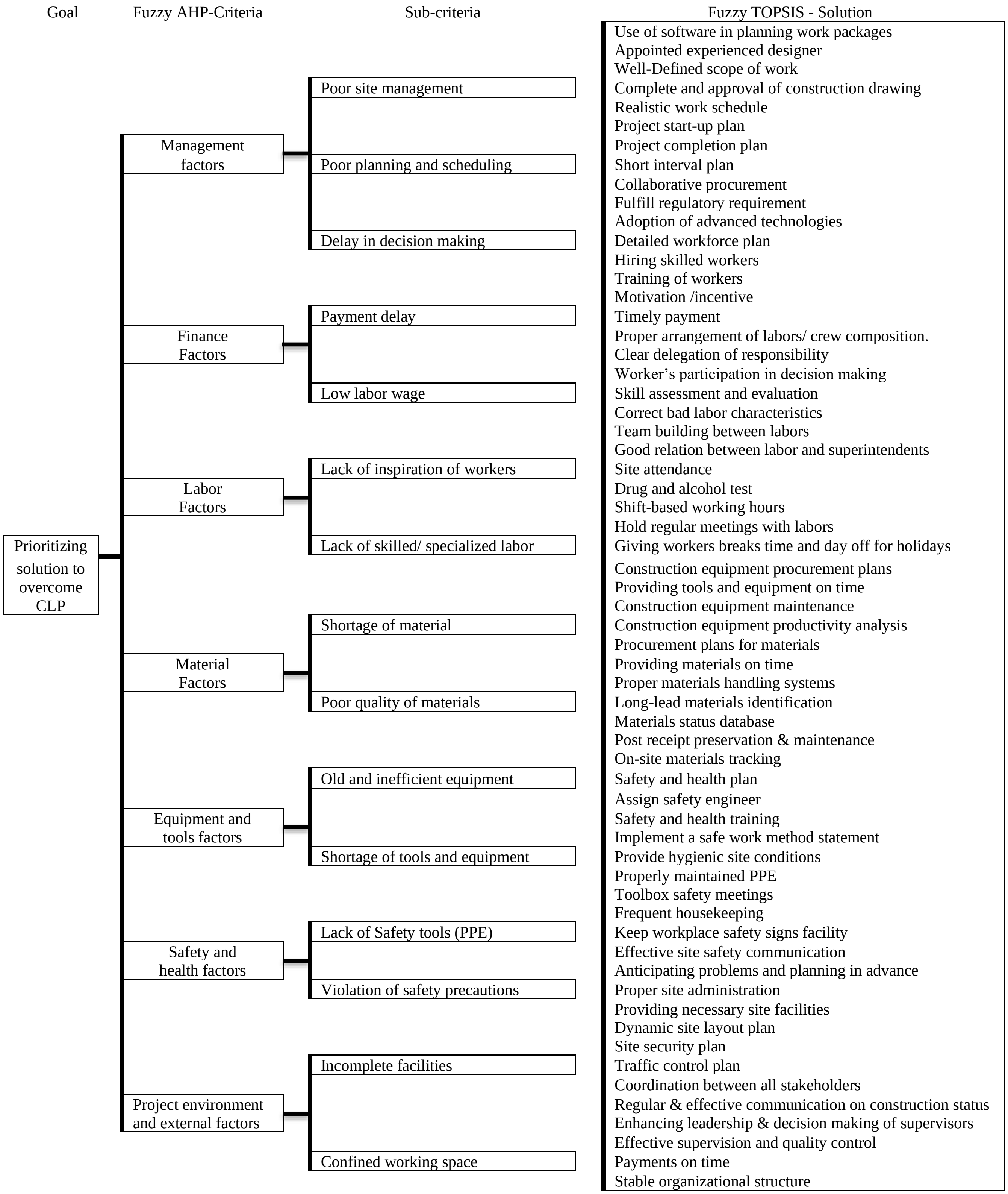

Figure 3.3 Decision hierarchy for prioritizing the solutions.

3.7.3.2 Fuzzy Analytic Hierarchy Process, F-AHP

Analytic Hierarchy Process AHP is a well-known multi-criteria analysis approach introduced by Thomas L. Satty in 1980 (Singh & Sarkar, 2019). It is a powerful and flexible decision-making method for prioritizing different attributes (Belhadi et al., 2017). Unfortunately, there are drawbacks associated with Satty's AHP, such as being unable to handle the vagueness and impreciseness in human judgment, which is greatly influenced by decision-makers preferences and an unbalanced scale of judgment (Singh & Sarkar, 2019). To solve this issue, the fuzzy approach is integrated with AHP. F-AHP effectively handles the vagueness and uncertainty associated with the linguistic inputs of the experts, accordingly.

This study adopts F-AHP to weight the significant factors affecting CLP, obtained from previous analysis. However, before computing F-AHP, factors to be weighted are represented by codes for easy analysis. The seven major and fifteen sub-factors are shown with their corresponding codes in Table 3.1.

Table 3.1 Factors affecting CLP and their code

Main factors		Sub factors	
MF	Management related factors	MF1	Poor site management
		MF2	Poor planning and scheduling
		MF3	Delay in decision making
FF	Finance related factors	FF1	Payment delay
		FF2	Low labor wage
LF	Labor related factors	LF1	Lack of inspiration of workers
		LF2	Lack of skilled and specialized labor
MTF	Material related factors	MTF1	Shortage of construction material
		MTF2	Poor quality of construction materials
ETF	Equipment and tools related factors	ETF1	Old and inefficient equipment
		ETF2	Shortage of Tools and Equipment
SHF	Safety and health related factors	SHF1	Lack of Safety tools (PPE)
		SHF2	Violation of safety precautions
PEF	Project environment and external related factors	PEF1	Incomplete facilities
		PEF3	Confined working space

The systematic step using F-AHP followed in this study are described below. A similar procedure was adopted by Parung et al. (2018), Belhadi et al. (2017), Singh & Sarkar (2019), Yadav et al. (2018), and Patil & Kant (2014).

Step 1: Structure the problem: While using F-AHP, the first step is defining the decision hierarchy structure by integrating the goal, main criteria, and sub-criteria. Therefore, the problem in this study was decomposed into a three-level hierarchical structure, which includes the top level (goal), middle level (criteria), and bottom level (sub-criteria). Figure 3.4 presents the hierarchical structures of the problem of this research.

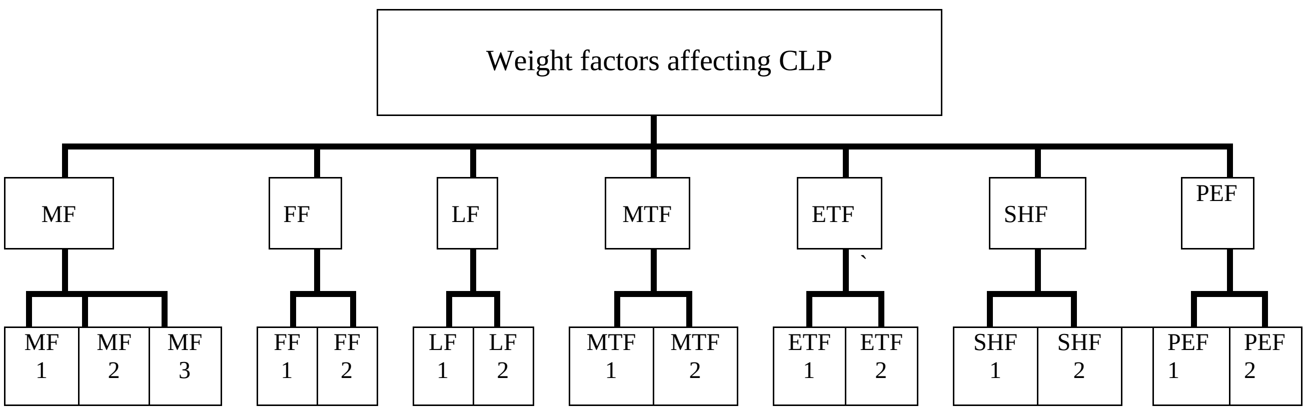

Figure 3.4 F-AHP hierarchal structure

Step 2: Define fuzzy numbers: Triangular Fuzzy Number scale is adopted. TFNs are used to improve the original nine-point scale of Saaty (1977) based on linguistic variables to determine the fuzzy weights for the pair-wise comparisons. The TFNs are defined with the corresponding membership function. A TFN Ã can be denoted by a triplet as Ã= (l, m, u), where l and u mean the lower and upper bounds of the fuzzy number Ã, and m is the modal value for Ã.

Table 3.2 Scale of relative importance used in the pairwise comparison matrix

Intensity of importance	Fuzzy no	Linguistic variables	Membership function
1	$\tilde{1}$	Equally Important	(1,1,3)
3	$\tilde{3}$	Weak Important	(1,3,5)
5	$\tilde{5}$	Strong Important	(3,5,7)
7	$\tilde{7}$	Very strong Important	(5,7,9)
9	$\tilde{9}$	Extremely strong Important	(7,9,11)

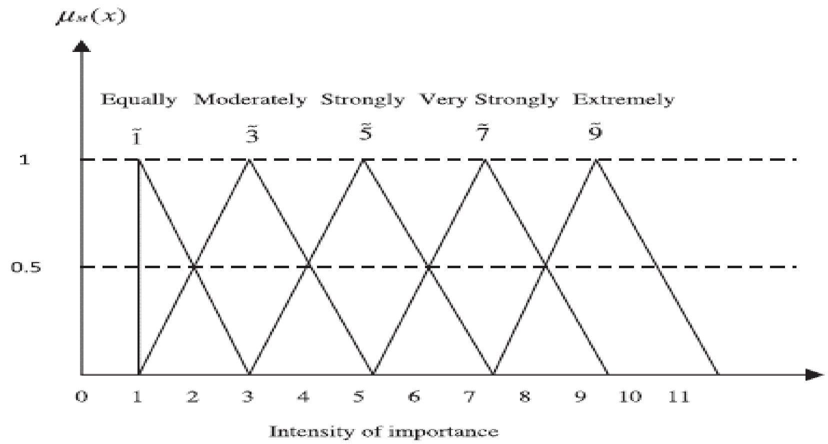

Figure 3.5 Fuzzy membership function

Step 3: Establish the fuzzy pairwise comparison matrix: Let $[\tilde{A}_{ij}]_{n\times n}$ be the matrix for *n* criteria against the goal. $\tilde{A}_{ij}$ is a fuzzy set representing the relative importance of criterion *i* over *j*. Its reciprocal, $1/\tilde{A}_{ij}$, is equal to the relative importance of criterion j over I, $\tilde{A}ij$.

$$\tilde{A} = \begin{bmatrix} 1 & \widetilde{a12} & \cdots & \cdots & \widetilde{a1n} \\ \widetilde{a21} & 1 & \cdots & \cdots & \widetilde{a2n} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \widetilde{an1} & \widetilde{an2} & \cdots & \cdots & 1 \end{bmatrix}$$

Where $\tilde{a}_{ij} = 1$, If *i* equals to *j* and $\tilde{a}_{ij} = \tilde{1}, \tilde{3}, \tilde{5}, \tilde{7}, \tilde{9}$ or $\tilde{1}^{-1}, \tilde{3}^{-1}, \tilde{5}^{-1}, \tilde{7}^{-1}, \tilde{9}^{-1}$ if *i* is not equal to *j*. When scoring is conducted for a pair, a reciprocal value is automatically assigned to the reverse comparison within the matrix. That is, if $\tilde{A}_{ij}$ is a matrix value assigned to the relationship of component i to component j, then $\tilde{A}_{ij}$ is equal to 1.

Step 4: Synthesize the judgments: if there are multiple experts, their opinions should be aggregated, either before or after calculating the fuzzy weights, i.e., synthesizing the pairwise comparisons or the fuzzy weights. This study uses the geometric mean to aggregate the expert's judgment. The geometric mean is a very simple, widely used, and valid means of synthesizing different perspectives and also an approximation to the eigenvalues of a matrix. Let $\tilde{A}_{ij} = (l_{ij}, m_{ij}, u_{ij})$, be a TFN representing the relative importance of A_i over A_j judged by q number of experts.

$$\tilde{A}_{ij} = (l_{ij}, m_{ij}, u_{ij}) = (\prod_{t=1}^{q} \tilde{A}ij^{(t)})^{1/q} = ((\prod_{t=1}^{q} l_{ij}^{(t)})^{1/q}), (\prod_{t=1}^{q} m_{ij}^{(t)})^{1/q}), (\prod_{t=1}^{q} u_{ij}^{(t)})^{1/q})) \quad \text{[Eq. 3.2]}$$

Step 5: Calculate the fuzzy weights of the criteria: this step aggregates multiple fuzzy sets in the matrix into a single fuzzy set. Similar to step 4, synthesizing the judgments, the weight of multiple TFN aggregated to a single TFN fuzzy set using the geometric mean.

Step 6: Defuzzify the fuzzy weights: this step compares maps of a fuzzy set (i.e., fuzzy weight) to a crisp value (i.e., crisp weight) for further comparison. Fuzzy sets are difficult to compare directly because they are partially ordered rather than the linear or strictly ordered crisp values. In this study, the fuzzy weights were Defuzzified using the centroid method.

$$\tilde{A}_{ij} = (l_{ij}, m_{ij}, u_{ij)} \quad X^* = \frac{\mathbf{l+m+h}}{3} \quad \text{[Eq. 3.3]}$$

Step 7: Calculate and Normalize the weight vector of each layer: To be convenient to compare the relative importance between each layer, these crisp weights are normalized. Therefore, the weights for each factor are obtained by normalizing either row or column. Normalized weighted calculated using the following equation.

$$NW_i^c = \frac{wi^c}{\sum i=1^k \ wi^c} \quad \text{[Eq. 3.4]}$$

Where NW_i^c is the normalized weight, and W_i^c is the weight of each criterion and sub-criteria.

Step 8: Check the consistency: a consistency ratio is computed for each matrix to check the consistency of the F-AHP result, as uniformity in experts' judgments is extremely significant to achieving optimum results. The matrix is considered consistent if the contradictions among the pairwise comparisons are within a predefined threshold: consistency ratio. The consistency was checked using [Eq.3.5].

$$CR = \frac{CI}{RI} \quad \text{[Eq. 3.5]}$$

$$CI = \frac{\lambda max - n}{n-1} \quad \text{[Eq. 3.6]}$$

Where CR and CI refer to consistency ratio and consistency index, respectively. RI denotes random index, it is referred from table 3.3, λmax *is* the max eigenvalue of the comparison matrix, and *n* is the number of the elements

Table 3.3 Scale of relative importance used in the pairwise comparison matrix.

Size(n)	1	2	3	4	5	6	7	8
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40

All pairwise comparisons done by considering the group of factors and factors must reflect the value of CI ≤ 0.1, whereas if CI value is not achieved within the mentioned limit for any matrix, then the judgment is invited again to debate and revise the comparison matrix. In this study, the consistency ratio was done for all the matrixes. The matrix with a consistency ratio greater than 0.1 was rejected and proceeded only with the consistent matrixes.

Step 9: The calculations of the global weights: The sub-criteria weights are 'local weights,' which are transformed to 'global weights' by multiplying with the weight of their parent criterion.

3.7.3.3 Fuzzy Technique for Order Preference by Similarity to Ideal Solution, F- TOPSIS

TOPSIS is a multi-criteria decision-making method introduced by Huang and Yoon (1981). The basic idea behind this approach is that the chosen alternative should have the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution. This approach is effective and practical in finding the best possible solution to complex problems where a multi-criteria decision is to be made (Kaushik & Singh, 2020).

In the conventional TOPSIS method approach, personal judgments are represented by crisp values. However, assigning a crisp value to individual preferences is not always possible. In such cases, linguistic judgments are preferred over crisp values (Kaushik & Singh, 2020). Fuzzy set theory can be used to present linguistic value. Singh & Sarkar (2019) stated that F-TOPSIS is an appropriate method for solving real-life problems. It allows decision-makers to assign linguistic performance ratings to the alternatives instead of precise numbers. It has been extensively used in various fields for solving complex issues of quality control, design of products, human resources management, location analysis, transport, production, etc. (Kaushik & Singh, 2020).

Table 3.4 Management practices to overcome significant factors affecting CLP and their code

Preconstruction phase management	
Use of software in planning work packages	SPPM1
Appointed experienced designer	SPPM2
Well-Defined scope of work	SPPM3
Complete and approval of drawing before commencement of construction	SPPM4
Realistic work schedule	SPPM5
Collaborative procurement	SPPM6
Project completion plan	SPPM7
Short interval plan	SPPM8
Project start-up plan	SPPM9
Fulfill Regulatory requirement	SPPM10
Site management and construction method	
Proper site administration	SSM1
Provide necessary site facilities	SSM2
Proper construction site layout	SSM3
Dynamic site layout plan	SSM4
Site security plan	SSM5
Traffic control plan	SSM6
Adoption of advanced technologies	SSM7
Effective supervision and quality control	SSM8
Human resource management	
Detailed Workforce Plan	SHRM1
Hiring skilled workers	SHRM2
Training of workers	SHRM3
Incentive/Bones	SHRM4
Increase labors wage/salary	SHRM5
Timely payment	SHRM6
Proper arrangement of labors	SHRM7
Clear delegation of responsibility	SHRM8
Worker's participation in decision making	SHRM9
Skill assessment and evaluation	SHRM10
Correct bad labor characteristics	SHRM11
Team building between labors	SHRM12
Good relation between labor and superintendents	SHRM13
Site attendance	SHRM14
Drug and alcohol test	SHRM15
Shift-based working hours	SHRM16
Hold regular meetings with labors	SHRM17
Giving workers breaks time and day off for holidays	SHRM18
Materials management	
Procurement plans for materials	SMM1
Provide materials on time	SMM2
Just-in-time material delivery	SMM3
Proper materials handling systems	SMM4
Long-lead materials identification	SMM5
Materials status database	SMM6
Post receipt preservation and maintenance	SMM7
On-site materials tracking	SMM8
Equipment and tools management	
Equipment procurement plans	SETM1
Provide tools and equipment on time	SETM2
Just-in-time equipment and tool	SETM3
Equipment maintenance	SETM4
Equipment productivity analysis	SETM5
Safety and health management	
Safety and health plan	SSHM1
Assign safety engineer	SSHM2
Safety and health training	SSHM3
Implement safe work method statement	SSHM4
Provide hygienic site conditions	SSHM5
Toolbox safety meetings	SSHM6
Frequent housekeeping	SSHM7
Keep workplace safety signs facility	SSHM8
Provide properly maintained PPE	SSHM9
Effective site safety communication	SSHM10
Anticipating problems and planning in advance	SSHM11
Stakeholders' management	
Coordination between all stakeholders	SSTM1
Regular and effective communication on construction status	SSTM2
Enhancing leadership and decision making of supervisors	SSTM3
Proper project financing	SSTM4
Stable organizational structure	SSTM5

In this study, F-TOPSIS is adopted to rate management practices based on their potential to overcome each significant factor affecting CLP. Therefore, 65 management practices to overcome factors affecting CLP are rated by their potential to overcome the 15 significant factors, weighted through F-AHP. Before computing F-TOPSIS, Similar to the Fuzzy AHP phase, the management practice to overcome CLP barriers are represented by code before starting the F-TOPSIS procedure to ease the analyses and save space for data presentation. Table 3.4 illustrates the identified management practices with their respective codes and the hierarchical structure used for F-TOPSIS.

The systematic step using F-TOPSIS followed in this study are described below. A similar procedure was adopted by Belhadi et al. (2017), Singh & Sarkar (2019), Patil & Kant (2014), Ali Sadat et al. (2021), and Parung et al. (2018). Figure 3.6 presents the hierarchical structure used for F-TOPSIS.

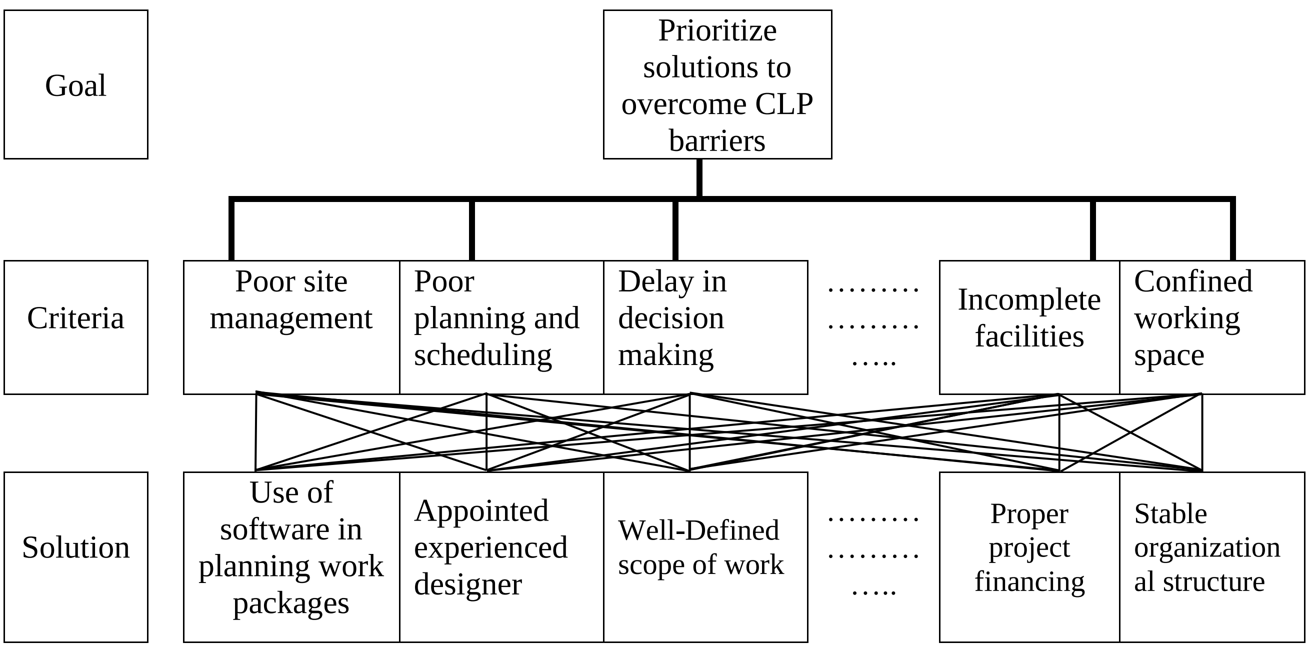

Figure 3.6 Hierarchical structure used for F-TOPSIS.

Step 1: Define each alternative's linguistic value/rating value corresponding to the criteria. The linguistic variables used in this study are illustrated in table 3.5 below.

Table 3.5 Linguistic variables and TFN for solutions ratings.

Variables	Fuzzy no defined	Membership functions (TFN)
VH	Very high	(7,9,11)
H	High	(5,7,9)
M	Medium	(3,5,7)
L	Low	(1,3,5)
VL	Very Low	(1,1,3)

Step 2: Construct the fuzzy decision matrix for alternatives by considering a group of k decision makers (D1, D2, D3 …, Dk) containing m alternatives (A1, A2, A3, …, Am) and n criteria (C1, C2, C3, …, Cn).

$$\begin{array}{c c} & \begin{array}{cccc} C1 & C2 & \cdots & Cn \end{array} \\ \begin{array}{c} A1 \\ A2 \\ \vdots \\ Am \end{array} & \begin{bmatrix} r11 & r12 & \cdots & r1n \\ r21 & r22 & \cdots & r2n \\ \vdots & \vdots & \vdots & \vdots \\ rm1 & rm2 & \cdots & rmn \end{bmatrix} \end{array}$$

Where r_{mn} is the rating of alternative Am with respect to criterion C_n

Step 3: Aggregate fuzzy rating for the solutions: Fuzzy rating of the N[th] decision maker $\tilde{X}_{abN}$ = (l_{abN}, p_{abN}, u_{abN}) where a = 1,2,3, 4,…,m and b = 1,2,3,4,…,n then the fuzzy aggregated fuzzy rating $\tilde{X}_{ab}$ of solutions with respect to all criteria is given by $\tilde{X}_{ab}$ = (l_{ab},p_{ab},u_{ab}), where

$$a = \min_N \{l_{abN}\},\ b = \frac{1}{N}\sum_{n=1} N\, P_{abN},\ c = \max_N \{u_{abN}\} \qquad \text{[Eq. 3.7]}$$

Step 4: Calculate the Normalized fuzzy-decision matrix. A linear scale transformation normalizes the raw data so that all criteria become comparable. The normalized fuzzy decision matrix denoted by $\tilde{R}$ is defined as follows:

$$\tilde{R} = [r_{ij}]_{m\times n},\ i=1,2\ldots\ldots m;\ j=1,2,\ldots\ldots n \qquad \text{[Eq. 3.8]}$$

Where $$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right) \text{ where } c_j^* = \max_i c_{ij} \text{ (Benefit criteria)} \qquad \text{[Eq. 3.9]}$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right) \text{ where } a_j^- = \min_i a_{ij} \text{ (Cost criteria)} \qquad \text{[Eq. 3.10]}$$

Cost criteria negatively contribute to the objective. Therefore, this study considers sub-criteria as a cost criterion since the study's goal is to minimize/overcome the criteria (i.e., factors) and improve CLP.

Step 5: Compute the weighted Fuzzy normalized matrix. The weighted normalized matrix $\tilde{u}$ for each criterion is obtained by multiplying its weight w_j with the normalized fuzzy matrix $\tilde{r}_{ij}$.

$$\tilde{V}=[\tilde{u}_{ij}]_{m\times n},\ i=1,2,\ldots m;\ ,\ j=1,2,\ldots n \qquad \text{[Eq. 3.11]}$$

where $$\tilde{u}_{ij}=\tilde{r}_{ij}(.)W_j \qquad \text{[Eq. 3.12]}$$

Step 6: For each alternative, determine the fuzzy positive-ideal solution (FPIS) and fuzzy negative-ideal solution (FNIS). FPIS A^+ (aspiration levels) and FNIS A^- (the worst levels) are defined as:

$$A^{+}=\{v_1^{+},\ldots\ldots v_n^{+}\},\text{where } v_j^{+}=\{\max(v_{ij}) \text{ if } j\in J;\ \min(v_{ij}) \text{ if } j\in J'\}\ j=1,2,3,4,\ldots\ldots..,n \qquad \text{[Eq. 3.13]}$$

$$A^{-}=\{v_1^{-},\ldots\ldots v_n^{-}\},\text{where } v_j^{-}=\{\min(v_{ij}) \text{ if } j\in J;\ \max(v_{ij}) \text{ if } j\in J'\},\ j=1,2,3,4,\ldots\ldots..,n \qquad \text{[Eq. 3.14]}$$

Step 7: Calculate the distance of each solution from FPIS and FNIS. The distances ($d_i^{+}$and d_i^{-}) of each alternative from A^{+} and A^{-} can be currently calculated by the area compensation method.

$$d_i^{+}=\{\textstyle\sum_{j=1}^{n}(\ v_{ij}-v_{ij}^{+})^2\}^{1/2},\ i=1\ldots..,m \qquad \text{[Eq. 3.15]}$$

$$d_i^{-}=\{\textstyle\sum_{j=1}^{n}(\ v_{ij}-v_{ij}^{-})^2\}^{1/2},\ i=1\ldots..,m \qquad \text{[Eq. 3.16]}$$

Step 8: Determine the relative closeness coefficients (relative gaps-degree) and improve alternatives for achieving aspiration levels in each criterion. Relative closeness is defined as:

$$CC_i=\frac{d_i^{-}}{d_i^{-}+d_i^{+}}\ ,\ i=1,\ldots\ldots m\ C_i\in(0,1) \qquad \text{[Eq. 3.17]}$$

Step 9. Rank the alternatives based on their closeness coefficient Cci. The set of alternatives is arranged according to descending order. The final rankings are obtained according to their priorities as the most preferred and least preferred ideal solution to the given problem/factors affecting CLP.

3.7.4 Sensitivity Analysis

A sensitivity analysis is a valuable and powerful tool to check the robustness of the solution ranking by varying the weight of the barriers (Singh & Sarkar, 2019). Its primary purpose is to discover the new ranking of the alternatives by varying the weights of criteria in various cases. Sensitivity analysis can be conducted in multiple ways, such as varying the weights given to a criterion or altering the weights assigned to a particular expert.

In this study, single-dimensional weight sensitivity analysis was adopted. According to Karande et al. (2016), the weight of the most critical criterion in a decision-making problem was varied within a feasible range, and all other criteria weights were adjusted equally to satisfy the weight additivity constraint. Since a criterion with the highest weight assumes to have a significant influence on the preference ranking of the alternatives. The difference in weight for the most crucial criterion is apportioned equally among the remaining criteria. In this case, the weight of the critical criterion can be reduced up to 0 and increased up to w'_j, the value of w'_j can be obtained applying the following equation 3.18.

$$w'_{j=} [\ w_{jmax} +(n-1)\ w_{jmin}] \qquad \text{[Eq. 3.18]}$$

Where w_{jmax} is the highest criterion weight, w_{jmin} is the lowest criterion weight and n. Increasing the weight of the most important criterion beyond w'j will make the lowest criterion weight to be negative. Similarly, Gani et al. (2021) adopted this approach to conduct a sensitivity analysis.

3.8 Reliability and Validity

According to Richard & Anita (2015), it is crucial to be sure of the validity and reliability of the work for the confidence that someone may have in the findings. Therefore, this study's reliability and validity checking process is discussed below.

3.8.1 Reliability Analysis

Reliability refers to the stability of the measuring instrument used and its consistency over time, what happens if a study is carried out again if it is replicated (Dey et al., 2017). Cronbach's Alpha coefficient measures the reliability or internal consistency of test items.

The normal range of Cronbach's Alpha value is between 0 and 1, in which a higher value reflects a higher degree of consistency (Dey et al., 2017). The Cronbach's Alpha Coefficient calculated using the following equation.

$$\alpha = \frac{k}{k-1}[1 - \frac{\sum s^2 y}{s^2 x}] \qquad \text{[Eq. 3.19]}$$

Where k is a number of items in the measuring instrument, $\sum s^2 y$ is the sum of the variance points of each item in the measuring instrument and $s^2 x$ = variance of each item (Sürücü & Maslakçi, 2020).

Table 3.6 The classification of Cronbach's Alpha Coefficient

Cronbach's Alpha Coefficient	Internal Consistency
$\geq 0,9$	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

In this study, Cronbach's Alpha coefficient measure was conducted using equation 3.9 by excel to check the reliability of the data collected through the first questionnaire survey.

Table 3.7 Reliability test result for survey I

Variable	Description	Values	Internal Consistency
A	Cronbach's Alpha coefficient	0.73	Acceptable

Based on table 3.7, Cronbach's Alpha coefficient result is 0.73, $0.8 \leq \alpha < 0.7$, it indicated that the internal consistency of the first questionnaire's is acceptable, implying the data's reliability.

For questioner survey II, the reliability of the pair-wise subjective judgments was verified using the consistency check. This consistency check was conducted for all comparison matrices. The consistency result for all matrices lay below 0.1(CI $\leq$ 0.1), the higher limit for matrices to be consistent.

3.8.2 Validity Analysis

Content validity was conducted for validity analysis. It validates the questionnaire through piloting among colleagues and construction professionals. Therefore, five academicians and construction professionals evaluated the draft questionnaire to check the clarity, comprehensiveness, and appropriateness of the questions, range of responses, and efficiency with which the respondents completed it. The number of professionals who participated fulfills the minimum number of professionals who should be participated in the pilot study specified by Hertzog (2008), which is more than 5% of the total questionnaire distributed. After receiving their feedback and comments, the questionnaire was slightly modified as per the comment.

3.9 Operationalization of Variables

The following table illustrates the operationalization of variables, including the objective variable, indicator, data source, method of data collection, and data analysis adopted to complete the research.

Table 3.8 Operationalization of variables

Objective	Variable	Indicator	Data Source	Data Collection	Data Analysis
Explore the determinant factors affecting CLP	62 factors affecting CLP	Top 20% with high RII value	Primary and secondary data	Questionnaire survey I	RII
Prioritize the significant factors affecting CLP.	15 significant factors CLP	Priority /pairwise comparison	Primary data	Questionnaire survey II	F-AHP
Determine management practices to overcome significant factors affecting CLP.	65 management practices	Top 20% with high C_{ci} value	Primary and secondary data	Questionnaire survey II	F-TOPSIS
Develop a framework to determine means for better CLP.	15 factors and 13 solutions	Robust solution	Primary data	Questionnaire survey II	Sensitivity analysis

3.10 Ethical Consideration

According to Richard & Anita (2015), the essential aspects of moral and ethical concerns for research include the use of other people's 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 purposes.

CHAPTER FOUR – DATA ANALYSIS AND DISCUSSION

4.1 Introduction

This chapter analyzes and discusses the data from the questionnaire surveys. Its primary goal is to determine factors affecting CLP and management practices to overcome those factors. Two distinct sets of questionnaires were used to collect the data. The data were analyzed using Excel spreadsheets and RII, F-AHP, and F-TOPSIS data analysis techniques.

As discussed in the above sections, two questionnaire surveys were conducted to address the research objectives. Therefore, 40 questionnaires were distributed to project managers and site engineers for survey I, and 35 questionnaires were returned successfully. Similarly, 40 questionnaires were distributed for questionnaire survey II to the same respondents who participated in survey I and 32 questionnaires returned successfully. Table 4.1 shows the total response rate for both surveys.

Table 4.1 Summary of questionnaire distribution and response rate

Questionnaire no	**Survey I**	**Survey II**
Total distributed	40	40
Questionnaires collected	35	32
Questionnaire’s response rate	87.5%	80%

Based on table 4.1, the questionnaire response rate for questionnaires survey I is 87.5%, and for survey II is 80%. It implies that the data response rate is enough to conduct the analysis.

4.2 General Respondent’s Information

The general respondent's information/demographic analysis involves all the possible detailed information about the respondent's type of organization, years of experience, and respondent qualification (Abdul et al., 2019). In order to attain this, the first sections of both questionnaires were mainly designed to provide background information about the respondents regarding category classification, educational background, and working experience.

4.2.1 Organization's Category

This section describes the category of the organization under which the respondents work. In this study, the firms that participated in this survey are categorized into contractors and clients. Table 4.2 illustrates the company's category.

Table 4.2 Organization's category of the respondents

	Survey I		Survey II	
Organization	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Client	6	17.2%	6	18.7%
Contractor	29	82.8%	26	81.3%

The results indicated that most of the respondents for both surveys are contractors, 82.8% and 81.3% for surveys I and II, respectively. Furthermore, the response rate of clients for survey I is 17.2% and 18.7% for survey II. It shows that most respondents were contractors who knew about labor productivity in detail.

4.2.2 Grade of Companies

As discussed in section 4.2, 82.8% of the respondents work for different contractors. Therefore, the following table 4.3 provides the grade of the contractors for which the respondents work.

Table 4.3 Grade of companies

Grade of companies	Survey I		Survey II	
	Frequency	**Percentage**	**Frequency**	**Percentage**
Bc1	8	27.6%	7	26.9%
Bc2	2	6.9%	2	7.7%
Bc3	3	10.3%	3	11.5%
Bc4	6	20.7%	6	23%
Bc5	10	34.5%	8	30.7%

The grade of contractors who participated in surveys I are 27.6% BC1, 6.9% BC2, 10.3 % BC3, 20.7% and 34.5% BC5. Similarly, for survey II, the participants are 26.9% BC1, 7.7% BC2, 11.5% BC3, 23% BC5 and 30.7% BC5. The result indicates that most data were collected from BC1 five and BC5 grade contractors.

The result indicates that most data were collected from BC1 five and BC5 grade contractors. It implies that most of the active building construction projects in Adama city have been undertaken by BC1 five and BC5 grade contractors.

4.2.3 Respondents' Profile

4.2.3.1 Respondents' Working Position

The respondents selected for this study are directly associated with Adama city 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 resident engineer.

Table 4.4 Respondents' work position

Job position	Survey I		Survey II	
	Frequency	Percentage	Frequency	Percentage
Project manager	8	22.9%	6	18.7%
Site engineer	21	60%	20	62.5%
Resident engineer	6	17.1%	6	18.7%

Based on table 4.4, 22.9% project managers, 60% site engineers, 17.1% resident engineers participated in survey I. And 18.7% project managers, 62.5% site engineers, 18.7% resident engineers participated in survey II. The result confirmed that site engineers have a higher participation rate in the study than project managers and resident engineers.

4.2.3.2 Educational Background of the Respondents

This section discusses the educational background of the respondent in the construction field. Table 4.5 presents the educational level of the respondents.

Table 4.5 Educational background of the respondent

Educational background	Survey I		Survey II	
	Frequency	Percentage	Frequency	Percentage
Master's Degree	4	11.4%	4	12.5%
Bachelor Degree	31	88.6%	28	87.5%

The result shows that most of the respondents have a Degree of Bachelor of Science in a construction related field, with percentages of 88.6% for survey I and 87.5% for survey II, respectively. Moreover, 11.4% and 12.5% of participants have Master's degrees for surveys I and II, respectively. According to the statistic, the respondents have the adequate educational qualification to recognize and respond to the questions listed in the survey.

4.2.4 Experience of the respondent

Section 4.3.6.1 describes that the respondents are project managers, site engineers, and resident engineers. Therefore, this section describes the respondents' experience in construction-related work. The below table provides the work experience of the respondents for both surveys.

Table 4.6 Experience of the respondent in the construction project

Work Experience (Year)	Survey I		Survey II	
	Frequency	Percentage	Frequency	Percentage
0-5	17	48.6%	15	46.9%
6-10	11	31.4%	10	31.3%
11-15	5	14.3%	5	15.6%
16-20	2	5.7%	2	6.3%

Of the respondents, 48.6% have 0-5 years of experience, 31.4% have 6-10 years of experience, 14.3% have 11-15 years of experience, and 5.7% have 16-20 years of experience in the construction industry for the survey I. Similarly, for survey II, 46.9% have 0-5 years of experience, 31.3% have 6-10 years of experience, 15.6% have 11-15 years of experience, and 6.3% have 16-20 years of experience in the construction industry. The result also indicates that the respondents have sufficient years of work experience to understand the questions and reply to adequate answers.

4.3 Factors Affecting CLP

In this section, respondents' responses are ranked according to the factors' effect level by computing their mean score and relative importance index (RII). The results are categorized into subsections for the categories and the overall factors. Finally, the determined significant factors are presented and discussed at the end of this sub section.

4.3.1 Factors Affecting CLP with Their Respective Group

Among the eight groups of factors, material related factors (average RII=0.775) ranked 1st, followed by equipment tools and related factors (average RII= 0.738). Similarly, technical related factors (average RII= 0.645), finance related factors (average RII=0.644), and labor related factors (average RII=0.620) ranked from 3rd to 5th. The three least ranked groups of factors are management related factors (average RII=0.618), safety and health related factors (average RII=0.565), and project environment and external related factors (average RII=0.558).

Table 4.7 Ranked groups of factors affecting CLP

Groups of factors affecting CLP	**Average**		
	Mean score	**RII**	**Rank**
Management related factors	3.088	0.618	6th
Technical related factors	3.223	0.645	3rd
Finance related factors	3.219	0.644	4th
Labor related factors	3.101	0.620	5th
Material related factors	3.875	0.775	1st
Equipment tools and related factors	3.688	0.738	2nd
Safety and health related factors	2.823	0.565	7th
Project environment and external related factors	2.792	0.558	8th

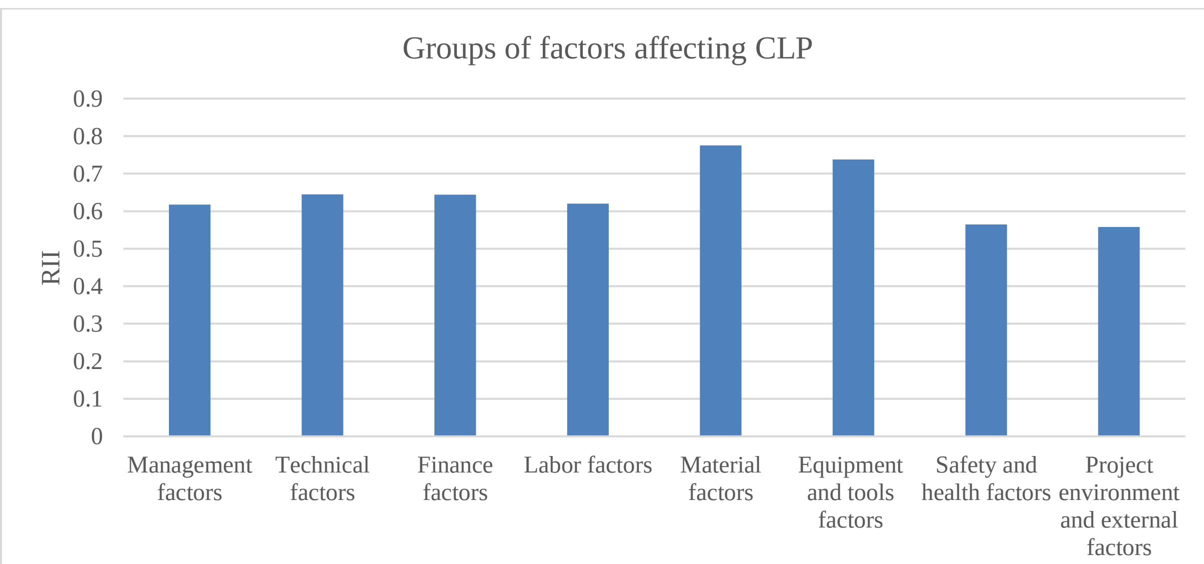

Figure 4.1 Groups of factors affecting CLP

4.3.1.1 Management Related Factors

Based on table 4.7, management related factors are ranked 6th out of the eight groups, with an average of 0.618 RII. There are 15 factors affecting CLP in this group, three of which are most significant. These factors are poor site management, poor planning and scheduling, and delays in decision making. Table 4.8 illustrates the mean score, RII, and management-related factors ranking.

Table 4.8 Ranked management related factors

Management related factors	Mean score	RII	Group rank	Overall rank
Poor planning and scheduling	4.125	0.825	2nd	5th
Poor control and supervision	3.688	0.738	5th	18th
Lack of supervisors' experience	1.688	0.338	14th	59th
Inspection delay	3.688	0.738	5th	18th
Delay in decision making	3.938	0.788	3rd	9th
Delay in responding to information	2.938	0.588	10th	42nd
Poor site management	4.250	0.850	1st	3rd
Unclear instruction to labors	1.563	0.313	15th	62nd
Lack of periodic meetings with labors	2.375	0.475	11th	50th
Lack of providing incentive	3.750	0.750	4th	16th
Lack of training to labor	3.563	0.713	7th	23rd
Crew size and composition	3.563	0.713	7th	23rd
Contractual dispute	2.250	0.450	12th	52nd
Insufficient coordination among parties	1.813	0.363	13th	57th
Misunderstanding between labor and superintendent	3.125	0.625	9th	38th

The first ranked management related factor is poor site management (0.85 RII) and ranked 3rd among overall factors. Following poor site management, the 2nd significant factor in this group is poor planning and scheduling (0.825 RII), which is ranked 5th overall. Delay in decision making (0.788 RII) ranked 3rd and 9th in this group and overall factors, respectively. Lack of providing an incentive (0.75 RII) ranked 4th and 16th within this group and among the overall factors, respectively. Poor control and supervision (0.738 RII) and inspection delay (0.738 RII) ranked 5th within this group and 18th among the overall factors, respectively.

Lack of training to labor (0.713RII) and crew size and composition (0.713 RII) ranked 7th in this group and 23rd among the overall factors. Misunderstanding between labor and superintendent (0.625 RII), delay in responding to information (0.588 RII), lack of periodic meetings with labor (0.475 RII), and contractual dispute (0.45 RII) ranked from 9th to 12th in this group, and ranked 38th, 42nd, 50th, and 52nd, respectively, from the overall factors. Insufficient coordination among parties (0.363 RII), lack of supervisors' experience (0.338 RII), and unclear instruction to labor (0.313 RII) are determined as the least three factors affecting CLP under management related groups and ranked 57th, 59th, and 62nd from the overall factors, respectively.

4.3.1.2 Technical Related Factors

Technical related factors (0.645 average RII) are the 3rd group affecting CLP out of eight groups, following equipment and tools and material related factors. Table 4.9 shows seven factors under this group with their mean score, RII, and ranking.

Table 4.9 Ranked technical related factors

Technical related factors	Mean Score	RII	Group Rank	Overall rank
Rework	3.375	0.675	4th	30th
Variation/ change of orders during execution	3.563	0.713	2nd	23rd
Complexity of the design and project	2.688	0.538	6th	45th
Lack of compatibility among contract documents	3.188	0.638	5th	37th
Incomplete and Inaccurate drawing	3.688	0.738	1st	18th
Lack of clarity of technical specifications	3.563	0.713	2nd	23rd
Improper construction method	2.500	0.500	7th	48th

Incomplete and inaccurate drawing (RII 0.738) is ranked 1st in this group and 18th among overall factors, respectively. Variation/change of orders during execution (0.713RII) and lack of clarity of technical specifications (0.713 RII) are the top factors affecting from this group following incomplete and inaccurate drawing (RII 0.738) and ranked 23rd from the overall group. Similarly, rework (0.675 RII), lack of compatibility among contract documents (0.638 RII), the complexity of the design and project (0.538 RII), and improper construction method (0.5 RII) are the least ranked factors in their group and ranked 30th, 37th,45th and 48th among the overall factors.

4.3.1.3 Finance Related Factors

Finance related factors (0.644 average RII) ranked in 4th place out of the eight groups of factors affecting CLP. Of the four factors identified in this group, payment delay was determined to be the most significant factor affecting CLP. Table 4.10 illustrates the mean score, RII, and ranking of four factors affecting CLP under this group.

Table 4.10 Ranked finance related factors

Finance related factors	Mean Score	RII	Group Rank	Overall rank
Inflation in the cost of execution	2.625	0.525	3rd	47th
Improper project financing	2.375	0.475	4th	50th
Payment delay	4.063	0.813	1st	7th
Low labor wage	3.813	0.763	2nd	13th

Payment delay (0.813 RII) is ranked 1st and 7th among this group and overall factors, respectively, indicating that this factor is one of the significant factors affecting CLP. Low labor wage (0.763 RII) is the 2nd most important factor affecting CLP in this group and ranked 13th among the overall factors. Similarly, Inflation in the cost of execution (0.525 RII) and improper project financing (0.475 RII) are ranked 3rd and 4th in their group, and 47th and 50th among the overall factors, respectively.

4.3.1.4 Labor Related Factors

The labor related factors (0.620 average RII) are ranked 5th out of eight. Table 4.7 shows that there are 13 factors affecting CLP in this group. Of these factors, lack of labor motivation and lack of skilled and specialized labor are the most significant factors affecting CLP.

Lack of motivation of labor (0.800 average RII) ranked 1st in this group and 8th overall. Following the lack of motivation of workers, lack of skilled and specialized labor ranked (0.763 RII) as the 2nd most significant factor affecting CLP in this group and 13th among overall factors. Bad labor characteristics (0.688 RII), Misunderstanding among labor (0.675 RII), and physical fatigue (0.663 RII) are ranked from 3rd to 5th within their group and 28th,30th, and 32nd from the overall factors, respectively.

Both drug abuse and alcoholism (0.650 RII) and late arrival, early quit, and unscheduled break (0.650RII) are ranked 6th and 34th within the group and overall factors, respectively. Similarly, the poor economic condition of workers (0.625RII) and labor personal problems (0.625 RII) ranked 8th and 38th within the group and overall factors, respectively. Physical fitness of labor (0.563 RII), increase in laborer's age (0.550 RII), communication/language barrier (0.438 RII), and labor absenteeism (0.375 RII) are the least ranked factors in this group and ranked 43rd, 44th, 42nd, 53rd and 56th from the overall factors, respectively. Table 4.11 provides each factor's mean score, RII, and ranking under labor related group.

Table 4.11 Ranked labor related factors

Labor related factors	**Mean score**	**RII**	**Group rank**	**Overall rank**
Lack of skilled and specialized labor	3.813	0.763	2nd	13th
Lack of motivation of workers	4.000	0.800	1st	8th
Bad labor characteristics	3.438	0.688	3rd	28th
Late arrival, early quit, unscheduled break	3.250	0.650	6th	34th
Misunderstanding among labors	3.375	0.675	4th	30th
Communication/ Language Barrier	2.188	0.438	12th	53th
Poor economic condition of workers	3.125	0.625	8th	38th
Increase in laborer’s age	2.750	0.550	11th	44th
Physical fitness of labor	2.813	0.563	10th	43rd
Labor absenteeism	1.875	0.375	13th	56th
Physical fatigue	3.313	0.663	5th	32nd
Labor personal problems	3.125	0.625	8th	38th
Drug abuse and alcoholism	3.250	0.650	6th	34th

4.3.4.5 Material Related Factors

Table 4.7 shows that material related factors (0.775 average RII) affect are ranked 1st out of eight factors. It indicates that factors categorized under material related factors highly affect CLP. This category consists of four factors: the shortage of construction materials and the poor quality of construction materials are the most significant factors affecting CLP. Table 4.12 shows the mean score, RII, and ranking of material related factors.

Table 4.12 Ranked material related factors

Material related factors	Mean Score	RII	Group rank	Overall rank
Shortage of construction material	4.375	0.875	1st	1st
Slow adoption of materials	3.750	0.750	3rd	16th
Poor quality of construction materials	3.938	0.788	2nd	9th
Unsuitable material storage location	3.438	0.688	4th	28th

The shortage of construction materials (0.875 RII) is the most significant factor affecting CLP in this category and among overall factors. Poor quality of construction materials (0.788 RII) is the major factor affecting CLP in this group, following the shortage of construction materials and 9th among the overall factors. Slow adoption of materials (0.75 RII) and unsuitable material storage locations (0.688 RII) ranked 3rd and 4th in their group, respectively, and ranked 16th and 28th in the overall factors.

4.3.4.6. Equipment and Tools Related Factors

The above table 4.7 reveals that equipment and tools related factors (0.738 average RII) are the 2nd highest ranked group of factors affecting CLP out of eight groups. It indicates that the factors under equipment and tools have a high effect on CLP. Two of the four factors categorized under this group are the most significant factors affecting CLP. Table 4.13 shows the equipment and tool-related factors with their mean score, RII, and ranking.

Table 4.13 Ranked equipment and tools related factors

Equipment and tools related factors	Mean score	RII	Group rank	Overall rank
Shortage of tools and equipment	3.938	0.788	2nd	10th
Waiting for equipment to arrive	3.625	0.725	3rd	21st
Poor quality of tools	3.500	0.700	4th	27th
Old and inefficient equipment	4.313	0.863	1st	2nd

Old and inefficient equipment is the most significant factor affecting CLP (0.863 RII) in this group and 2nd among the overall factors. The 2nd most significant factor affecting CLP within this group is the shortage of tools and equipment (0.788 RII). It is also ranked 10th among the overall factors affecting CLP.

Waiting for equipment to arrive (0.725 RII) and poor quality of tools (0.700 RII) ranked 3rd and 4th within this group and 21st and 27th in the overall factors, respectively.

4.3.4.7 Safety and Health Related Factors

The safety and health-related factors (0.565 average RII) ranked 7th out of 8 groups. Out of the six safety and health factors identified, the lack of safety tools and violation of safety precautions are the most significant factors affecting CLP. Table 4.14 provides the mean score, RII, and safety and health factors ranking.

Table 4.14 Ranked safety and health related factors

Safety and health related factors	Mean score	RII	Group rank	Overall rank
Site accident	3.313	0.663	3rd	32nd
Lack of Safety tools (PPE)	4.188	0.838	1st	4th
Absence of safety training and program	1.625	0.325	5th	60th
Violation of safety precautions	3.813	0.763	2nd	13th
Insufficient lighting	1.500	0.300	6th	62rd
Hazardous Work Area	2.500	0.500	4th	48th

Lack of safety tools (PPE) (RII 0.838) ranked 1st in this group and 4th among the overall factors. Violation of safety precautions (RII 0.763) ranked 2nd and 13th within this group and overall factors, respectively. Site accidents (0.663 RII), hazardous work areas (0.500 RII), absence of safety training and program (0.325 RII), and insufficient lighting (0.300 RII) are the least four factors affecting CLP in this group and ranked 32nd, 48th, 60th, and 62nd, respectively among the overall factors.

4.3.4.8 Project Environment and External Factors

From table 4.7, the project environment and external related factors (0.558 average RII) are the least ranked group out of eight. Nine project environments and external related factors were identified, out of which the incomplete facilities (water, power supply, and sanitary) and confined working space are the most significant factors affecting CLP. Table 4.15 illustrates the mean score, RII, and ranking of the project environment and external related factors.

Table 4.15 Ranked project environment and external related factors

Project environment and external	Mean Score	RII	Group rank	Overall rank
Confined of working space	3.875	0.775	2nd	12th
Project location	3.625	0.725	3rd	21st
Incomplete facilities	4.125	0.825	1st	5th
Restricted site access	2.000	0.400	7th	55th
Culture/ customs of the community	1.625	0.325	9th	60th
Religious and other holidays	3.250	0.650	4th	34th
Extreme weather conditions	2.688	0.538	5th	45th
Government policies	1.750	0.350	8th	58th
Political instability	2.188	0.438	6th	53rd

Incomplete facilities (water, power supply, and sanitary) (RII 0.825) ranked 1st and 5th in this group and overall factors. Confinement of working space (0.755RII) is the most significant factor following incomplete facilities in this group, ranked 12th among the overall factors. Project location (0.725 RII), religious and other holidays (0.650 RII), and extreme weather conditions (0.538 RII) ranked from 3rd to 5th within this group, but 21st, 34th, and 45th in the overall factors, respectively. Similarly, political instability (0.438 RII), restricted site access (0.400RII), government policies (0.350 RII), and culture/customs of the community (0.325RII) are the four least ranked factors in this group 53rd, 55th, 58th, and 60th, respectively among overall factors.

4.4 Significant Factors Affecting CLP

Based on the Pareto principle, the top 20% of factors are determined as significant factors that cause 80% of the CLP loss. Accordingly, 20% of 62 factors are 13 factors. However, the three factors have the same ranking to be the 13th most significant factor. Therefore, 15 factors are determined as the most significant factors affecting CLP. The 20% factors are shortage of construction material, old and inefficient equipment, poor site management, lack of safety tools (PPE), poor planning and scheduling, incomplete facilities (water, power supply, and sanitary), payment delay, lack of inspiration of workers, delay in decision making, shortage of tools and equipment, poor quality of construction materials, confined working space, low labor wage, lack of skilled and specialized labor and violation of safety precautions. The mean score and RII of these factors are provided in table 4.16.

Table 4.16 Significant factors affecting CLP

Significant factors affecting CLP	Mean Score	RII	Related Group	Rank
Shortage of construction material	4.375	0.875	Material	1st
Old and inefficient equipment	4.313	0.863	Equipment and tools	2nd
Poor site management	4.25	0.85	Management	3rd
Lack of Safety tools (PPE)	4.188	0.838	Safety and health	4th
Poor planning and scheduling	4.125	0.825	Management	5th
Incomplete facilities	4.125	0.825	Project environment and external	6th
Payment delay	4.063	0.813	Finance	7th
Lack of inspiration of workers	4	0.8	Labor	8th
Delay in decision making	3.938	0.788	Management	9th
Shortage of tools and equipment	3.938	0.788	Equipment and tools	10th
Poor quality of materials	3.938	0.788	Material	11th
Confined working space	3.875	0.775	Project environment and external	12th
Low labor wage	3.813	0.763	Finance	13th
Lack of skilled /specialized labor	3.813	0.763	Labor	14th
Violation of safety precautions	3.813	0.763	Safety and health	15th

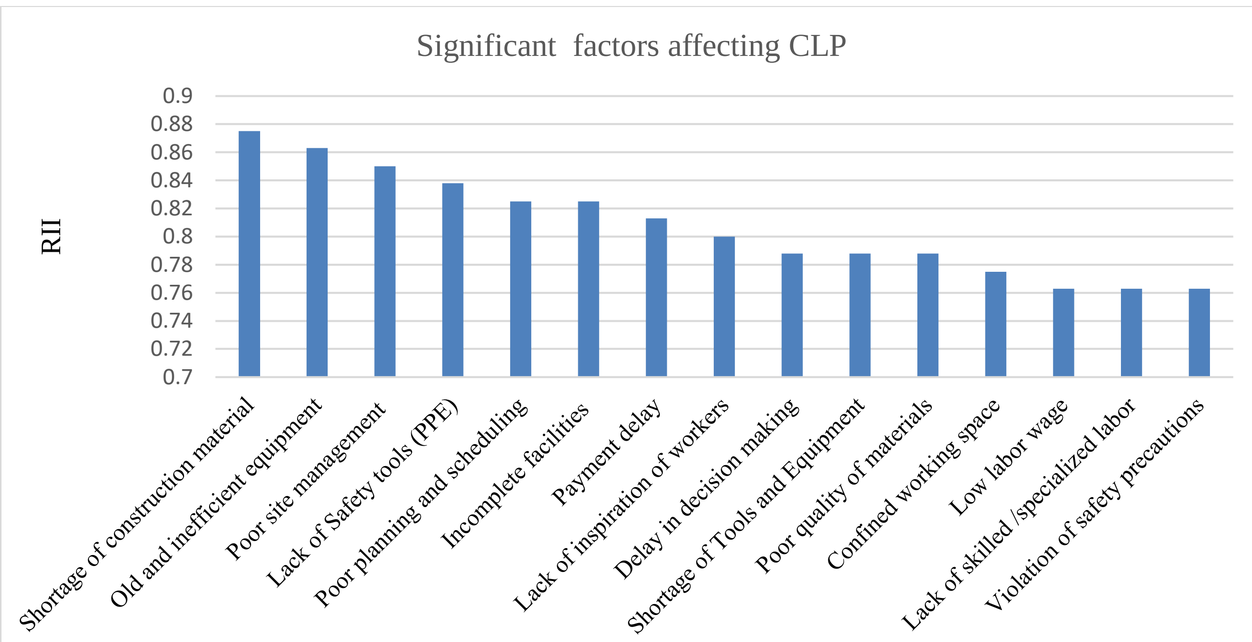

Figure 4.2 Significant factors affecting CLP

The shortage of construction materials (0.875 RII) is the most significant factor affecting CLP among overall factors. The shortage of construction materials is currently an issue in the country, and the result of this study implies that material shortages make a considerable negative contribution to the CLP. As Ghanim (2016) explains, the labor force wastes its time on unproductive work due to unavailability or shortage of materials. Similarly, the study conducted by Manoharan (2017) determined that the shortage of construction materials is the most significant factor affecting CLP and ranked 1st. Additionally, in Ethiopia, the significance of this factor is agreed upon and ranked 5th in studies by Eba (2019). Ashebir et al. (2020) ranked it as the 2nd critical factor causing low labor productivity.

Old and inefficient equipment is the most significant factor affecting CLP (0.863 RII), next to the shortage of construction materials, ranked 2nd among the overall factors. The result implies that the construction workers are unproductive since the activity cannot be performed progressively with the required quality due to old and inefficient equipment. Mengistu et al. (2016) also revealed that this factor highly affects CLP and is ranked 5th. Similarly, Ghanim (2016) and Gerges et al. (2016) justify the significant effect of the old and inefficient equipment on CLP and rank 2nd and 1st, respectively.

Poor site management (0.85 RII) is the 1st ranked management-related factor and 3rd among overall factors. It indicates that poor site management is one of the significant factors affecting CLP. Poor site management can result from a series of factors, such as poor labor management, poor communications between laborers and managers, poor communications between construction parties, poor material management, lack of site managers' experience, and lack of labor skill/ experience (Manoharan, 2017). Moreover, it leads to a bad labor mood, interrupting labor and machinery movement on the construction site. Similarly, the significance of this factor is agreed upon in the study by Akomah et al. (2020) and Ghanim (2016) and ranked as 3rd, 4th, and 5th, respectively.

Lack of safety tools (PPE) (RII 0.838) ranked 1st among safety and health related factors and 4th among the overall factors. It is the most significant factor affecting CLP, following the shortage of construction materials, old and inefficient equipment, and poor site management.

The result of lack of safety tools indicates that there is a problem in providing adequate PPE for laborers to perform their jobs safely, which lowers productivity. According to Mengistu et al. (2016), employees who do not feel safe tend to be overly cautious when performing their work tasks, thus lowering productivity. Eba (2019) also ranked this lack of PPE as the 4th factor affecting CLP.

Poor planning and scheduling (0.825 RII) are the 2nd significant factor among management related factors, following poor site management (0.85 RII) and ranked 5th among the overall factors. It implies that poor planning and scheduling is one of CLP's most significant factors. According to Venkatesh & Saravana (2019), a proper plan is required for any successful work because a lack of proper planning affects productivity to a greater extent. Both the studies by Gunduz & Abu-Hijleh (2020) and Ghanim (2016) ranked poor planning and scheduling as the 1st factor affecting CLP. Similarly, Irfan et al. (2020) ranked this factor 3rd.

Incomplete facilities (water, power supply, and sanitary) (RII 0.825) ranked 1st and 5th in project environment and external group and overall factors, respectively. It indicates that the problem related to necessary facilities in the county also affects CLP. As Eba (2019) stated, the incompleteness of facilities is the most critical factor affecting CLP, especially in developing counties, and is not easy to overcome. It severely causes workers to idle as a result of the interruption of work due to the unavailability of water and power. Besides, a lack of appropriate sanitary facilities for labor critically affects workers' productivity.

Payment delay (0.813 RII) ranked 1st and 7th among finance related factors and the overall factors, respectively. The result indicates that this factor is one of the significant factors affecting CLP. Previous studies also agree on the considerable impact of payment delays on CLP. For instance, a study conducted in Wolita Zone, Ethiopia, by Ashebir et al. (2020) ranked payment delays as the 3rd factor affecting CLP, with the RII value of 0.855. Similarly, a study in the Bale Zone by Mengistu et al. (2016) determined the delay in payment as a significant factor affecting CLP and ranked 9th.Moreover, Irfan et al. (2020), Gunduz & Abu-Hijleh (2020), and Gerges et al. (2016) agree that this factor is one of the most significant factors affecting CLP and ranked 2nd and 3rd, respectively.

Lack of motivation of labor (0.800 RII) ranked 1st among labor related factors and 8th among the overall factors. The result implies that lack of motivation is a significant factor affecting CLP and that motivation should be exercised. The lack of motivation of the workers is also determined as one of the top factors affecting CLP in a study by Akomah et al. (2020), and ranked 5th.

Delay in decision making (0.788 RII) ranked 3rd among management related factors. It indicates that decision makers frequently delay decisions, which highly affects labor productivity. This factor is also significantly influencing CLP in other parts of Ethiopia. A study by Ashebir et al. (2020) conducted in the Wolita zone, Ethiopia, determined delay in decision making as the most significant factor influencing CLP.

Following Delay in decision making, the 10th most significant factor is the shortage of tools and equipment (0.788 RII). It is also ranked 2nd among equipment and tools related factors. According to Ghanim (2016), the shortage of these items causes idle time since employed laborers cannot progress in their work as they need a minimum quantity of equipment to work effectively. In the study by Ashebir et al. (2020), a shortage of equipment and tools is also ranked 6th. Manoharan (2017) and Ghanim (2016) also agreed with the result and ranked shortage of equipment and tools as the 1st and 3rd factors affecting CLP, respectively.

Poor quality of construction materials (0.788 RII) is the major factor affecting CLP in material related factors following the shortage of construction materials and 9th among the overall factors. It shows that the poor quality of materials reduces the productivity rate, as it requires extra effort to keep up with them. Hai & Nguyen (2019) and Gerges et al. (2016) agreed on the result and ranked 4th and 8th, respectively.

Confinement of working space (0.755RII) ranked 12th among the overall factors affecting CLP and 2nd among project environment and external related factors following incomplete facilities. As Rashid (2015) mentioned, if a project site is confined, production suffers because materials, equipment and workers could not be available when and where they are required to enable effective project completion. To achieve good productivity, each crew member must have sufficient working space to perform their work without being interfered with by other craftsmen or objects.

Low labor wages (0.763 RII) are the 2nd most significant factor affecting CLP among labor-related factors and 13th among the overall characteristics. The result implies that low labor wages are a considerable factor affecting CLP. It reduces workers' job satisfaction, which matches the rewards offered by the employer and the labor preferences for those rewards.

Lack of skilled and specialized labor ranked (0.763 RII) as the 2nd most significant factor affecting CLP in this group and 13th among overall factors. Similarly, a study by Mengistu et al. (2016) revealed that the Ethiopian construction industry suffers from a lack of trained and skilled workers. Accordingly, investment in manpower is very valuable, especially in a country like Ethiopia, with a relatively high population and abundant labor. Violation of safety precautions (RII 0.763) ranked 2nd among safety and health related factors and 13th among overall factors, respectively. Referring to table 4.14 and the result of this factor, there is a lack of safety tools. Even though there is no adequate PPE, the labors fail to fulfil the safety precautions.

4.5 Weight of Significant Factors Affecting CLP

As mentioned above, the tool used to determine the weight of significant factors affecting CLP is F-AHP. The respondents are requested to prepare a pairwise comparison of the seven groups of factors affecting CLP and 15 significant factors. The judgment of experts is analyzed with the help of a linguistic scale given in Table 3.2. The geometric mean is calculated for the pairwise comparisons to aggregate respondents' responses. The aggregated comparison matrix for groups of main and sub-criteria is shown in table 4.17 and table 4.18, respectively.

Table 4.17 Aggregated comparison matrix of main criteria /group of factors

	MF	**FF**	**LF**	**MF**	**ETF**	**SHF**	**PEF**
MF	(1.0,1.0,1.0)	(0.1,0.1,0.2)	(0.3,0.8,0.9)	(0.1,0.1,0.2)	(0.1,0.2,0.4)	(0.7,0.8,2.0)	(0.8,0.8,2.3)
FF	(4.8,6.8,8.9)	(1.0,1.0,1.0)	(3.5,5.0,7.3)	(0.3,0.4,1.0)	(0.8,0.8,2.3)	(3.3,4.8,7.1)	(3.5,4.9,7.3)
LF	(1.1,1.2,3.3)	(0.1,0.2,0.3)	(1.0,1.0,1.0)	(0.1,0.1,0.2)	(0.2,0.3,0.7)	(1.0,1.0,3.0)	(1.0,1.0,3.0)
MTF	(5.7,7.8,6.6)	(1.1,2.3,3.9)	(4.8,6.8,8.1)	(1.0,1.0,1.0)	(1.8,2.7,4.3)	(4.4,5.9,8.3)	(5.5,6.8,9.3)
ETF	(2.3,4.5,6.6)	(0.4,1.2,1.3)	(1.5,3.6,5.7)	(0.2,0.4,0.6)	(1.0,1.0,1.0)	(3.4,5.4,7.4)	(3.7,5.8,7.8)
SHF	(0.5,1.2,1.5)	(0.1,0.2,0.3)	(0.3,1.0,1.0)	(0.1,0.2,0.2)	(0.1,0.2,0.3)	(1.0,1.0,1.0)	(1.0,1.0,3.0)
PEF	(0.4,1.2,1.3)	(0.1,0.2,0.3)	(0.3,1.0,1.0)	(0.1,0.1,0.2)	(0.1,0.1,0.3)	(0.3,1.0,1.0)	(1.0,1.0,1.0)
						λmax=7.59	CI=0.009
							CR-0.073

Similarly, each sub-criteria factor's weight is determined within its respective category. Table 4.18 provide the aggregated matrix for all significant factors affecting CLP.

Table 4.18 Aggregated comparison matrix of sub criteria / significant factors

MF	**MF1**	**MF2**	**MF3**	
MF1	(1.00,1.00,1.00)	(1.10,1.28,2.91)	(4.84,6.22,8.67)	λmax=3.115
MF2	(0.34,0.78,0.91)	(1.00,1.00,1.00)	(3.14,4.13,6.63)	CI=0.058
MF3	(0.12,0.16,0.12)	(0.15,0.24,0.32)	(1.00,1.00,1.00)	CR=0.009
FF	**FF1**	**FF2**		
FF1	(1.00,1.00,1.00)	(1.45,1.83,3.55)		
FF2	(0.28,0.55,0.69)	(1.00,1.00,1.00)		
LF	**LF1**	**LF2**		
LF1	(1.00,1.00,1.00)	(2.42,2.96,5.53)		
LF2	(0.18,0.34,0.41)	(1.00,1.00,1.00)		
MTF	**MTF1**	**MTF2**		
MTF1	(1.00,1.00,1.00)	(2.92,3.87,6.35)		
MTF2	(0.16,0.26,0.34)	(1.00,1.00,1.00)		
ETF	**ETF1**	**ETF2**		
ETF1	(1.00,1.00,1.00)	(1.39,2.26,3.12)		
ETF2	(0.32,0.44,0.72)	(1.00,1.00,1.00)		
SHF	**SHF1**	**SHF2**		
SHF1	(1.00,1.00,1.00)	(0.75,1.41,2.72)		
SHF2	(0.37,0.71,1.34)	(1.00,1.00,1.00)		
PEF	**PEF1**	**PEF2**		
PEF1	(1.00,1.00,1.00)	(1.66,3.15,5.40)		
PEF2	(0.19,0.32,0.60)	(1.00,1.00,1.00)		

After the aggregated matrix using fuzzy geometric mean is calculated, the fuzzy weight is obtained and Defuzzified. Finally, the defuzzified weights are normalized to get the final weight for criteria and sub criteria. Table 4.19 illustrates the final weight for the main criteria/group of factors affecting CLP and their ranking. The result reveals that material related factor (CW=0.362) is dominant in all groups of factors. The second most influencing group of factors is finance related factor (CW=0.238) and followed by the equipment tools and related factor (CW=0.2) and labor related factor (CW=0.064). Safety and health related factors (CW=0.049), management related factors (CW=0.045), and project environment and external related factors (CW=0.041) are the least three dominant groups of factors.

Table 4.19 Weight and ranking of the main criteria

Main factors	Fuzzy geometric mean	Fuzzy weight	Defuzzified weight	Final Weight	Rank
MF	(0.311,0.420,0.676)	(0.022,0.041,0.096)	0.053	0.045	6th
FF	(1.684,2.251,3.518)	(0.118,0.220,0.498)	0.279	0.238	2nd
LF	(0.444,0.517,1.024)	(0.031,0.051,0.145)	0.076	0.064	4th
MTF	(2.801,3.880,4.927)	(0.196,0.379,0.697)	0.424	0.362	1st
ETF	(1.235,2.174,2.857)	(0.087,0.213,0.404)	0.235	0.200	3rd
SHF	(0.325,0.501,0.706)	(0.023,0.049,0.100)	0.057	0.049	5th
PEF	(0.265,0.484,0.564)	(0.019,0.047,0.080)	0.049	0.041	7th

Following a similar procedure as the main criteria, the weights of each 15 sub-criteria/significant factors affecting CLP are obtained and presented in Table 4.20.

Table 4.20 Weight and ranking sub criteria

Group	Factors	Fuzzy geometric mean	Fuzzy weight	Defuzzified weight	Final local weight	Local rank
MF	MF1	(1.746,1.995,2.932)	(0.343,0.523,0.968)	0.611	0.560	1st
	MF2	(1.026,1.479,1.820)	(0.202,0.388,0.600)	0.397	0.364	2nd
	MF3	(0.259,0.339,0.332)	(0.051,0.089,0.110)	0.083	0.076	3rd
FF	FF1	(1.203,1.351,1.884)	(0.443,0.646,1.086)	0.725	0.679	1st
	FF2	(0.531,0.740,0.831)	(0.196,0.354,0.479)	0.343	0.321	2nd
LF	LF1	(1.555,1.719,2.352)	(0.519,0.747,1.187)	0.818	0.770	1st
	LF2	(0.425,0.582,0.643)	(0.157,0.253,0.325)	0.245	0.230	2nd
MTF	MTF1	(1.708,1.968,2.519)	(0.550,0.795,1.197)	0.847	0.806	1st
	MTF2	(0.397,0.508,0.586)	(0.128,0.205,0.278)	0.204	0.194	2nd
ETF	ETF1	(1.178,1.502,1.766)	(0.451,0.693,1.012)	0.719	0.681	1st
	ETF2	(0.566,0.666,0.849)	(0.217,0.307,0.486)	0.337	0.319	2nd
SHF	SHF1	(0.865,1.187,1.649)	(0.308,0.585,1.121)	0.671	0.587	1st
	SHF2	(0.607,0.842,1.157)	(0.216,0.415,0.786)	0.472	0.413	2nd
PEF	PEF1	(1.289,1.775,2.324)	(0.416,0.759,1.352)	0.842	0.753	1st
	PEF3	(0.430,0.563,0.776)	(0.139,0.241,0.451)	0.277	0.753	2nd

Based on table 4.20, poor site management MF1 (LW=0.560) is a dominant factor within the management related factors, followed by poor planning and scheduling MF2 (LW=0.364) and delay in decision making MF3 (LW=0.076).

Regarding finance-related factors, payment delay FF1 (LW=0.679) is the most influencing factor than low labor wage FF2 (LW=0.321). Under labor related category, the most influencing factor is the Lack of inspiration of workers LF1 (LW=0.770), followed by lack of skilled and specialized labor LF2 (LW=0.230). Shortage of construction material MTF1 (LW=0.806) is the most significant factor under material factor, while the poor quality of construction materials MTF2 (LW=0.194) is the least. For equipment and tools related factors, old and inefficient equipment ETF1 (LW=0.681) is the most influential and followed by shortage of tools and equipment ETF2 (LW=0.319).

Lack of safety tools SHF1 (LW=0.587) is the most influential factor under safety and health related categories, following the violation of safety precautions SHF2 (LW=0.413). Under project environment and external related factors, incomplete facilities PEF1 (LW=0.753) is the most influencing factor, followed by confined working space PEF2 (LW=0.753). Combining the result, which is presented in table 4.19 and table 4.20, the outcome of F-AHP is obtained and provided in table 4.21, which illustrates the final weights of factors.

Table:4.21 Final weight and ranking of significant factors affecting CLP

Group	Weight of the group	Factors	Factors/local weight	Local rank	Global weight	Global rank
MF	0.045	MF1	0.560	1st	0.025	10th
		MF2	0.364	2nd	0.016	13th
		MF3	0.076	3rd	0.003	15th
FF	0.238	FF1	0.679	1st	0.162	2nd
		FF2	0.321	2nd	0.076	4th
LF	0.064	LF1	0.770	1st	0.050	7th
		LF2	0.230	2nd	0.021	11th
MTF	0.362	MTF1	0.806	1st	0.292	1st
		MTF2	0.194	2nd	0.070	5th
ETF	0.200	ETF1	0.681	1st	0.136	3rd
		ETF2	0.319	2nd	0.064	6th
SHF	0.049	SHF1	0.587	1st	0.029	9th
		SHF2	0.413	2nd	0.020	12th
PEF	0.041	PEF1	0.753	1st	0.031	8th
		PEF3	0.247	2nd	0.010	14th

Shortage of construction material (GW=0.292), payment delay FF1 (GW=0.162), and old and inefficient equipment ETF1 (GW=0.136) are the top three most influencing significant factors. Low labor wage FF2 (GW=0.076), poor quality of construction materials MTF2 (GW=0.07), Shortage of tools and equipment ETF2 (GW= 0.064), and lack of inspiration of workers LF1 (GW=0.05) ranked from 4^{th} to 7^{th}. Similarly, incomplete facilities PEF1 (GW=0.031), lack of safety tools (PPE) SHF1 (GW=0.029), poor site management MF1 (GW=0.025), and lack of skilled and specialized labor LF2 (GW=0.021) ranked from 8^{th} to 12^{th}. Violation of safety precautions SHF2 (GW=0.02), poor planning and scheduling MF2 (GW=0.016), confined working space PEF3 (GW=0.01), and delay in decision making MF3 (GW=0.003) are the least four significant factors.

The second objective of this study is to reveal each significant factor's weight. Therefore, the weight is obtained in this section through F-AHP. The global weight is used for further analysis (F-TOPSIS) to find the most crucial solution/ management practice to overcome these factors affecting CLP and improve the current CLP.

4.6 Management Practices to Overcome Factors Affecting CLP

Sixty-five management practices to overcome significant CLP barriers have been identified through the literature review. F-TOPSIS method is employed to prioritize the most critical practices to overcome CLP affecting factors. The third objective of the study focus on the solution to overcome factors affecting CLP, this section presents the result in detail. Based on the responses, a fuzzy evaluation matrix is constructed through the experts' inputs using the linguistic variables given in Table 3.4. These linguistic variables are converted into TFN, and thus the fuzzy evaluation matrix is obtained. It is achieved by comparing all the solutions under each significant factor affecting CLP separately. The responses of construction experts are aggregated to get a Fuzzy aggregate decision matrix.

Table 4.22 shows the aggregated decision matrix of the solution, and it provides the aggregated result of only a few solutions due to space limitations. Table 4.23 presents the normalized fuzzy decision matrix for the solutions.

Table 4.22 Fuzzy aggregate decision matrix for solutions.

	Solutions	MF				PEF	
		MF1	**MF2**	**MF3**		**PF1**	**PF2**
SPPM	SPPM1	(1,1,3)	(1,7.75,11)	(1,1,3)	…	(1,1,3)	(1,1,3)
	SPPM2	(1,1,3)	(1,1,3)	(1,1,3)	…	(1,1,3)	(1,1,3)
	SPPM3	(1,1,3)	(3,7.625,11)	(1,2,7)	…	(1,1,3)	(1,1,3)
	SPPM4	(1,1,3)	(3,7.875,11)	(1,1,3)	…	(1,1,3)	(1,1,3)
	SPPM5	(1,1.25,7)	(7,9,11)	(1,1.5,7)	…	(1,1,3)	(1,1,3)
	SPPM6	(1,3.125,9)	(3,7.375,11)	(1,2.375,9)	…	(1,1,3)	(1,1,3)
	SPPM7	(3,7.125,11)	(3,7,11)	(1,2,7)	…	(1,1.875,9)	(1,1,3)
	SPPM8	(3,7,11)	(3,7.5,11)	(1,2.5,9)	…	(1,1.75,9)	(1,6,9)
	SPPM9	(1,1,3)	(1,1,3)	(1,1,3)	…	(1,1,3)	(1,1,3)
	SPPM10	(1,1,3)	(3,7.375,11)	(1,1,3)	…	(1,1,3)	(1,1,3)
….	….	….	….	….	…	….	….
SSTM	SSTM1	(1,6.875,11)	(3,7.375,11)	(1,6.75,11)	…	(3,7.5,11)	(1,1,3)
	SSTM2	(3,7,11)	(3,7.5,11)	(5,7.875,11)	…	(1,6.75,11)	(1,5.87,9)
	SSTM3	(1,7.625,11)	(1,7.5,11)	(5,7.625,11)	…	(1,2,11)	(1,1,3)
	SSTM4	(1,7.125,11)	(1,1,3)	(1,1,3)	…	(1,1,3)	(1,1,3)
	SSTM5	(3,7.625,11)	(3,7.5,11)	(3,5,7)	…	(1,2.5,11)	(1,1,3)

Table 4.23 Normalized fuzzy decision matrix for solutions.

	Solution	MF			PEF	
		MF1	**MF2**		**PF1**	**PF2**
SPPM	SPPM1	(0.3,1,1)	(0.09,0.1,1)	..	(0.3,1,1)	(0.33,1,1)
	SPPM2	(0.3,1,1)	(0.3,1,1)	..	(0.3,1,1)	(0.3,1,1)
	SPPM3	(0.3,1,1)	(0.09,0.13,0.3)	..	(0.3,1,1)	(0.3,1,1)
	SPPM4	(0.3,1,1)	(0.09,0.13,0.3)	..	(0.3,1,1)	(0.3,1,1)
	SPPM5	(0.14,0.8,1)	(0.09,0.1,0.14)	..	(0.3,1,1)	(0.3,1,1)
	SPPM6	(0.1,0.32,1)	(0.09,0.14,0.3)	..	(0.3,1,1)	(0.3,1,1)
	SPPM7	(0.09,0.14,0.3)	(0.09,0.14,0.3)	..	(0.1,0.5,1)	(0.3,1,1)
	SPPM8	(0.09,0.14,0.3)	(0.09,0.13,0.3)	..	(0.1,0.6,1)	(0.1,0.17,1)
	SPPM9	(0.3,1,1)	(0.3,1,1)	..	(0.3,1,1)	(0.3,1,1)
	SPPM10	(0.3,1,1)	(0.09,0.14,0.3)	..	(0.3,1,1)	(0.3,1,1)
	..	..	..	..	..	..
SSTM	SSTM1	(0.09,0.15,1)	(0.09,0.14,0.3)	..	(0.09,0.1,0.3)	(0.3,1,1)
	SSTM2	(0.09,0.14,0.3)	(0.09,0.13,0.3)	..	(0.09,0.15,1)	(0.1,0.17,1)
	SSTM3	(0.09,0.13,1)	(0.091,0.13,1)	..	(0.09,0.5,1)	(0.3,1,1)
	SSTM4	(0.09,0.14,1)	(0.333,1,1)	..	(0.3,1,1)	(0.3,1,1)
	SSTM5	(0.091,0.131,0.2)	(0.09,0.1,0.3)	..	(0.09,0.4,1)	(0.3,1,1)

The normalized fuzzy decision matrix for the solutions is presented in table 4.23. After aggregating the experts' responses, the values are normalized to get a normalized fuzzy decision matrix. Since the solutions overcome CLP factors, the criteria/factors affecting CLP are considered as cost criteria, the full table is provided in the appendix section Table II 1.

Table 4.24 Weighted normalized fuzzy decision matrix for solutions.

		MF			PRF
	Solution	**MF1**	**MF2**		**PF2**
SPPM	SPPM1	(0.008,0.025,0.025)	(0.001,0.002,0.016)	..	(0.003,0.01,0.01)
	SPPM2	(0.008,0.025,0.025)	(0.005,0.016,0.016)	..	(0.003,0.01,0.01)
	SPPM3	(0.008,0.025,0.025)	(0.001,0.002,0.005)	..	(0.003,0.01,0.01)
	SPPM4	(0.008,0.025,0.025)	(0.001,0.002,0.005)	..	(0.003,0.01,0.01)
	SPPM5	(0.004,0.020,0.025)	(0.001,0.002,0.002)	..	(0.003,0.01,0.01)
	SPPM6	(0.003,0.008,0.025)	(0.001,0.002,0.005)	..	(0.003,0.01,0.01)
	SPPM7	(0.002,0.004,0.008)	(0.001,0.002,0.005)	..	(0.003,0.01,0.01)
	SPPM8	(0.002,0.004,0.008)	(0.001,0.002,0.005)	..	(0.001,0.002,0.01)
	SPPM9	(0.008,0.025,0.025)	(0.005,0.016,0.016)	..	(0.003,0.01,0.01)
	SPPM10	(0.008,0.025,0.025)	(0.001,0.002,0.005)	..	(0.003,0.01,0.01)
……..		…	……..	……..	……..
SSTM	SSTM1	(0.002,0.004,0.025	(0.001,0.002,0.005)	..	(0.003,0.010,0.01)
	SSTM2	(0.002,0.004,0.008	(0.001,0.002,0.005)	..	(0.001,0.002,0.01)
	SSTM3	(0.002,0.003,0.025	(0.001,0.002,0.016)	..	(0.003,0.010,0.01)
	SSTM4	(0.002,0.004,0.025	(0.005,0.016,0.016)	..	(0.003,0.010,0.01)
	SSTM5	(0.002,0.003,0.008	(0.001,0.002,0.005)	..	(0.003,0.010,0.01)
FPIS	A^+	(0.002,0.003,0.005)	(0.001,0.002,0.002)	..	(0.001,0.001,0.001)
FNIS	A^-	(0.008,0.025,0.025)	(0.005,0.016,0.016)	..	(0.003,0.01,0.010)

The weighted evaluation matrix is established using the weight of the barrier calculated by F-AHP (table 4.21) and the normalized fuzzy decision matrix (table 4.23). After that, Fuzzy positive-ideal solution FPIS (A^+) and fuzzy negative-ideal solution FNIS (A^-) are computed, as shown in Table 4.24. The table presents the fuzzy weighted Evaluation matrix. Finally, the coefficient of closeness Cc_i is calculated to obtain the final result.

Table 4.25 shows the final Cci result of each management practice, their respective category, and the overall ranking.

Table 4.25 Closeness coefficient (Cc_i) and final ranking of solutions

	D_i^+	D_i^-	Cc_i	Rank		D_i^+	D_i^-	Cc_i	Rank
Preconstruction phase management					SHRM16	0.352	0.045	0.113	34th
SPPM1	0.37	0.015	0.039	60th	SHRM17	0.28	0.146	0.342	11th
SPPM2	0.372	0.01	0.027	63rd	SHRM18	0.364	0.025	0.064	49th
SPPM3	0.344	0.058	0.143	25th	**Materials management**				
SPPM4	0.366	0.016	0.042	59th	SMM1	0.277	0.154	0.356	8th
SPPM5	0.364	0.02	0.051	52nd	SMM2	0.287	0.145	0.336	12th
SPPM6	0.34	0.07	0.17	22nd	SMM3	0.368	0.014	0.037	61st
SPPM7	0.275	0.15	0.353	9th	SMM4	0.349	0.038	0.098	40th
SPPM8	0.241	0.221	0.478	7th	SMM5	0.322	0.14	0.303	15th
SPPM9	0.279	0.134	0.326	13th	SMM6	0.347	0.039	0.1	38th
SPPM10	0.351	0.039	0.1	39th	SMM7	0.352	0.03	0.079	44th
Site management					SMM8	0.297	0.136	0.313	14th
SSM1	0.156	0.3	0.657	3rd	**Equipment and tools management**				
SSM2	0.348	0.046	0.117	33rd	SETM1	0.287	0.099	0.255	17th
SSM3	0.344	0.046	0.118	31st	SETM2	0.329	0.054	0.141	26th
SSM4	0.359	0.027	0.071	46th	SETM3	0.368	0.014	0.036	62nd
SSM5	0.363	0.023	0.06	51st	SETM4	0.302	0.092	0.234	19th
SSM6	0.362	0.026	0.067	48th	SETM5	0.311	0.073	0.19	21st
SSM7	0.298	0.103	0.256	16th	**Safety and health management**				
SSM8	0.282	0.15	0.347	10th	SSHM1	0.347	0.037	0.096	41st
Human resource management					SSHM2	0.357	0.032	0.081	43rd
SHRM1	0.333	0.08	0.194	20th	SSHM3	0.364	0.018	0.046	57th
SHRM2	0.364	0.019	0.049	54th	SSHM4	0.368	0.016	0.042	58th
SHRM3	0.365	0.018	0.047	55th	SSHM5	0.338	0.057	0.145	24th
SHRM4	0.327	0.057	0.149	23rd	SSHM6	0.365	0.024	0.061	50th
SHRM5	0.343	0.039	0.101	37th	SSHM7	0.347	0.044	0.112	35th
SHRM6	0.289	0.094	0.246	18th	SSHM8	0.348	0.04	0.102	36th
SHRM7	0.348	0.049	0.123	30th	SSHM9	0.336	0.048	0.125	29th
SHRM8	0.362	0.027	0.069	47th	SSHM10	0.357	0.033	0.085	42nd
SHRM9	0.351	0.047	0.117	32nd	SSHM11	0.359	0.03	0.076	45th
SHRM10	0.365	0.018	0.047	56th	**Stakeholders' management**				
SHRM11	0.366	0.019	0.05	53rd	SSTM1	0.125	0.31	0.712	2nd
SHRM12	0.342	0.05	0.128	28th	SSTM2	0.181	0.274	0.602	4th
SHRM13	0.344	0.051	0.128	27th	SSTM3	0.207	0.245	0.542	6th
SHRM14	0.372	0.01	0.027	63rd	SSTM4	0.17	0.251	0.596	5th
SHRM15	0.372	0.01	0.027	63rd	SSTM5	0.125	0.316	0.716	1st

4.6.1 Management Practices to Overcome Each Significant Factor Affecting CLP

This section discusses the top ten solutions to overcome each significant CLP barrier (poor site management, poor planning and scheduling, delay in decision making, payment delay, low labor wage, lack of inspiration of workers, lack of skilled and specialized labor, shortage of construction material, poor quality of construction materials, old and inefficient equipment, shortage of tools and equipment, lack of safety tools (PPE), violation of safety precautions, incomplete facilities, confined working space) together with their respective categories based on the weight given from F-AHP.

4.6.1.1 Management Practices to Overcome Management Related Factors

Poor site management, poor planning and scheduling, and delay in decision making are significant factors under the management related category with 0.85, 0.825 and 0.788 RII, respectively. The global weight using F-AHP is 0.025,0.016, and 0.003 for poor site management, poor planning and scheduling and delay in decision making, respectively. The best solutions to overcome these barriers are computed separately using F-TOPSIS and presented in table 4.26.

Table 4.26 Solutions to the management related factors

Poor site management			**Poor planning and scheduling**			**Delay in decision making**		
Solutions	**Cc_i**	**Rank**	**Solutions**	**Cc_i**	**Rank**	**Solutions**	**Cc_i**	**Rank**
SSM1	1	1st	SPPM5	1	1st	SSTM2	1	1st
SSM3	0.999	2nd	SPPM4	0.855	2nd	SHRM17	0.998	2nd
SSM2	0.997	3rd	SPPM3	0.854	3rd	SSTM3	0.998	2nd
SSM8	0.997	3rd	SPPM8	0.854	4th	SSM8	0.995	4th
SSM4	0.988	5th	SSHM11	0.854	4th	SSM1	0.991	5th
SHRM7	0.987	6th	SSTM2	0.854	4th	SSTM5	0.868	6th
SSTM5	0.987	6th	SSTM5	0.854	4th	SHRM13	0.53	7th
SMM4	0.983	8th	SPPM6	0.853	8th	SSTM1	0.525	8th
SPPM7	0.979	9th	SPPM10	0.853	8th	SHRM9	0.525	9th
SMM2	0.893	10th	SMM1	0.853	8th	SPPM8	0.454	10th
SSHM10	0.892	11th	SSTM1	0.853	8th	SPPM9	0.405	11th
SPPM8	0.891	12th	SPPM7	0.852	12th	SPPM7	0.405	11th
SSTM2	0.891	12th	SSM4	0.852	12th	SPPM3	0.377	13th

Proper site administration SSM1(Cc_i =1), proper construction site layout SSM3Cc_i=0.999), provide necessary site facilities SSM2(Cc_i=0.997), and effective supervision and quality control SSM8(Cc_i=0.997), are the top three management practice to overcome CLP problem due to poor site management. Dynamic site layout plan SSM4(Cc_i=0.988), shift-based working hours SHRM7(Cc_i=0.987), stable organizational structure SSTM5(Cc_i=0.987), Proper materials handling systems SMM4(Cc_i=0.983), project completion plan SPPM7(Cc_i=0.979) ranked from 5th to 9th. Provide materials on time SMM2(Cc_i=0.893), effective site safety communication SSHM10(Cc_i=0.892), short interval plan SPPM8(Cc_i=0.891) and regular and effective communication on construction status SSTM2(Cc_i=0.891) ranked from 10th from 12th.

Realistic work schedule SPPM5(Cc_i=1), complete and approval of construction drawing before the commencement of construction SPPM4Cc_i=0.855), and well-defined scope of work SPPM3(Cc_i=0.854) are the top three management practices to overcome CLP problem due to poor planning and scheduling. Short interval plan SPPM8(Cc_i=0.854), anticipating problems and planning in advance SSHM11(Cc_i=0.854), regular and effective communication on construction status SSTM2(Cc_i=0.854) and stable organizational structure SSTM5 (Cc_i=0.854) ranked 4th. Collaborative procurement SPPM6(Cc_i=0.853), fulfill Regulatory requirement SPPM10(Cc_i=0.853), Procurement plans for materials SMM1(Cc_i=0.853) and Coordination between all stakeholders SSTM1(Cc_i=0.853) ranked 8th. Both project completion plan SPPM7(Cc_i= 0.852) and dynamic site layout plan SSM4(Cc_i=0.852) ranked 12th.

Regular and effective communication on construction status SSTM2(Cc_i=1), holding regular meetings with labors SHRM17(Cc_i=0.998), and enhancing leadership and decision making of supervisors SSTM3(Cc_i=0.998), are the top three management practice to overcome CLP due to delay in decision making. Effective supervision and quality control SSM8(Cc_i=0.995), proper site administration SSM1(Cc_i=0.991), stable organizational structure SSTM5(Cc_i=0.868), good relation between labor and superintendents SHRM13(Cc_i=0.53) and coordination between all stakeholders SSTM1(Cc_i=0.525) ranked from 4th to 8th. Worker's participation in decision making SHRM9(Cc_i=0.525), short interval plan SPPM8(Cc_i=0.454), project startup plan SPPM9(Cc_i=0.405), project completion plan SPPM7(Cc_i=0.405) and a well-defined scope of work SPPM3(Cc_i=0.377) ranked from 9th to 13th.

Table 4.27 and figure 4.3 above present the overall solution to overcome management-related factors. The local weights by F-AHP of the three factors under management using F-AHP are considered, which are 0.560, 0.364 and 0.076 for poor site management, poor planning and scheduling and delay in decision making, respectively.

Table 4.27 Solutions to the overall management related factors

Solution	**Cc_i**	**Rank**
SSTM2	0.885	1st
SSTM5	0.877	2nd
SPPM8	0.837	3rd
SPPM7	0.834	4th
SSM1	0.628	5th
SSM8	0.627	6th
SSTM1	0.627	7th
SSM4	0.598	8th
SMM1	0.597	9th
SSHM11	0.596	10th
SSM5	0.593	11th
SPPM9	0.589	12th
SSTM3	0.549	13th

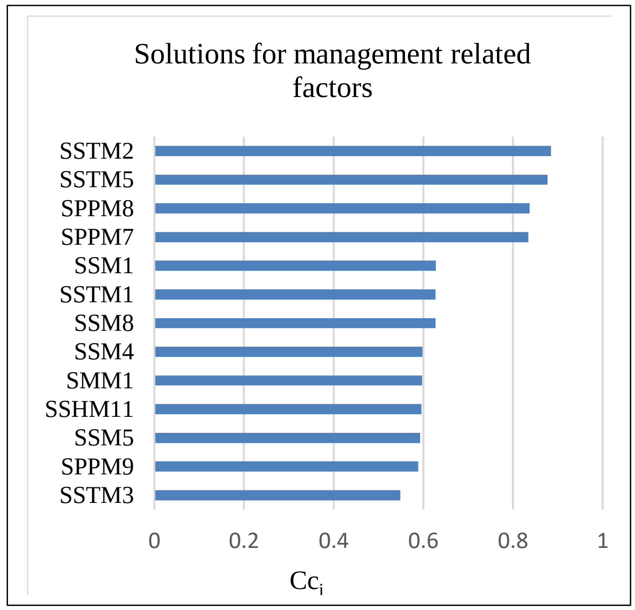

Figure 4.3 Solutions to the overall management related factors

Based on table 2.7 and figure 4.3, regular and effective communication on construction status SSTM2(Cc_i=0.885), stable organizational structure SSTM5(Cc_i=0.877), and short interval plan SPPM8(Cc_i=0.837) are the top three management practices to overcome management related factors. Project completion plan SPPM7(Cc_i=0.834), procurement plans for materials SSM1(Cc_i=0.628), effective supervision and quality control SSM8(Cc_i=0.627), coordination between all stakeholders SSTM1(Cc_i=0.627) and dynamic site layout plan SSM4(Cc_i=0.598) ranked from 4th to 8th. Procurement plans for materials SMM1(Cc_i=0.597), anticipating problems and planning in advance SSHM11(Cc_i=0.596), site security plan SSM5(Cc_i=0.593), project start-up plan SPPM9(Cc_i=0.589) and enhancing leadership and decision making of supervisors SSTM3(Cc_i=0.549) ranked from 9th to 13th.

4.6.1.2 Management Practices to Overcome Finance Related Factors

Payment delay and low labor wage are the two significant factors affecting CLP under finance related category, with 0.813 and 0.763 RII, respectively. Their global weights using F-AHP are 0.162 and 0.076 for payment delay and low labor wage, respectively. The best solutions to overcome these barriers using F-TOPSIS are presented in table 4.28.

Table 4.28 Solutions to the finance related factors

Payment delay			Low labor wage		
Solution	**Cc_i**	**Rank**	**Solution**	**Cc_i**	**Rank**
SHRM6	1	1st	SHRM5	1	1st
SSTM4	0.99	2nd	SHRM4	0.995	2nd
SSTM5	0.989	3rd	SSTM5	0.975	3rd
SSTM3	0.892	4th	SSTM4	0.568	4th
SSTM1	0.888	5th	SHRM1	0.525	5th
SPPM7	0.526	6th	SHRM9	0.515	6th
SSTM2	0.523	7th	SSM1	0.512	7th
SPPM9	0.522	8th	SSTM1	0.504	8th
SPPM8	0.522	8th	SHRM12	0.501	9th
SSM1	0.376	10th	SPPM10	0.495	10th
SPPM3	0.488	11th	SSTM3	0.47	11th
SHRM1	0.269	12th	SHRM17	0.465	12th
SHRM17	0.269	12th	SHRM13	0.427	13th

Based on table 4.28, timely payment SHRM6(Cc_i=1), proper project financing SSTM4 (Cc_i=0.99), and stable organizational structure SSTM5(Cc_i=0.989) are determined as the top three management practices to overcome CLP problems due to payment delay. Enhancing leadership and decision making of supervisors SSTM3(Cc_i=0.892), coordination between all stakeholders SSTM1(Cc_i=0.888), SPPM7(Cc_i=0.526), and regular and effective communication on construction status SSTM2 (Cc_i =0.523) ranked from 4th to 7th. Both project start-up plan SPPM9(Cc_i=0.522) and short interval plan SPPM 8(Cc_i =0.522) ranked 8th. Proper site administration SSM1(Cc_i=0.376), well-defined scope of work SPPM3(Cc_i = 0.488), detailed workforce plan SHRM1(Cc_i=0.269) and hold regular meetings with labors SHRM17(Cc_i = 0.269) ranked from 9th to 12th.

The result also revealed that increasing labors wage/salary SHRM5(Cc_i=1), incentive/bones SHRM4(Cc_i=0.995), and stable organizational structure SSTM5(Cc_i=0.975) are the top three management practices to overcome CLP problems due to low labor wage. Similarly, proper project financing SSTM4(Cc_i=0.568), detailed workforce plan SHRM1(Cc_i=0.525), worker's participation in decision making SHRM9(Cc_i=0.515), proper site administration SSM1(Cc_i=0.512) and coordination between all stakeholders SSTM1(Cc_i=0.504) ranked from 4th to 8th. Team building between labors SHRM12(Cc_i=0.501), SPPM10(Cc_i=0.495), enhancing leadership and decision making of supervisors SSTM3(Cc_i=0.47), holding regular meetings with labors SHRM17(Cc_i=0.465) and good relation between labor and superintendents SHRM13(Cc_i=0.427) ranked from 9th to 13th.

Table 4.29 and figure 4.4 present the overall solution to overcome finance related factors by considering the two significant financial related factors. The local weights of the factors under finance related category using F-AHP are considered, which are 0.679 and 0.321 for payment delay and low labor wage, respectively.

Table 4.29 Solutions to the overall finance related factors

Solutions	**Cc_i**	**Rank**
SSTM5	0.985	1st
SSTM4	0.833	2nd
SSTM1	0.754	3rd
SSTM3	0.749	4th
SHRM6	0.696	5th
SPPM7	0.401	6th
SSTM2	0.397	7th
SPPM9	0.397	8th
SPPM8	0.397	8th
SSM1	0.394	10th
SPPM3	0.36	11th
SHRM1	0.35	12th
SHRM17	0.324	13th

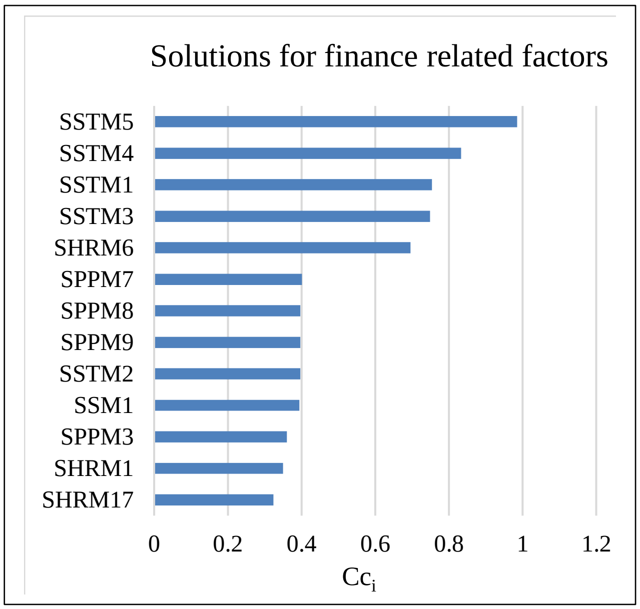

Figure 4.4 Solutions to the overall finance related factors

Stable organizational structure SSTM6 (Cc_i=0,985), proper project financing SSTM5(Cc_i=0.833), and coordination between all stakeholders SSTM1(Cc_i=0.754) are the top three critical management practices to overcome management finance related factors. Enhancing leadership and decision making of supervisors SSTM3(Cc_i=0.749), timely payment SHRM6(Cc_i=0.696), SPPM7(Cc_i=0.401), regular and effective communication on construction status SSTM2(Cc_i=0.397) ranked from 4th to 7th. Both project start-up plan SPPM9(Cc_i=0.397) and short interval plan SPPM8(Cc_i=0.397) ranked 8th. Proper site administration SSM1(Cc_i=0.394), well-defined scope of work SPPM3(Cc_i=0.36), detailed workforce plan SHRM1(Cc_i=0.35), and hold regular meetings with labors SHRM17(Cc_i=0.324) ranked from 10th to 13th.

4.6.1.3 Management Practices to Overcome Labor Related Factors

Lack of inspiration of workers and lack of skilled and specialized labors are the two significant factors affecting CLP under labor related category with 0.800 and 0. 0.763 RII, respectively. After their weighted using F-AHP are 0.050 and 0.021 for lack of inspiration of workers and lack of skilled and specialized labors, respectively. The best solutions to overcome these barriers using F-TOPSIS for the labor related factors are presented separately in table 4.30.

Table 4.30 Solutions to the labor related factors

Lack of inspiration of workers			**Lack of skilled and specialized labor**		
Solutions	**Cc_i**	**Rank**	**Solutions**	**Cc_i**	**Rank**
SHRM13	0.873	1st	SHRM2	1	1st
SHRM6	0.785	2nd	SHRM3	0.893	2nd
SHRM4	0.785	2nd	SHRM7	0.893	3rd
SSHM9	0.784	4th	SHRM10	0.888	4th
SMM2	0.783	5th	SHRM1	0.526	5th
SHRM12	0.783	6th	SHRM8	0.523	6th
SSM1	0.782	7th	SHRM17	0.522	7th
SETM2	0.782	8th	SSM8	0.521	8th
SSHM7	0.78	9th	SHRM12	0.43	9th
SHRM9	0.475	10th	SPPM6	0.397	10th
SHRM18	0.475	10th	SHRM13	0.376	11th
SSM2	0.473	11th	SSM1	0.338	12th
SHRM16	0.471	12th	SSTM5	0.269	13th

As table 4.30 illustrates, good relation between labor and superintendents SHRM13(Cc_i =0.873), timely payment SHRM6(Cc_i=0.785), and provide incentive/bones SHRM4(Cc_i =0.785) are determined as the top three management practice to overcome CLP problem due to lack of inspiration of workers. Provide properly maintained PPE SSHM9(Cc_i= 0.784), provide materials on time SMM2(Cc_i=0.783), team building between labors SHRM12(Cc_i=0.783), proper site administration SSM1(Cci=0.782) and provide tools and equipment on time SETM2(Cc_i=0.782) ranked from 4^{th} to 8^{th}. Frequent housekeeping SSHM7(Cc_i=0.78), worker's participation in decision making SHRM9(Cc_i=0.475), giving workers breaks time and day off for holidays SHRM18(Cc_i=0.475), provide necessary site facilities SSM2(Cc_i =0.473), and shift-based working hours SHRM16(Cc_i=0.471) ranked from 9^{th} to 13^{th}.

Hiring skilled workers SHRM2(Cc_i=1), training of workers SHRM3(Cc_i=0.893), and proper arrangement of labors/ crew composition SHRM7(Cc_i=0.893) determined as the top three management practices to overcome CLP problems due to lack of skilled and specialized labor. Skill assessment and evaluation SHRM10(Cc_i=0.888), detailed workforce plan SHRM1(Cc_i=0.526), clear delegation of responsibility SHRM8(Cc_i=0.523), hold regular meetings with labors SHRM17(Cc_i=0.522), effective supervision and quality control SSM8(Cc_i=0.521) and team building between labors SHRM12(Cc_i=0.43) ranked from 4^{th} to 8^{th}. SPPM6(Cc_i=0.397), good relation between labor and superintendents SHRM13(Cc_i=0.376), proper site administration SSM1(Cc_i=0.338) and stable organizational structure SSTM5(Cc_i =0.269) ranked from 9^{th} to 13^{th}.

Table 4.31 and figure 4.5 present the overall solution to overcome labor related factors. The local weights by F-AHP of the factors under labor related category using F-AHP are considered, which are 0.770 and 0.230 for lack of inspiration of workers and lack of skilled and specialized labor, respectively. Good relations between labor and superintendents SHRM13(Cci=0.76), team building between labors SHRM12(Cci=0.692) and incentive/bones SHRM4(Cci=0.676) are the top three significant management practices to overcome labor related factors.

Proper site administration SSM1(Cci=0.671), timely payment SHRM6(Cci=0.627), provide properly maintained PPE SSHM9(Cci=0.625), provide materials on time SMM2(Cci=0.624) and provide tools and equipment on time SETM2(Cci=0.622) ranked from 4^{th} to 8^{th}.

Proper construction site layout SSM3(Cci=0.621), frequent housekeeping SSHM7(Cci=0.620), effective supervision and quality control SSM8(Cci=0.480), hold regular meetings with labors SHRM17(Cci=0.480) and provide necessary site facilities SSM2(Cci=0.439) ranked 8th to 13th.

Table 4.31 Solutions to the overall labor related factors

Solutions	Cci	Rank
SHRM13	0.760	1st
SHRM12	0.692	2nd
SHRM4	0.676	3rd
SSM1	0.671	4th
SHRM6	0.627	5th
SSHM9	0. 625	6th
SMM2	0.624	7th
SETM2	0.622	8th
SSM3	0.621	9th
SSHM7	0.620	10th
SSM8	0.480	11th
SHRM17	0.480	12th
SSM2	0.439	13th

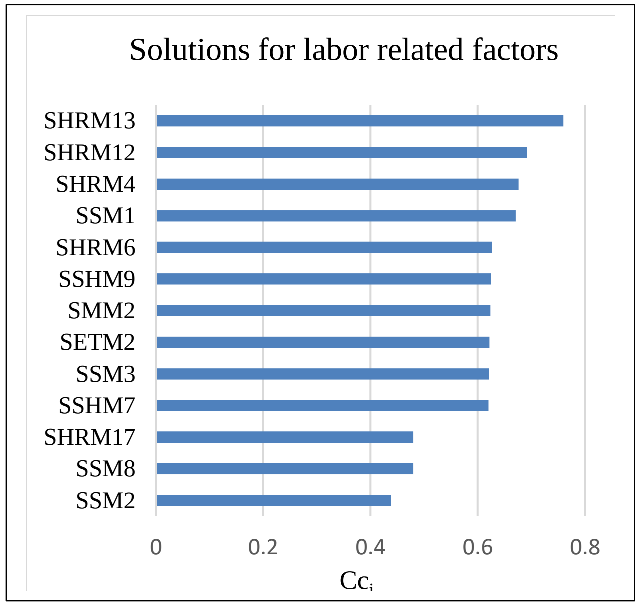

Figure 4.5 Solutions to the overall labor related factors

4.6.1.4 Management Practices to Overcome Material Related Factors

The two significant factors affecting CLP under material related category with 0.875 and 0.788 RII are shortage of construction material and poor quality of construction materials, respectively. The global weights using F-AHP are 0.292 and 0.070 for the shortage of construction material and poor quality of construction materials, respectively. Solutions to overcome these barriers using F-TOPSIS are presented separately in table 4.32.

Table 4.32 Solutions to the material related factors

Shortage of construction material			Poor quality of construction materials		
Solutions	Cci	Rank	Solutions	Cci	Rank
SMM5	0.931	1st	SMM6	1	1st
SMM8	0.919	2nd	SMM1	0.51	2nd
SMM1	0.919	3rd	SSM8	0.509	3rd

Shortage of construction material			Poor quality of construction materials		
Solutions	**Cc_i**	**Rank**	**Solutions**	**Cc_i**	**Rank**
SMM2	0.919	4th	SMM4	0.503	4th
SSTM3	0.914	5th	SMM7	0.503	4th
SPPM8	0.914	6th	SSTM2	0.495	6th
SSM1	0.913	7th	SSTM1	0.489	7th
SSTM5	0.911	8th	SHRM17	0.487	8th
SSTM2	0.536	9th	SPPM9	0.382	9th
SSTM1	0.529	10th	SPPM8	0.325	10th
SSTM4	0.528	11th	SMM8	0.309	11th
SPPM9	0.465	12th	SSTM3	0.273	12th
SPPM7	0.39	13th	SSTM4	0.25	13th

As table 4.32 illustrates, long-lead materials identification SMM5(Cc_i=0.931), on-site materials tracking SMM8(Cc_i=0.919) and procurement plans for materials SMM1(Cc_i=0.0.9191), and provide necessary site facilities SMM2(Cc_i=0.919) are determined as the top management practice to overcome CLP problem due to shortage of construction material. Provide materials on time SMM2(Cc_i=0.919), enhancing leadership and decision making of supervisors SSTM3(Cc_i=0.914), short interval plan SPPM8(Cc_i=0.914), proper site administration SSM1(Cc_i=0.913) and stable organizational structure SSTM5(Cc_i=0.911) ranked from 4th to 8th. Regular and effective communication on construction status SSTM2(Cc_i=0.536), coordination between all stakeholders SSTM1(Cc_i=0.529), proper project financing SSTM4(Cc_i=0.528), project start-up plan SPPM9(Cc_i=0.465) and project completion plan SPPM7(Cc_i=0.391) ranked from 9th to 13th.

Materials status database SMM6(Cc_i=1), procurement plans for materials SMM1(Cc_i=0.51), and effective supervision and quality control SSM8(Cc_i=0.509) are the top three management practices to overcome CLP problems due to poor quality of construction materials. Proper site administration SSM1(Cc_i=0.826), stable organizational structure SSTM5(Cc_i=0.823), effective supervision and quality control SMM8(Cc_i=0.819), site security plan SMM5(Cc_i=0.801) and provide materials on time SMM2(Cc_i=0.778) ranked from 4th to 8th. Regular and effective communication on construction status SSTM2(Cc_i=0.582), coordination between all stakeholders SSTM1(Cc_i=0.574), proper project financing SSTM4(Cc_i=0.532), project start-up plan SPPM9(Cc_i=0.485) and project completion plan SPPM7(Cc_i=0.337) ranked from 9th to 13th.

Table 4.33 and figure 4.6 present the overall solution to overcome material related factors. The local weights by F-AHP of the factors under the material related category are considered, which are 0.806 and 0.194 for the shortage of construction material and poor quality of construction materials, respectively.

Table 4.33 Solutions to the overall material related factors

Solutions	**Cc_i**	**Rank**
SMM1	0.926	1st
SPPM8	0.851	2nd
SSTM3	0.835	3rd
SSM1	0.826	4th
SSTM5	0.823	5th
SMM8	0.819	6th
SMM5	0.801	7th
SMM2	0.778	8th
SSTM2	0.582	9th
SSTM1	0.574	10th
SSTM4	0.532	11th
SPPM9	0.485	12th
SPPM7	0.337	13th

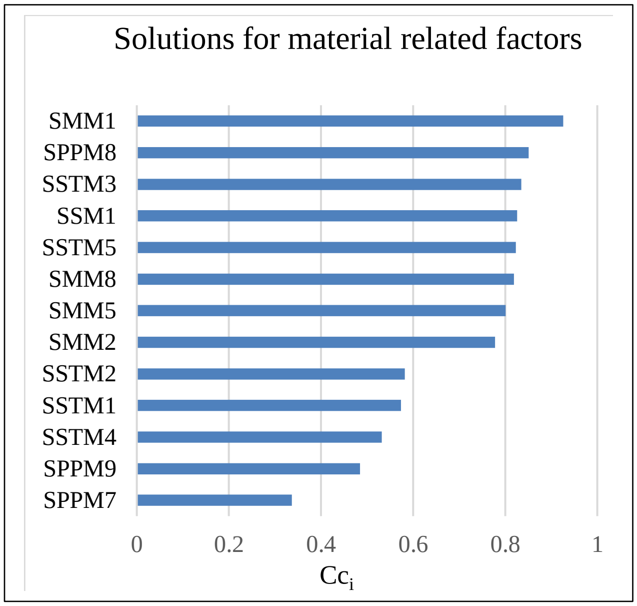

Figure 4.6 Solutions to the overall material related factors

Based on table 4.33 and figure 4.6, procurement plans for materials SMM1(Cc_i=0.926), short interval plan SPPM8(Cc_i=0.851) and enhancing leadership and decision making of supervisors SSTM3(Cc_i=0.835) are the three important management practice to overcome material related factors. Proper site administration SSM1(Cc_i=0.826), stable organizational structure SSTM5(Cc_i=0.823), effective supervision and quality control SMM8(Cc_i=0.819), site security plan SMM5(Cc_i=0.801) and provide materials on time SMM2(Cc_i=0.778) ranked from 4th to 8th.

Regular and effective communication on construction status SSTM2(Cc_i=0.582), coordination between all stakeholders SSTM1(Cc_i=0.574), proper project financing SSTM4(Cc_i=0.532), project start-up plan SPPM9(Cc_i=0.485) and project completion plan SPPM7(Cc_i=0.337) ranked from 9th to 13th.

4.6.1.5 Management Practices to Overcome Equipment and Tools Related Factors

Old and inefficient equipment and shortage of tools and equipment are the two significant factors affecting CLP under the equipment and tools related category, with 0.875 and 0.788 RII, respectively. Their global weights obtained using F-AHP are 0.136 and 0.064 for old and inefficient equipment and shortage of tools and equipment, respectively. The best management practices and their ranking to overcome both barriers are presented in table 4.34.

Table 4.34 Solutions to the equipment and tools related factors

Old and inefficient equipment			Shortage of Tools and Equipment		
Solutions	**Cc_i**	**Rank**	**Solutions**	**Cc_i**	**Rank**
SSM7	1	1st	SETM2	0.992	1st
SETM4	0.952	2nd	SETM1	0.892	2nd
SETM5	0.951	3rd	SHRM7	0.533	3rd
SETM1	0.852	4th	SETM4	0.529	4th
SSTM4	0.852	5th	SHRM1	0.526	5th
SSTM2	0.85	6th	SSTM1	0.521	6th
SSTM5	0.849	7th	SSTM2	0.517	7th
SSTM1	0.849	8th	SPPM10	0.515	8th
SSM1	0.848	9th	SSM8	0.515	8th
SSM8	0.516	10th	SHRM17	0.513	10th
SPPM9	0.389	11th	SSM1	0.503	11th
SPPM8	0.325	12th	SSTM5	0.43	12th
SHRM17	0.325	12th	SPPM9	0.405	13th

Adoption of advanced technologies SSM7(Cc_i=1), construction equipment maintenance SETM4 (Cc_i=0.952), and construction equipment productivity analysis SETM5(Cc_i=0.951) are the top management practice to overcome CLP problems due to old and inefficient equipment. Equipment procurement plans SETM1(Cc_i=0.852), proper project financing SSTM4(Cc_i=0.852), regular and effective communication on construction status SSTM2(Cc_i=0.85), stable organizational structure SSTM5(Cc_i=0.849) and coordination between all stakeholders SSTM1(Cc_i=0.849) ranked from 4th to 8th. Proper site administration SSM1(Cc_i=0.848), effective supervision and quality control SSM8(Cc_i=0.516), SPPM9(Cc_i=0.389), short interval plan SPPM8(Cc_i=0.325) and hold regular meetings with labors SHRM17(Cc_i=0.325) ranked from 9th to 13th.

Provide tools and equipment on time SETM2(Cc_i=0.992), construction equipment procurement plans SETM1(Cc_i=0.892), and proper arrangement of labors/ crew composition. SHRM7 (Cc_i=0.533) are the top three management practices to overcome CLP problems due to the shortage of tools and equipment. Equipment maintenance SETM4(Cc_i=0.529), detailed workforce plan SHRM1(Cc_i=0.526), coordination between all stakeholders SSTM1(Cc_i=0.521), regular and effective communication on construction status SSTM2(Cc_i=0.517) and fulfill regulatory requirement SPPM10(Cc_i=0.515) ranked from 4th to 8th. Effective supervision and quality control SSM8(Cc_i=0.515), hold regular meetings with labors SHRM17(Cc_i=0.513), proper site administration SSM1(Cc_i=0.503), stable organizational structure SSTM5(Cc_i=0.43) and project start-up plan SPPM9(Cc_i=0.405) ranked from 9th to 13th.

Table 4.35 and figure 4.7 illustrates the overall management practices to overcome equipment and tools related factors. Based on the result from local weights by F-AHP, the factors under the equipment and tools related factors category are considered, which are 0.681 and 0.319.

Table 4.35 Solutions to the overall equipment and tools related factors

Solutions	Cc_i	Rank
SETM1	0.892	1st
SETM4	0.807	2nd
SSM7	0.751	3rd
SSTM2	0.746	4th
SSTM1	0.745	5th
SSM1	0.741	6th
SSTM5	0.726	7th
SETM5	0.672	8th
SSTM4	0.612	9th
SSM8	0.528	10th
SPPM9	0.404	11th
SHRM17	0.4	12th
SETM2	0.316	13th

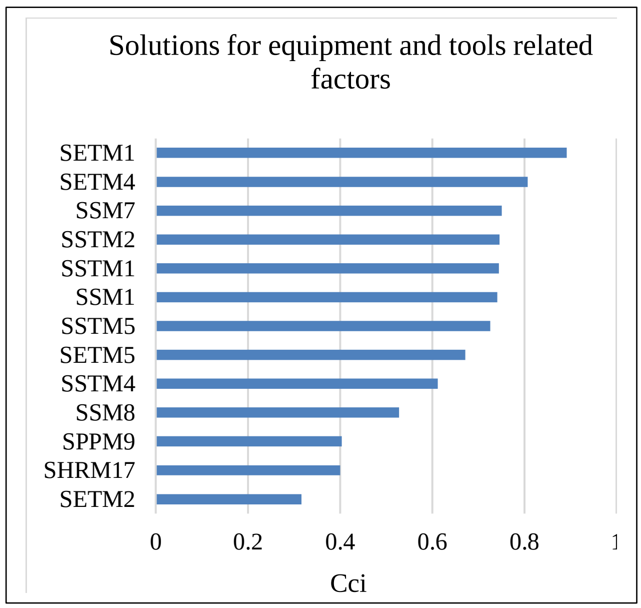

Figure 4.7 Solutions to the overall equipment and tools related factors

Construction equipment procurement plans SETM1(Cc_i=0.892), construction equipment maintenance SETM4(Cc_i=0.807), and adoption of advanced technologies SSM7(Cc_i=0.751) are the top three important management practices to overcome equipment and tools related factors.

Regular and effective communication on construction status SSTM2(Cc_i=0.746), coordination between all stakeholders SSTM1(Cc_i=0.745), proper site administration SSM1(Cc_i=0.741), stable organizational structure SSTM5(Cc_i=0.726) and equipment productivity analysis SETM5(Cc_i=0.672) ranked from 4th to 8th. Proper project financing SSTM4(Cc_i=0.612), effective supervision and quality control SSM8(Cc_i=0.528), project start-up plan SPPM9(Cc_i=0.404), hold regular meetings with labors SHRM17(Cc_i=0.4) and SETM2(Cc_i=0.316) ranked from 9th to 13th.

4.6.1.6 Management Practices to Overcome Safety and Health Related Factors

Lack of safety tools (PPE) and violation of safety precautions are the two significant factors affecting CLP under the safety and health related category, with 0.838 and 0.763 RII, respectively. The weights obtained from F-AHP are 0.292 and 0.070 for lack of safety tools (PPE) and violation of safety precautions, respectively. The best management practices and their ranking to overcome these barriers separately using F-TOPSIS are presented in Table 4.36.

Table 4.36 Solutions to the safety and health related factor

Lack of Safety tools (PPE)			**Violation of safety precautions**		
Solutions	**Cci**	**Rank**	**Solutions**	**Cc_i**	**Rank**
SSHM9	1	1st	SSHM3	1	1st
SSHM1	0.893	2nd	SSHM2	0.989	2nd
SSHM8	0.893	3rd	SSHM5	0.987	3rd
SSM1	0.891	4th	SSHM1	0.985	4th
SSM8	0.886	5th	SSHM8	0.985	4th
SSTM1	0.886	6th	SSHM9	0.983	6th
SSHM10	0.522	7th	SHRM17	0.975	7th
SSTM5	0.52	8th	SSHM10	0.968	8th
SSHM6	0.493	9th	SSM1	0.961	9th
SSHM2	0.466	10th	SSM3	0.57	10th
SSHM5	0.432	11th	SSHM6	0.569	11th
SSHM11	0.432	11th	SSHM7	0.564	12th
SSHM4	0.429	13th	SSM8	0.563	13th

The top three management practices for overcoming the CLP problem caused by a lack of safety tools are keeping workplace safety signs facility SSHM8(Cc_i=0.893), provide properly maintained (PPE) SSHM9(Cc_i=1), and safety and health plan SSHM1(Cc_i=0.893).

Proper site administration SSM1(Cc_i=0.891), short interval plan SSM8(Cc_i=0.886), coordination between stakeholders SSTM1(Cc_i=0.886), effective safety communication SSHM10(Cc_i=0.522) and stable organizational structure SSTM5(Cc_i=0.52) ranked 4th to 8th. Toolbox safety meetings SSHM6(Cc_i=0.493), assign safety engineer SSHM2(Cc_i=0.466), provide hygienic site conditions SSHM5(Cc_i=0.432), anticipating problems and planning in advance SSHM11(Cc_i=0.432) and implement safe work method statement SSHM4(Cc_i=0.429 ranked 9th to 13th.

Safety and health training SSHM3(Cci=1), assigning a safety engineer SSHM2(Cc_i=0.989), and provide hygienic site conditions SSHM5(Cc_i=0.987), are the three best management practices for overcoming CLP issues that are caused by the violation of safety precautions. Safety and health plan SSHM1(Cc_i=0.985), keep workplace safety signs facility SSHM8(Cc_i=0.985), provide properly maintained PPE SSHM9(Cc_i=0.983), hold regular meetings with labors SHRM17(Cc_i=0.975) and effective site safety communication SSHM10(Cc_i=0.968) ranked from 4th to 8th. Proper site administration SSM1(Cc_i=0.961), SSM3(Cc_i=0.57), toolbox safety meetings SSHM6(Cc_i=0.569), frequent housekeeping SSHM7(Cc_i=0.564) and short interval plan SSM8(Cc_i=0.563) ranked from 9th to 13th.

Table 4.37 Solutions to the overall safety and health related factors

Solutions	**Cci**	**Rank**
SSHM9	0.993	1st
SSHM1	0.929	2nd
SSHM8	0.929	3rd
SSM1	0.918	4th
SSM8	0.736	5th
SSHM10	0.666	6th
SSHM2	0.644	7th
SSHM5	0.626	8th
SHRM17	0.596	9th
SSTM1	0.539	10th
SSHM6	0.523	11th
SSHM3	0.396	12th
SSTM5	0.352	13th

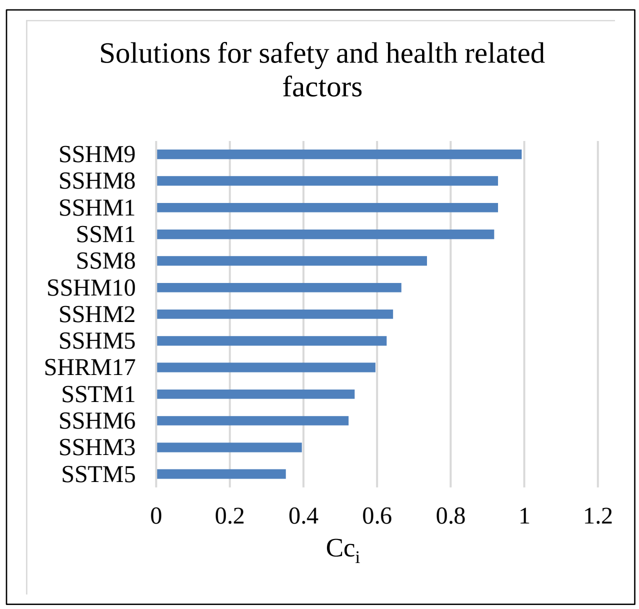

Figure 4.8 Solutions to the overall safety and health related factors

Table 4.37 and figure 4.8 present the overall solution to overcome safety and health related factors. Incomplete facilities and confined working space are the two most significant factors affecting CLP under this category, with 0.825 and 0.775 RII, respectively. Their global weights using F-AHP are 0.292 and 0.070 for incomplete facilities and confined working space, respectively.

Provide properly maintained SSHM9(Cc_i=0.993), safety and health plan SSHM1(Cc_i=0.929), and keeping workplace safety signs facility SSHM8(Cc_i=0.929) are the top three management practices to overcome CLP problems due to safety and health related factors. Proper site administration SSM1(Cc_i=0.918), short interval plan SSM8(Cc_i=0.736), effective site safety communication SSHM10(Cc_i=0.666) and assign safety engineer SSHM2(Cc_i=0.644) ranked from 4^{th} to 8^{th}. Provide hygienic site conditions SSHM5(Cc_i=0.626), hold regular meetings with labors SHRM17(Cc_i=0.596), coordination between all stakeholders SSTM1(Cc_i=0.539), toolbox safety meetings SSHM6(Cc_i=0.523), safety and health training SSHM3(Cc_i=0.396), stable organizational structure SSTM5(Cc_i=0.352) ranked from 9^{th} to 13^{th}.

4.6.1.7 Management Practices to Overcome Project Environment and External Factors

Incomplete facilities and confined working space are the two significant factors affecting CLP under the project environment and external related factors category with 0.825 and 0.775 RII, respectively. Their global weights using F-AHP are 0.292 and 0.070 for incomplete facilities and confined working space, respectively.

Table 4.38 Solutions to the project environment and external factors

Incomplete facilities			**Confined working space**		
Solutions	**Cc_i**	**Rank**	**Solutions**	**Cc_i**	**Rank**
SSM2	1	1^{st}	SSM3	1	1^{st}
SSM1	0.999	2^{nd}	SSM6	0.812	2^{nd}
SSTM1	0.998	3^{rd}	SHRM7	0.812	3^{rd}
SSHM5	0.997	4^{th}	SMM3	0.812	4^{th}
SSTM2	0.778	5^{th}	SSM4	0.657	5^{th}
SSM8	0.778	6^{th}	SETM3	0.657	5^{th}
SSTM5	0.745	7^{th}	SSTM2	0.543	7^{th}
SHRM17	0.725	8^{th}	SPPM8	0.543	8^{th}

Incomplete facilities			Confined working space		
Solutions	**Cc_i**	**Rank**	**Solutions**	**Cc_i**	**Rank**
SSTM3	0.725	8th	SSM8	0.542	9th
SPPM7	0.716	10th	SHRM1	0.542	10th
SPPM8	0.707	11th	SMM8	0.542	11th
SSHM8	0.668	12th	SSHM1	0.542	12th
SSTM4	0.564	13th	SSHM7	0.541	13th

Provide necessary site facilities SSM2(Cc_i=1), proper site administration SSM1(Cc_i=0.999), and coordination between all stakeholders SSTM1(Cc_i=0.998) are the top three management practices to overcome CLP problems due to incomplete facilities. Provide hygienic site conditions SSHM5(Cc_i=0.997), regular and effective communication on construction status SSTM2(Cc_i=0.778), effective supervision and quality control SSM8(Cc_i=0.778), stable organizational structure SSTM5(Cc_i=0.745) and hold regular meetings with labors SHRM17(Cc_i=0.725) ranked from 4th to 8th. Enhancing leadership and decision making of supervisors SSTM3(Cc_i=0.725), project completion plan SPPM7(Cc_i=0.716), short interval plan SPPM8(Cc_i=0.707), keep workplace safety signs facility SSHM8(Cc_i=0.668) and proper project financing SSTM4(Cc_i=0.564) ranked from 9th to 13th.

Proper construction site layout SSM3(Cc_i=1), traffic control plan SSM6(Cc_i=812), proper arrangement of labors/ crew composition SHRM7(Cc_i=0.812), and Just-in-time material delivery SMM3(Cc_i=0.812) are the top three management practices to overcome CLP problems due to confined working space labor. Just-in-time material delivery SMM3(Cc_i=0.812), dynamic site layout plan SSM4(Cc_i=0.657), Just-in-time equipment and tool SETM3(Cc_i=0.657), Regular and effective communication on construction status SSTM2(Cc_i=0.543) and short interval plan SPPM8(Cc_i=0.543) ranked from 4th to 8th. Effective supervision and quality control SSM8(Cc_i=0.542), detailed workforce plan SHRM1(Cc_i=0.542), on-site materials tracking SMM8(Cc_i=0.542), safety and health plan SSHM1(Cc_i=0.542) and frequent housekeeping SSHM7(Cc_i=0.541) ranked from 9th to 13th.

Table 4.39 and figure 4.9 present the overall solution to overcome the project environment and external related factors.

The local weights of the factors under project environment and external related category using F-AHP are considered, which are 0.753 and 0.247 for incomplete facilities and confined working space, respectively.

Table 4.39 Solutions to the overall project environment and external factors

Solutions	**Cc_i**	**Rank**
SSM2	0.836	1st
SSM1	0.835	2nd
SSTM1	0.834	3rd
SSHM5	0.833	4th
SSTM2	0.687	5th
SSM8	0.687	6th
SPPM8	0.608	7th
SSTM5	0.589	8th
SHRM17	0.566	9th
SSTM3	0.566	9th
SPPM7	0.556	11th
SSM3	0.553	12th
SMM3	0.546	13th

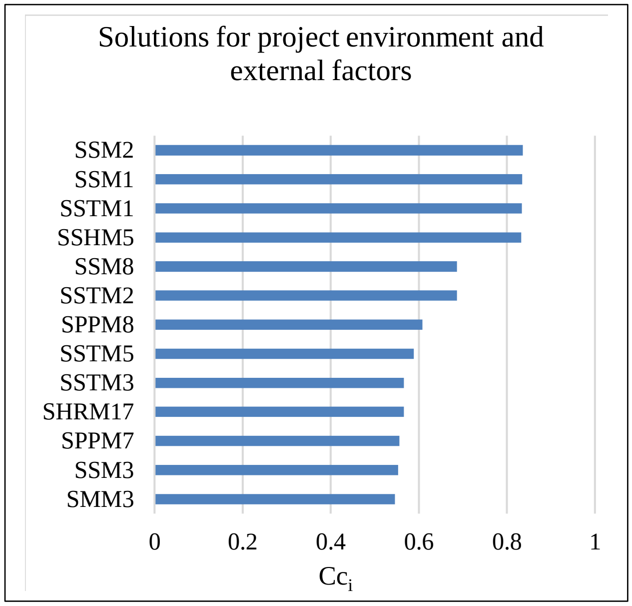

Figure 4.9 Solutions to the overall project environment and external factor

Based on table 4.39 and figure 4.9, Providing necessary site facilities SSM2(Cc_i=0.836), proper site administration SSM1(Cc_i=0.835), and coordination between all stakeholders SSTM1(Cc_i=0.834) are the top three important management practices to overcome CLP issues due to project environment and external related factor. Provide hygienic site conditions SSHM5(Cc_i=0.833), regular and effective communication on construction status SSTM2(Cc_i=0.687), effective supervision and quality control SSM8(Cc_i=0.687), Short interval plan SPPM8(Cc_i=0.608) and stable organizational structure SSTM5(Cc_i=0.589) ranked from 4th to 8th. Hold regular meetings with labors SHRM17(Cc_i=0.566), enhancing leadership and decision making of supervisors SSTM3(Cc_i=0.566), project completion plan SPPM7(Cc_i=0.556), proper construction site layout SSM3(Cc_i=0.553) and Just-in-time material delivery SMM3(Cc_i=0.546) ranked from 9th to 13th.

4.6.2 Overall Management Practices to Overcome Factors Affecting CLP

Sixty-five management practices are identified from the literature review and categorized into seven groups. The result is computed based on the average Cc_i value of management practices under each respective group and illustrated in table 4.40 and figure 4.10.

Table 4.40 Management practices categories to overcome CLP barriers

Management groups	Cc_i	Rank
SPPM	0.173	4th
SSM	0.212	2nd
SHRM	0.112	6th
SMM	0.203	3rd
SETM	0.171	5th
SSHM	0.088	7th
SSTM	0.532	1st

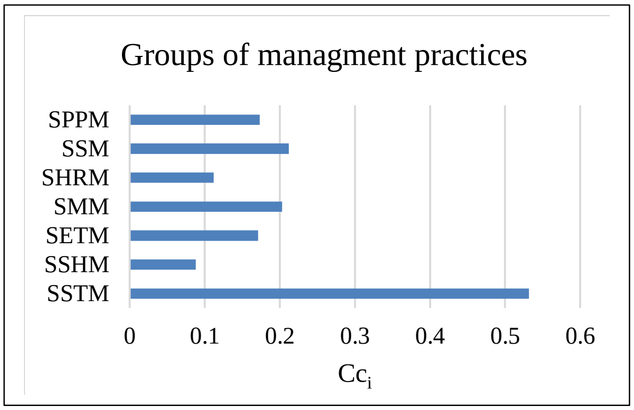

Figure 4.10 Management practices categories to overcome CLP barriers

Based on table 4.10, stakeholders' management practice SSTM (average Cc_i=0.532) in the top management category to overcome CLP barriers. Construction method and site management practices SSM (average Cc_i=0.212), Material management practices SMM (average Cc_i=0.203) preconstruction phase management practices SPPM (average Cc_i=0.173) ranked from 2nd to 4th. Similarly, equipment and tools management practices SETM (average Cc_i=0.171), Human resource management practice SHRM (average Cc_i=0.112) and safety and health-related management practices SSHM (average Cc_i=0.088) ranked from 5th to 7th to overcome factors affecting CLP.

4.6.2.1 Pre-Construction Phase Management Practices

Management practices related to preconstruction practices (average Cc_i=0.173) are ranked 4th out of the seven groups of management practices. Ten management practices are identified under this group. Table 4.41 and figure 4.11 illustrate the Cc_i and ranking of preconstruction phase management practices.

Table 4.41 Pre-construction management practices

SPPM	**Cc_i**	**Group rank**	**Overall ranking**
SPPM8	0.478	1st	7th
SPPM7	0.353	2nd	9th
SPPM9	0.326	3rd	13th
SPPM6	0.17	4th	22nd
SPPM3	0.143	5th	25th
SPPM10	0.1	6th	39th
SPPM5	0.051	7th	52nd
SPPM4	0.042	8th	59th
SPPM1	0.039	9th	60th
SPPM2	0.027	10th	63rd

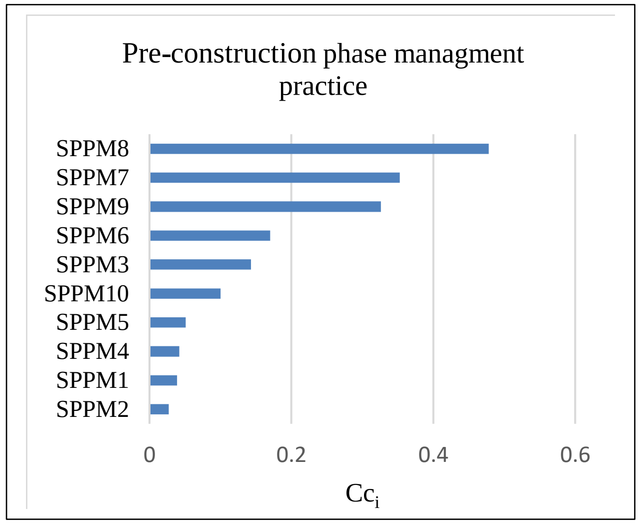

Figure 4.11 Pre-construction management practices

Short interval plan SPPM8 (Cc_i= 0.478) is ranked 1st in this group and 7th among the overall practices, respectively. Following the short interval plan, project completion plan SPPM7 (Cc_i= 0.478) is the most significant management practice to overcome factors affecting CLP, ranked 2nd and 9th within this group and overall practice, respectively. Project start-up plan SPPM9 (Cc_i=0.17) ranked 3rd and 12th within this group and general practice, respectively. Collaborative construction procurement SPPM6 (Cc_i=0.17), well-defined scope of work SPPM3 (Cc_i=0.143), fulfill regulatory requirement SPPM10 (Cc_i=0.1), and realistic work schedule SPPM5 (Cc_i=0.051) are ranked from 4th to 7th within this category and 22nd, 25th,39th, and 52nd from the overall solutions, respectively. Complete and approve of construction drawing before the commencement of construction SPPM4 (Cc_i=0.042), use of software in planning work packages SPPM1 (Cc_i=0.039), and appoint experienced designer SPPM2 (Cc_i=0.027) are the least significant pre-construction phase practices to overcome CLP barriers.

4.6.2.2 Construction Method and Site Management Practices

Construction method and site management practices (average Cc_i=0.212) ranked 2nd out of the seven groups. It implies that management practices categorized under construction method and site management are the most significant practices following stakeholders' management.

Eight practices are identified under this category, and table 4.42 and figure 4.12 presents their determined Cc_i and ranking.

Table 4.42 Construction method and site management practices

SSM	Cc_i	Group rank	Overall ranking
SSM1	0.657	1st	3rd
SSM8	0.347	2nd	10th
SSM7	0.256	3rd	16th
SSM3	0.118	4th	31st
SSM2	0.117	5th	33rd
SSM4	0.071	6th	46th
SSM6	0.067	7th	48th
SSM5	0.06	8th	51st

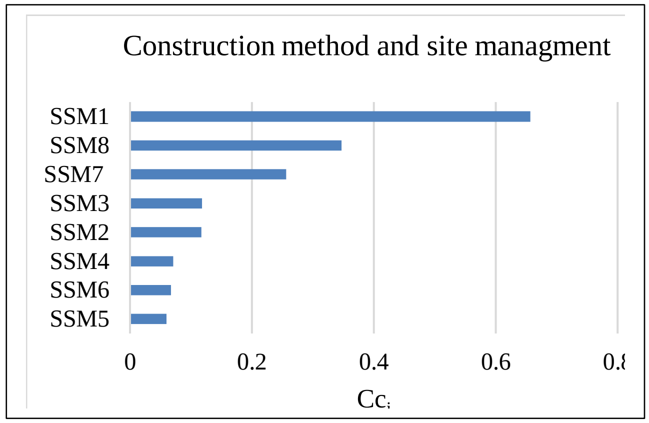

Figure 4.12 Construction method and site management practices

Proper site administration SSM1 (Cc_i=0.657) is ranked 1st in this category and 3rd among the overall solutions. Effective supervision and quality control (Cc_i=0.347) ranked 2nd and 10th in this category and among the overall solutions, respectively. Adoption of advanced technologies SSM7 (Cc_i=0.256), proper construction site layout SSM3 (Cc_i=0.118), and provide necessary site facilities SSM2 (Cc_i=0.117) are ranked from 2nd to 4th in this group and 16th, 31st and 33rd from the overall solutions, respectively. Dynamic site layout plan SSM4 (Cc_i=0.071), traffic control plan SSM6 (Cc_i=0.067), and site security plan SSM5 (Cc_i=0.06) are the three least solutions in this group and ranked 46th, 48th and 51st from the overall management practices to overcome significant CLP affecting factors, respectively.

4.6.2.3 Human Resource Management Practices

Human resource management practice (average Cc_i=0.112) ranked 6th out of the seven groups of management practices. This group consists eighteen human resource management practices to overcome significant factors affecting CLP. Table 4.43 and figure 4.13 illustrate their Cci, group ranking and overall ranking.

Table 4.43 Human resource management practices

SHRM	Cc_i	Group rank	Overall ranking
SHRM17	0.342	1st	11th
SHRM6	0.246	2nd	18th
SHRM1	0.194	3rd	20th
SHRM4	0.149	4th	23rd
SHRM13	0.128	5th	27th
SHRM12	0.128	6th	28th
SHRM7	0.123	7th	30th
SHRM9	0.117	8th	32nd
SHRM16	0.113	9th	34th
SHRM5	0.101	10th	37th
SHRM8	0.069	11th	47th
SHRM18	0.064	12th	49th
SHRM11	0.05	13th	53rd
SHRM2	0.049	14th	54th
SHRM3	0.047	15th	55th
SHRM10	0.047	16th	56th
SHRM14	0.027	17th	63rd
SHRM15	0.027	17th	63rd

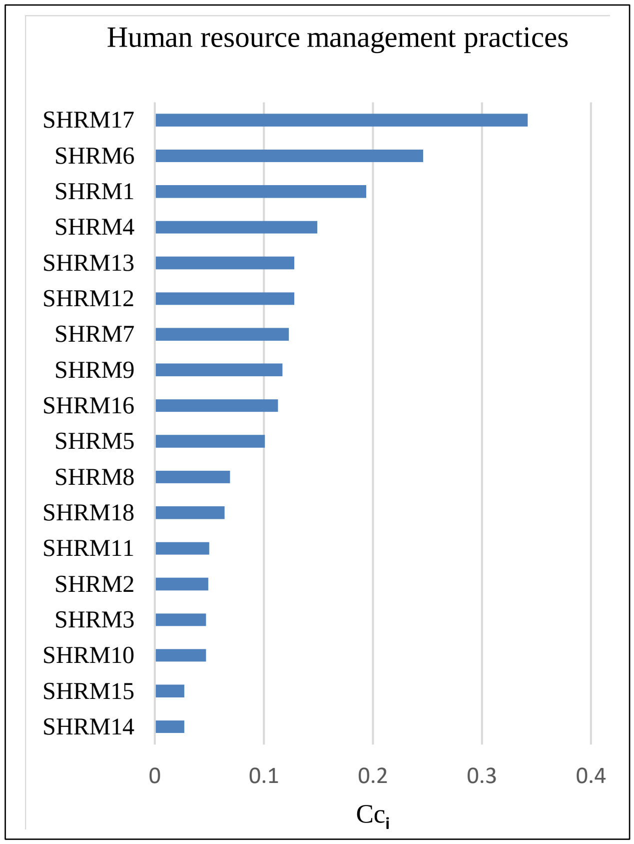

Figure 4.13 Human resource management practices

Hold regular meetings with labors SHRM17 (Cc_i=0.342) ranked 1st and 11th in this group and overall solution, respectively. Timely payment SHRM6 (Cc_i=0.246), detailed workforce plan SHRM1 (Cc_i=0.194), incentive/bones SHRM4 (Cc_i=0.149), and good relation between labor and superintendents SHRM13 (Cc_i=0.128) ranked from 2nd to 5th within this group and 18th, 20th, 23rd and 27th from the overall solutions, respectively. Similarly, team building between labors SHRM12 (Cc_i=0.128) and proper arrangement of labors/ crew composition SHRM7 (Cc_i=0.123) ranked 6th and 7th in this category and 29thand 30th from the overall ranking. Worker's participation in decision making SHRM9 (Cc_i=0.117), shift-based working hours SHRM16 (Cc_i=0.113) and increase of labors wage/salary SHRM5 (Cc_i=0.101), from 8th to 10th from this category and 32nd, 34th and 37th from the overall ranking, respectively.

Clear delegation of responsibility SHRM8 (Cc_i=0.069), giving workers breaks time and dayoff for holidays SHRM18 (Cc_i=0.064), and correct bad labor characteristics SHRM11 (Cc_i=0.05) ranked from 11th to 13th in this group and 47th ,49th, 53rd from the overall solutions, respectively. Hiring skilled workers SHRM2 (Cc_i=0.049), training of workers SHRM3 (Cc_i=0.047), and skill assessment and evaluation SHRM10 (Cc_i=0.047) ranked 14th, 15th, and 16th in this group, and 54th, 55th and 56th from the overall solutions, respectively. Site attendance SHRM14 (Cc_i=0.027) and drug and alcohol test SHRM15 (Cc_i=0.027) are the least significant solution, and both ranked 17th and 63rd among the overall management practices, respectively, to overcome CLP barriers.

4.6.2.4 Material Management Practices

Material management practices (average Cci=0.203) are ranked 3rd out of seven groups. It indicates that practices under material management have the high potential to overcome CLP barriers following the stakeholder and construction methods and site management. Tables 4.44 and figure 4.14 present the Cci and ranking of the eight material management practices.

Table 4.44 Material management practices

SMM	Cc_i	Group rank	Overall ranking
SMM1	0.356	1st	8th
SMM2	0.336	2nd	12th
SMM8	0.313	3rd	14th
SMM5	0.303	4th	15th
SMM6	0.1	5th	38th
SMM4	0.098	6th	42nd
SMM7	0.079	7th	45th
SMM3	0.037	8th	61st

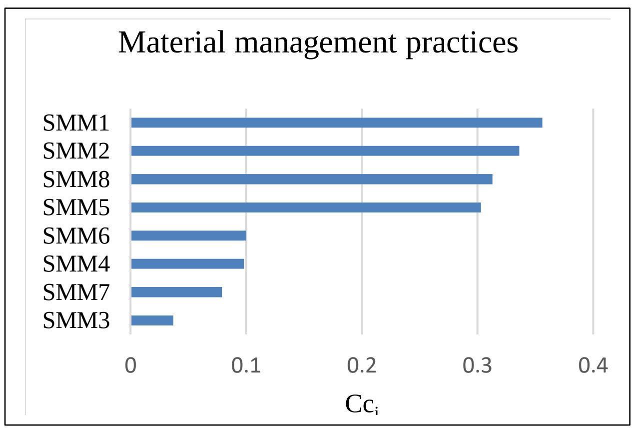

Figure: 4.14 Material management practices

Procurement plans for materials SMM1 (Cc_i=0.356) ranked 1st and 8th in this group and the overall practices, respectively. Provide materials on time SMM2 (Cci=0.336) ranked 2nd in this group and 12th among the overall solutions. On-site materials tracking SMM8 (Cc_i=0.313), long-lead materials identification SMM5 (Cc_i=0.303), and materials status database SMM6 (Cc_i=0.1) ranked from 3rd to 5th in this group and 14th, 15th and 38th from the overall solutions, respectively.

Proper materials handling systems SMM4 (Cc_i=0.098), post receipt preservation and maintenance SMM7 (Cc_i=0.079), and Just-in-time material delivery SMM3 (Cc_i=0.037) are the least ranked practices in this group and 40th, 44th and 61st from the overall solutions, respectively.

4.6.2.5 Equipment and Tools Management Practices

Table 4.40 shows that equipment and tools management practices (average Cci=0.171) ranked 5th out of seven groups. It indicates that management practices under equipment and tools have the potential to overcome CLP barriers. Table 4.45 and figure 4.15 illustrate the Cci result and ranking of equipment and tool management practices.

Table 4.45 Equipment and tools management practices

SETM	Cc_i	Group rank	Overall ranking
SETM1	0.255	1st	17th
SETM4	0.234	2nd	19th
SETM5	0.19	3rd	21st
SETM2	0.141	4th	26th
SETM3	0.036	5th	62nd

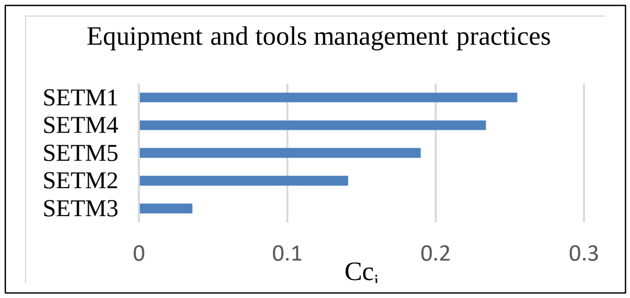

Figure 4.15 Equipment and tools management practices

Construction equipment procurement plans SETM1 (Cc_i=0.255), construction equipment maintenance SETM4 (Cc_i=0.234), and construction equipment productivity analysis SETM5 (Cc_i=0.19) are the top three equipment and tools management practices and ranked 17th,19th and 21st from the overall management practices to overcome CLP barriers, respectively. On the other hand, provide tools and equipment on time SETM2 (Cc_i=0.141) and Just-in-time equipment and tool SETM3 (Cc_i=0.036) ranked 4th and 5th in this category and 26th and 62nd among the overall solutions, respectively.

4.6.2.6 Safety and Health Management Practices

The safety and health-related management practices (average Cc_i=0.088) ranked 7th out of seven groups. Eleven safety and health factors are identified to overcome significant factors affecting CLP.

The Cc_i result and ranking of safety and health management practices are presented in table 4.46 and figure 4.16.

Table 4.46 Safety and health management practices

SSHM	Cc_i	Group rank	Overall ranking
SSHM5	0.145	1st	24th
SSHM9	0.125	2nd	29th
SSHM7	0.112	3rd	35th
SSHM8	0.102	4th	36th
SSHM1	0.096	5th	41st
SSHM10	0.085	6th	42nd
SSHM2	0.081	7th	43rd
SSHM11	0.076	8th	45th
SSHM6	0.061	9th	50th
SSHM3	0.046	10th	57th
SSHM4	0.042	11th	58th

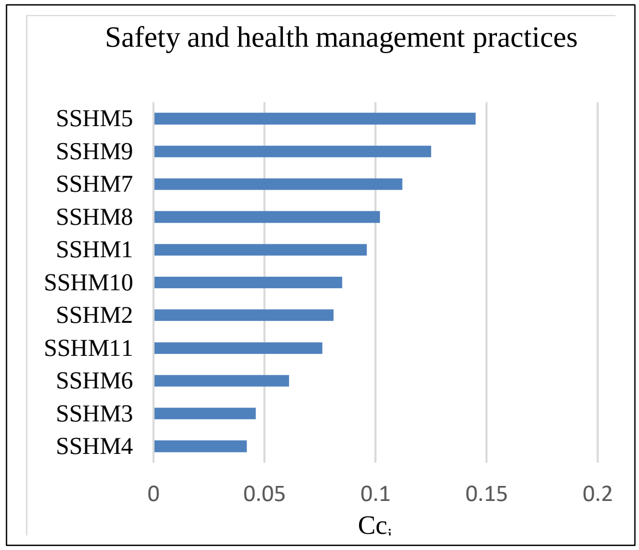

Figure 4.16 Safety and health management practices.

Provide hygienic site conditions SSHM5 (Cc_i=0.145), provide properly maintained PPE SSHM9 (Cc_i=0.125), and frequent housekeeping SSHM7 (Cc_i=0.112) are the top three safety and health management practices and ranked 24th, 29th, and 35th from the overall solution, respectively. Similarly, keep workplace safety signs facility SSHM8 (Cc_i=0.102), safety and health plan SSHM1 (Cc_i=0.096), effective site safety communication SSHM10 (Cc_i=0.085), and assign safety engineer SSHM2 (Cc_i=0.081) ranked from 4th to 7th within this group and 36th, 41st, 42nd and 43rd from the overall management practices, respectively.

Anticipating problems and planning in advance SSHM11 (Cci=0.076), toolbox safety meetings SSHM6 (Cc_i=0.061) and safety and health training SSHM3 (Cc_i=0.046) are ranked 8th,9th and 10th under this group and 45th,52nd and 58th from the overall management practices, respectively. Implementing a safe work method statement SSHM4 (Cc_i=0.042) are the least ranked safety and health management practices within this group and ranked 45th, 52nd, 57th and 58th from the overall solutions to overcome CLP barriers, respectively.

4.6.2.7 Stakeholders' Management Practice

Table 4.40 shows the stakeholders' management practice (average Cci=0.532) 1st ranked group out of seven management practices. It indicated that stakeholder management practices are the most significant to overcoming CLP factors. Five stakeholders' management practices were identified. Table 4.47 and figure 4.17 presents the result and ranking of stakeholders' management practice.

Table 4.47 Stakeholders' management practice

SSTM	Cc_i	Group rank	Overall ranking
SSTM5	0.716	1st	1st
SSTM1	0.712	2nd	2nd
SSTM2	0.602	3rd	4th
SSTM4	0.596	4th	5th
SSTM3	0.542	5th	6th

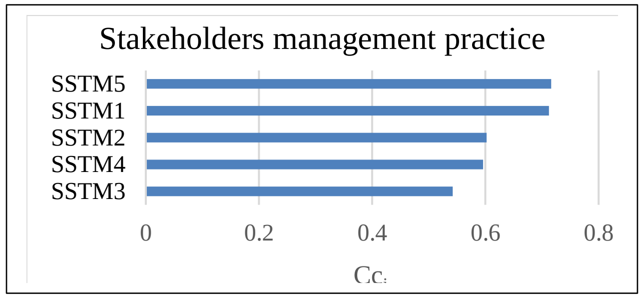

Figure 4.17 Stakeholders' management practice

Stable organizational structure SSTM5 (Cc_i=0.716) ranked 1st within this group and among overall solutions. Similarly, coordination between all stakeholders SSTM1 (Cc_i=0.712) ranked 2nd from within this group and overall solutions. Regular and effective communication on construction status SSTM2 (Cc_i=0.602), proper project financing SSTM 4 (Cci=0.596) and enhancing leadership and decision making of supervisors SSTM3 (Cc_i=0.542) ranked from 3rd to 5th from this group and 4th, 5th and 6th from the overall factors, respectively.

4.7 Significant Management Practices to Overcome Factors Affecting CLP

The Pareto principle is adopted to obtain significant management practices. According to the Pareto principle, the top 20% of management practices are determined as effective practices to overcome 80% of the CLP problem. Accordingly, 20% of 65 solutions are 13 solutions. Therefore, the top 13 management practices are determined as the most significant management practices to overcome factors affecting CLP and improve CLP. Table 4.48 illustrate the ranking and Cc_i of these significant solutions.

Table 4.48 Significant management practices

Solutions	Cc_i	Overall ranking
SSTM5	0.716	1st
SSTM1	0.712	2nd
SSM1	0.657	3rd
SSTM2	0.602	4th
SSTM4	0.596	5th
SSTM3	0.542	6th
SPPM8	0.478	7th
SMM1	0.356	8th
SPPM7	0.353	9th
SSM8	0.347	10th
SHRM17	0.342	11th
SMM2	0.336	12th
SPPM9	0.326	13th

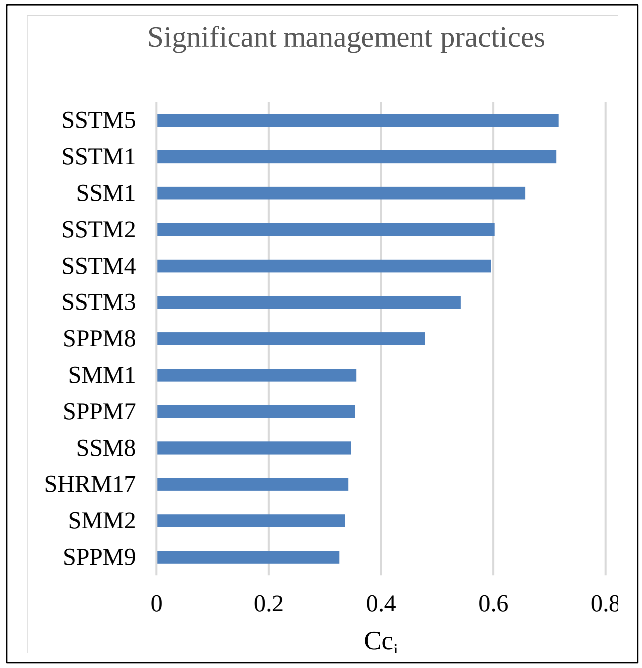

Figure 4.18 Significant management practices

Stable organizational structure SSTM5, coordination between all stakeholders SSTM1, proper site administration SSM1, regular and effective communication on construction status SSTM2, proper project financing SSTM 4, enhancing leadership and decision making of supervisors SSTM3, short interval plan SPPM8, procurement plans for materials SMM1, project completion plan SPPM7, effective supervision and quality control SSM8, hold regular meetings with labors SHRM17 provide materials on time SMM2 and project start-up plan SPPM9 are the thirteen most significant management practices.

Stable organizational structure SSTM5 (Cc_i=0.716) ranked 1st within the stakeholders' management practice group and among the overall solutions. It implies that maintaining a stable organizational structure is the most effective management solution to overcome factors affecting CLP. This practice is significant solution for management, finance, material, equipment and tools, safety and health, project environment, and external factors. Similarly, Gurmu & Aibinu (2018) supports this result. The organizational structure may alter as the building project progresses; however, the key personnel shouldn't leave the job site.

Furthermore, maintaining the stability of the organizational structure also enhances CLP, and employees working on a project starting from its commencement date have better information, accordingly. Similarly, this solution is ranked 3rd most crucial practice in the study by Gurmu & Ongkowijoyo (2020).

Coordination between all stakeholders SSTM1 (Cc_i=0.712) ranked 2nd in the stakeholders' management practice group and among overall solutions. It implies that coordination between all stakeholders is the most powerful management practice following a stable organizational structure to overcome CLP affecting factors. This practice is a significant solution for management, finance, material, equipment and tools, safety and health, project environment, and external related factors affecting CLP. Furthermore, Dixit (2021) agrees with the significance of this practice and ranked it as the 1st management practice affecting construction productivity.

Proper site administration SSM1 (Cc_i = 0.657) is ranked 1st in the construction method and site management category and 3rd among the overall solutions. It implies that proper site administration is the most significant factor in overcoming CLP barriers, following stable organizational structure and coordination between all stakeholders. It is a significant solution to overcome management, finance, labor, material, equipment and tools, safety and health, project environment and external factors. The study by Agrawal & Halder (2020) implemented this solution to mitigate improper managerial skills, on-site safety conditions, physical fatigue, and labor motivation.

Regular and effective communication on construction status SSTM2 (Cc_i=0.602) ranked 3rd in the stakeholders' management practice group and 4th among the overall factors. It implies that such practices can CLP affecting factors that can be overcome by having regular and effective communication on construction sites. This solution is significant to overcome management, finance and material, equipment and tools, and project environment and external related factors. A study by Ghodrati et al. (2018) agrees on the significance of Regular and effective communication on construction status in reducing loss of labor productivity and non-value-adding activities. Similarly, Agrawal (2019) implemented this solution to mitigate improper managerial skills, poor project planning and scheduling, labor disloyalty, safety conditions on-site, labor personal problem, and strikes due to political issues.

Proper project financing SSTM4 (Cc_i=0.596) ranked 4th in the stakeholders' management practice group and 5th among the overall factors. The result indicates that proper project financing is one of the significant management practices to overcome CLP problems. This management practice overcome financial, material, and equipment and tools related factors affecting CLP. The result indicates that this practice mitigates CLP issues such as labor motivation, financial constraints and labor disloyalty. It also ensures timely payment for good quality and speedy work.

Enhancing leadership and decision making of supervisors SSTM3 (Cc_i=0.542) ranked 5th in the construction method and site management practice group and 6th among the overall factors. This management practice is a significant solution to overcome material, finance, project environment and external, and management related factors affecting CLP. In the study by Agrawal & Halder (2020), improved managerial skills adopted to mitigate and improve problems related to supervision, unavailable of tools and equipment, clarity of technical specification, shortage of materials, motivation of labor, improper managerial skills, poor project planning, and scheduling drawing and specification alteration, construction method, type of project, and schedule compression.

Short interval plan SPPM8 (Cc_i= 0.478) is ranked 1st in the pre-construction phase management practices group and 7th among the overall practices. This solution is significant to overcome material, management, project environment and external, and financial related factors affecting CLP. In addition, the study by Gurmu & Aibinu (2018) revealed that the preparation of a short interval plan positively impacts labor productivity since it clearly shows the daily activities together with the resource requirements and look-ahead programs help to focus the job at hand.

Procurement plans for materials SMM1 (Cc_i=0.356) ranked 1st and 8th among the material management practices group and overall practices, respectively. The result indicates that preparing a procurement plan for materials is one of the most effective material management practices to overcome CLP barriers. This management practice is significant to overcome management and material related factors. Gurmu (2020) supports the finding and determined procurement plans for materials as one of the three most significant materials management practices which can enhance CLP.

The potential suppliers are identified, the required materials are estimated upfront, the tracking sheets and charts are prepared, different stages of the procurement are represented using different colors on the chart, and any changes made during the procurement process are tracked are steps in followed in preparing the material plan, accordingly.

Project completion plan SPPM7 (Cc_i= 0.353) ranked 2nd and 9th within the pre-construction phase management practices group and overall practice, respectively. Therefore, this practice is one of the most significant management practices to overcome CLP barriers. This management practice is a solution to overcome management, finance, material and project environment and external related factors. Gurmu et al. (2016) revealed that the project completion plan is one of the top five practices to improve CLP.

Effective supervision and quality control SSM8 (Cc_i=0.347) ranked 6th in the stakeholders' management practice group and 10th among the overall factors. Effective supervision and quality control is a significant solution for management, labor, equipment and tools, safety and health, project environment and external factors affecting CLP. Patkure & Kulkarni (2018) agree with the result and used effective supervision and quality control to mitigate labor productivity problems, including non-tool time, supervisor control labor, and motivating labors towards the completion of the project.

Hold regular meetings with labors SHRM17 (Cc_i=0.342) ranked 1st and 11th among human resource management practices group and overall solution, respectively. It indicates that regular meetings with laborers is one of the most significant solutions to overcome CLP factors. This management practice is a significant solution for financial, labor, equipment and tools, safety and health, and project environment and external related factors. In the study by Patkure & Kulkarni (2018), everyday communication between site engineers and labor contractors is implemented. The result shows positive outcomes in overcoming communication problems between site management and labor. Similarly, the finding is supported by Kazerooni et al. (2021) ranked holding regular meetings with labors schedules and remaining tasks as the 5th most effective management practice to improve CLP.

Provide materials on time SMM2 (Cc_i=0.336) ranked 2nd in the material management practices group and 12th among the overall solutions. It implies that delivering materials on time is the most effective practice. Provide materials on time is a significant solution to overcome material and labor related factors affecting CLP. Similarly, Mengistu et al. (2016) and Ghodrati et al. (2018) revealed the significance of provide materials on time. Sufficient construction materials on the project site should be delivered prior to the start of the project. Furthermore, materials should be stored at appropriate locations, easily accessible and close to the project site to avoid wasting labor time for multiple-handling materials, accordingly.

Project start-up plan SPPM9 (Cc_i=0.326) ranked 3rd and 13th within the Pre-construction phase management practices group and overall practice, respectively. The project start-up plan is one of most significant solutions to overcome management, finance, material and equipment and tools related factors. Similarly, the study by Gurmu (2020) considered project start-up planning among crucial practices that should be given priority in building projects. It includes the pre-commencement meeting dates, resource requirements, and any other information that could be forgotten during the commencement date.

4.7.1 Sensitivity Analysis of the Solutions

As discussed in section 3.8.3.4, single-dimensional weight sensitivity analysis is adopted to check the robustness of the ranking of the solutions. According to this approach, shortage of construction material, MTF1 is a critical criterion. Using Equation 3.18, the feasible weight range of MTF1 is $0 < MTF1 < 0.334$. Therefore, eight new set of weights for each criterion is arranged since it is possible to minimize the weight of the most important criterion to 0 and raise it to 0.334. The new sets of weights are arranged with a 0.05 gap within a feasible range, and all other criteria weights are adjusted equally to satisfy the weight additivity constraint, 1, to obtain the new ranking of the management solutions. After that, the solutions are rated using the new weights to obtain new Cc_i for each experiment separately.

Table 4.49 and table 4.50 illustrates the new sets of weights and the new Cc_i obtained new for every experiment, respectively.

Table 4.49 New sets of criteria weights

Significant Factors	New sets							
	1	2	3	4	5	6	7	8
MF1	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.02
MF2	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.01
MF3	0.02	0.02	0.02	0.01	0.01	0.01	0	0
FF1	0.18	0.18	0.18	0.17	0.17	0.16	0.16	0.16
FF2	0.1	0.09	0.09	0.09	0.08	0.08	0.08	0.07
LF1	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05
LF2	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02
MTF1	0.01	0.05	0.1	0.15	0.2	0.25	0.3	0.33
MTF2	0.09	0.09	0.08	0.08	0.08	0.07	0.07	0.07
ETF1	0.16	0.15	0.15	0.15	0.14	0.14	0.14	0.13
ETF2	0.08	0.08	0.08	0.07	0.07	0.07	0.06	0.06
SHF1	0.05	0.05	0.04	0.04	0.04	0.03	0.03	0.03
SHF2	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02
PEF1	0.05	0.05	0.04	0.04	0.04	0.03	0.03	0.03
PEF3	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01

Table 4.50 Experiments for sensitivity analysis

Set		SST M5	SST M1	SSM 1	SST M2	SST M4	SST M3	SPPM 8	SMM 1	SPPM 7	SSM 8	SHR M17	SMM 2	SPP M9
1	Cci	0.57	0.59	0.53	0.49	0.42	0.38	0.31	0.14	0.26	0.42	0.39	0.11	0.18
	Rank	2nd	1st	3rd	4th	5th	8th	9th	28th	11th	6th	7th	35th	19th
2	Cci	0.59	0.62	0.55	0.51	0.45	0.40	0.33	0.17	0.28	0.42	0.40	0.14	0.20
	Rank	2nd	1st	3rd	4th	5th	7th	9th	20th	10th	6th	8th	30th	16th
3	Cci	0.61	0.66	0.57	0.54	0.49	0.43	0.36	0.21	0.30	0.42	0.40	0.18	0.23
	Rank	2nd	1st	3rd	4th	5th	6th	9th	17th	10th	7th	8th	21st	15th
4	Cci	0.64	0.70	0.59	0.58	0.54	0.46	0.39	0.24	0.32	0.41	0.39	0.22	0.26
	Rank	2nd	1st	3rd	4th	5th	6th	9th	16th	10th	7th	8th	18th	13th
	Cci	0.66	0.73	0.62	0.61	0.58	0.48	0.42	0.28	0.34	0.39	0.38	0.26	0.29
5	Rank	2nd	1st	3rd	4th	5th	6th	7th	12th	10th	8th	9th	15th	11th
6	Cci	0.69	0.72	0.64	0.61	0.59	0.52	0.45	0.32	0.35	0.37	0.36	0.30	0.31
	Rank	2nd	1st	3rd	4th	5th	6th	7th	11th	10th	8th	9th	13th	12th
X	Cci	0.72	0.71	0.66	0.60	0.60	0.54	0.48	0.36	0.35	0.35	0.34	0.34	0.33
	Rank	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th
7	Cci	0.72	0.71	0.66	0.60	0.60	0.55	0.48	0.36	0.35	0.34	0.34	0.34	0.33
	Rank	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	11th	12th	10th	13th
8	Cci	0.74	0.70	0.68	0.60	0.60	0.57	0.51	0.39	0.36	0.32	0.32	0.37	0.34
	Rank	1st	2nd	3rd	5th	4th	6th	7th	8th	10th	13th	13th	9th	14th

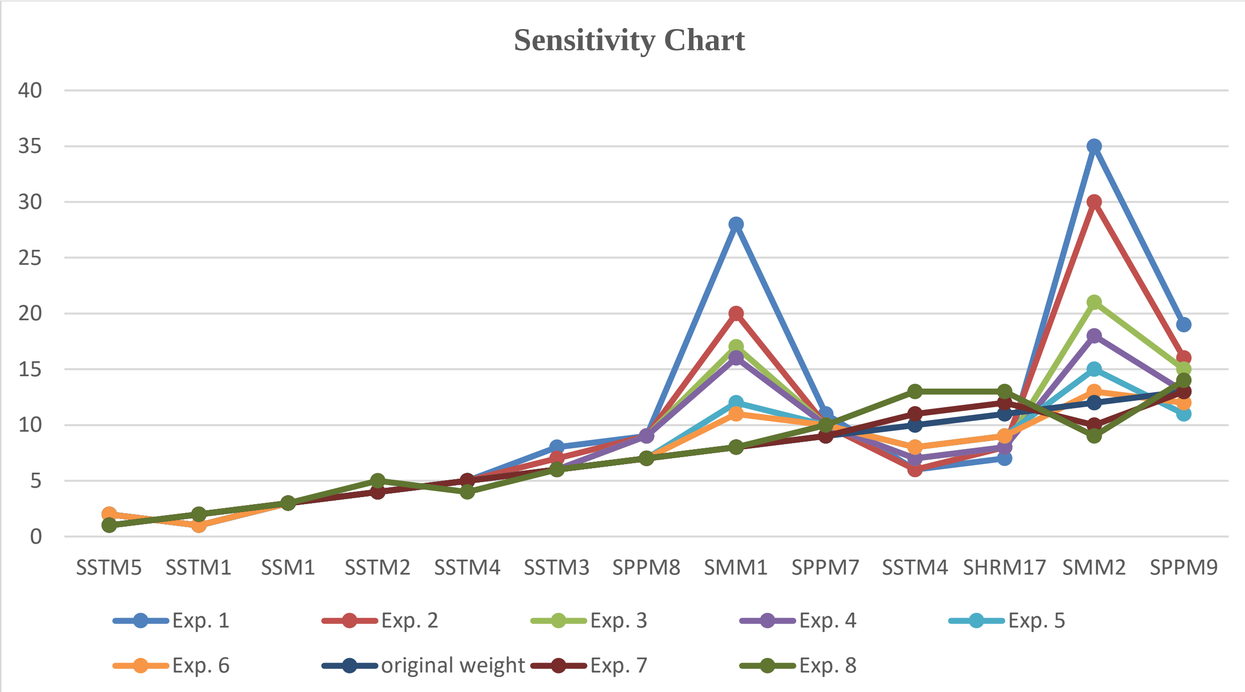

Figure 4.19 Sensitivity chart

It can be observed from table 4.50 and figure 4.19 that all the management practices determined as significant in the previous sections are still significant to overcome the critical factors affecting CLP, with changing weight of criteria except project start-up plan SPPM9, procurement plans for materials SMM1 and provide materials on time SMM2. While the rest management practices still remain significant. It indicated that stable organizational structure SSTM5, coordination between all stakeholders SSTM1, proper site administration SSM1, regular and effective communication on construction status SSTM2, proper project financing SSTM4, enhancing leadership and decision making of supervisors SSTM3, project completion plan SPPM7, effective supervision and quality control SSM8 and hold regular meetings with labors SHRM17 are the most stable effective management to factors affecting CLP.

4.8 Developed Framework

The following framework is developed based on the result obtained from a series of data analysis techniques on factors affecting CLP and management practices to overcome the barriers presented in figure 4.20.

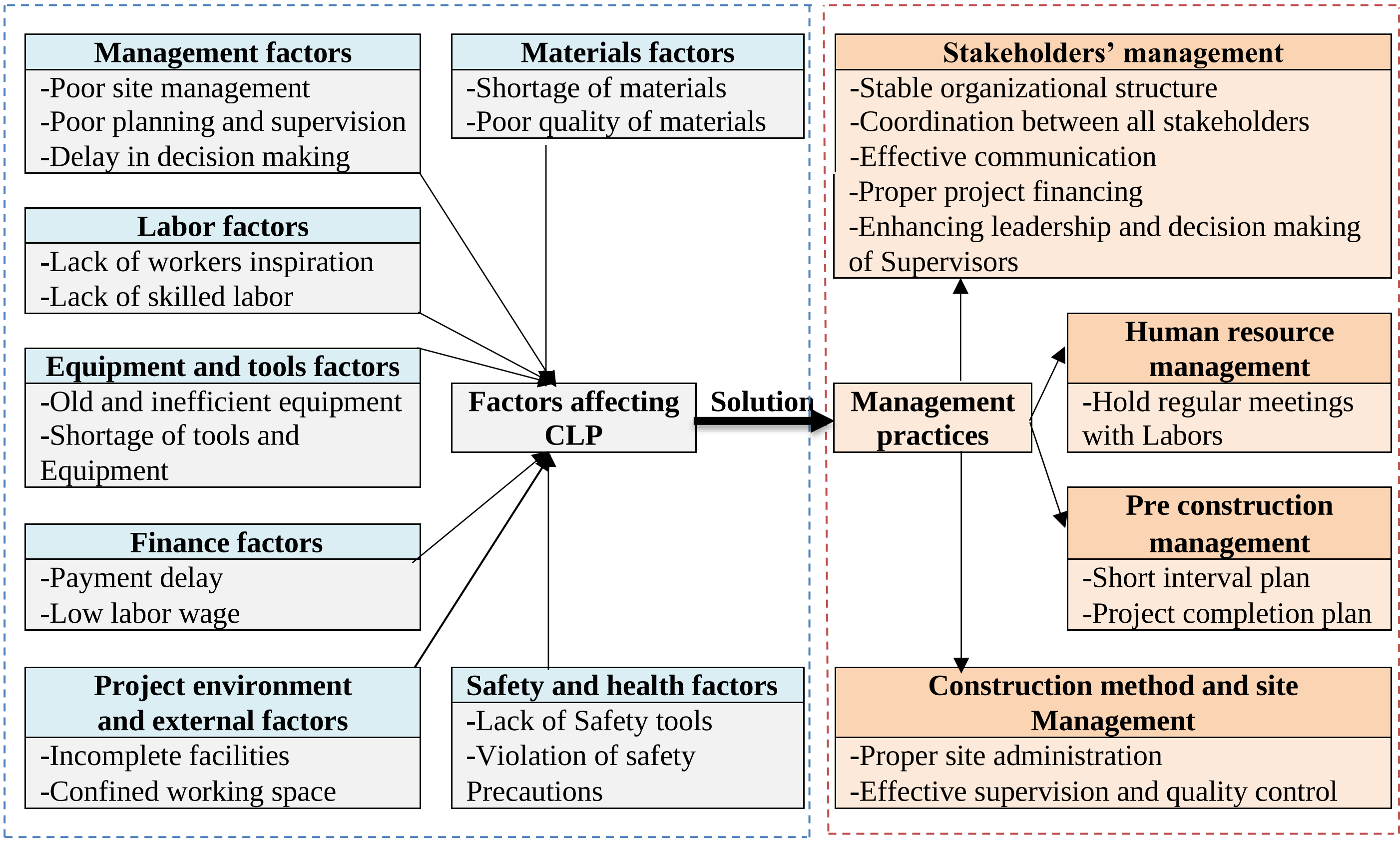

Figure 4.20 Framework for management practices to overcome factors affecting CLP

The developed framework provides the factors affecting CLP and the solutions to overcome CLP barriers for better productivity. It contains the most significant factors affecting CLP and crucial and strong management practices. The fifteen factors affecting CLP are presented along with their respective categories', which are determined using RII and the Pareto principle. The ten most crucial management practices to overcome the significant factors affecting CLP are also presented along with their respective management categories, which are determined through MCDM (F-AHP and F-TOPSIS) and sensitivity analysis.

CHAPTER FIVE-CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter is comprised of conclusions and recommendations of the research based on the finding of the study obtained and presented in the data analysis and discussions chapter. It also recommended further investigation.

5.2 Conclusions

Poor CLP has been a severe issue in many countries, where most construction work remains manual. It is always one of the causes of cost and time overruns in construction projects. Additionally, it adversely affects the success of construction organizations in the country, consequently reducing customer satisfaction. Overcoming this issue would not be possible without identifying specific disruption problems, working toward their elimination, and maintaining the improvements. Therefore, factors affecting it and management practices to overcome this productivity problem are determined in this study. Overcoming labor productivity affecting factors improves the overall construction performance, including increased output rate, cost reduction, planned production rate, and high-quality standards.

Eight groups of factors were identified, and the significance of these groups is determined by calculating the average value of the factors under their respective category. Material, equipment and tools, technical, finance, labor, management, safety and health, project environment and external related factors are the groups of factors that affect CLP in descending order of significance.

Sixty-two factors affecting CLP were considered and categorized under the eight groups of factors. Out of which shortage of construction material, old and inefficient equipment, poor site management, lack of safety tools, poor planning and scheduling, incomplete facilities, payment delay, lack of inspiration of workers, delay in decision making, shortage of tools and equipment, poor quality of materials, confined working space, low labor wage, lack of skilled /specialized labor, and violation of safety precautions are the most significant factors affecting CLP.

Seven groups of management practices to overcome factors affecting CLP were identified. Stakeholders' management, construction method and site management, material management, preconstruction management, equipment and tools management, human resource management, and safety and health management practices are in descending order of significance.

Sixty-five management practices were considered and listed under the seven categories to overcome CLP barriers. Out of which, stable organizational structure, coordination between all stakeholders, proper site administration, regular and effective communication, proper project financing, enhancing leadership and decision making of supervisors, short interval plan, procurement plans for materials, project completion plan, effective supervision and quality control, hold regular meetings with labors, project start-up plan and providing materials on time are the most significant management practices to overcome CLP. All the significant management practices are robust except the project start-up plan, procurement plans for materials, and providing materials on time.

5.3 Recommendations

Based on the research finding, the following recommendations are forwarded to overcome CLP factors and improve the overall CLP.

- To overcome factors affecting CLP, management practices should be implemented, including stable organizational structure, coordination between all stakeholders, proper site administration, regular and effective communication, proper project financing, enhancing leadership and decision-making of supervisors, short interval plan, project completion plan, effective supervision, and quality control, hold regular meetings with labors.

- The participation of all construction stakeholders is very crucial for better CLP. Mainly, the constructors, clients, and construction laborers should consider labor productivity to overcome poor CLP problems.

- Therefore, CLP can be improved by integrating the determined management solutions throughout the construction projects life cycle as well as the construction industry.

- Moreover, it is recommended to implement CLP management practice by developing CLP benchmarks and measuring the actual productivity. Which ease identifying the gap and barriers causing it and indicate.

Recommendations for Further Works

This study reveals the management practices that have the potential to overcome CLP. However, the actual productivity rate difference before and after implementing the management practices is not measured to benchmark the practical effectiveness of the solutions. Therefore, the researcher recommends further studies on the actual productivity effect of each management practice to overcome CLP barriers.

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APPENDICES

APPENDIX A
QUESTIONNAIRES

QUESTIONNAIRE NUMBER 1

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY
SCHOOL OF ENGINEERING
DEPARTMENT OF CIVIL ENGINEERING
DEGREE OF MASTER'S IN CONSTRUCTION ENGINEERING MANAGEMENT

Dear respondent,

I would like to express my appreciation and thanks for your time and effort to complete this questionnaire. This questionnaire is prepared to collect the necessary data for academic research entitled "Study on management practices to overcome factors affecting construction labor productivity in Adama City," which is being conducted as partial fulfillment of the MSc. in Construction Engineering and Management at Adama Science and Technology University. The specific objectives of the study are to,

- Determine the most significant factors affecting construction labor productivity.
- Weight the significant factors affecting construction labor productivity.
- Determine and prioritize management practices that have a potential to overcome significant factors affecting construction labor productivity.
- Develop a framework to determine means for better construction labor productivity.

All information in the questionnaire will be used only for academic research and will be strictly confidential. Therefore, I kindly request that you indicate your answer to each question by filling in the space provided with the correct answer.

Detail of the researcher:
Name: Lewam Kinfe Gebreyesus
Program: Master of Science in Civil Engineering
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Thank you in advance for your co-operation.
Lewam Kinfe
March 2022

1. Section One

1.1 Respondents’ Profile

1. Your organization

   Contractor ☐ Consultant ☐ Employer ☐

2. If your answer is a contractor for question number 1, what is the grade of the company?

   ________________________________.

3. What is your position in the firm/project?

   _____________________________________.

4. What is the highest level of education you have received?

   Ph.D. ☐ MSc. ☐ BSC. ☐ Diploma/level ☐

5. Years of experience in the construction industry

   0-5years ☐ 6-10 years ☐ 11-15years ☐ 16-20years ☐ 20 years ☐

2. Section Two- Factors Affecting Construction Labor Productivity

- **Define the rate of factors and frequency of occurrence.**

In this section, 62 factors affecting construction labor productivity are categorized into eight categories (management, finance, technical, labor, material, equipment and tools, safety and health, project environment, and external factors). By ticking (X or √), please define the rate of factors in the construction project you are currently working on.

Definition of scales

Scale	Definition
1	Very low effects
2	Low effects
3	Moderate effect
4	High effect
5	Very high effect

Factors affecting construction labor productivity	**I. Rate of factors**				
Management related factors	**1**	**2**	**3**	**4**	**5**
Poor planning and scheduling					
Poor control and supervision					
Lack of supervisors' experience					
Inspection delay					
Delay in decision making					
Delay in responding to information					
Poor site management					
Unclear instruction to labors					
Lack of periodic meetings with labors					
Lack of providing incentive					
Lack of training to labor					
Crew size and composition					
Contractual dispute					
Insufficient coordination among parties					
Misunderstanding between labor and superintendent					
Technical related factors	**1**	**2**	**3**	**4**	**5**
Rework					
Variation/ change of orders during execution					
Complexity of the design and project					
Lack of compatibility among contract documents					
Incomplete and Inaccurate drawing					
Lack of clarity of technical specifications					
Improper construction method					
Finance related factors	**1**	**2**	**3**	**4**	**5**
Inflation in the cost of execution					
Improper project financing					
Payment delay					
Low labor wage					
Labor related factors	**1**	**2**	**3**	**4**	**5**
Lack of skilled and specialized labor					
Lack of motivation of workers					
Bad labor characteristics					
Late arrival, early quit, unscheduled break					
Misunderstanding among labors					
Communication/ Language Barrier					

Poor economic condition of workers					
Labor related factors	**1**	**2**	**3**	**4**	**5**
Increase in laborer's age					
Physical fitness of labor					
Labor absenteeism					
Physical fatigue					
Labor personal problems					
Drug abuse and alcoholism					
Material related factors	**1**	**2**	**3**	**4**	**5**
Shortage of construction material					
Slow adoption of materials					
Poor quality of construction materials					
Unsuitability of material storage location					
Equipment and tools related factors	**1**	**2**	**3**	**4**	**5**
Shortage of Tools and Equipment					
Waiting for equipment to arrive					
Old and inefficient equipment					
Poor quality of tools					
Safety and health related factors	**1**	**2**	**3**	**4**	**5**
Site accident					
Lack of Safety tools (PPE)					
Absence of safety training & program					
Violation of safety precautions					
Insufficient lighting					
Hazardous Work Area					
Project environment and external related factors	**1**	**2**	**3**	**4**	**5**
Project location					
Confined working space					
Incomplete facilities					
Restricted site access					
Culture/ customs of community					
Religious and other holidays					
Extreme weather conditions					
Government policies					
Political instability					

QUESTIONNAIRE NUMBER 2

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY
SCHOOL OF ENGINEERING
DEPARTMENT OF CIVIL ENGINEERING
DEGREE OF MASTER'S IN CONSTRUCTION ENGINEERING MANAGEMENT

Dear respondent,

I would like to express my appreciation and thanks for your time and effort to complete this questionnaire. This questionnaire is prepared to collect the necessary data for academic research entitled "Study on management practices to overcome factors affecting construction labor productivity in Adama City," which is being conducted as partial fulfillment of the MSc. in Construction Engineering and Management at Adama Science and Technology University. The specific objectives of the study are to,

- Determine the most significant factors affecting construction labor productivity.
- Weight the significant factors affecting construction labor productivity.
- Determine and prioritize management practices that have a potential to overcome significant factors affecting construction labor productivity.
- Develop a framework to determine means for better construction labor productivity.

All information in the questionnaire will be used only for academic research and will be strictly confidential. Therefore, I kindly request that you indicate your answer to each question by filling in the space provided with the correct answer.

Detail of the researcher:
Name: Lewam Kinfe Gebreyesus
Program: Master of Science in Civil Engineering
(Construction Engineering and Management)
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Thank you in advance for your co-operation.
Lewam Kinfe,
April 2022

1. Section One

1.1 Respondents' profile

6. Your organization

Contractor ☐ Consultant ☐ Employer ☐

7. If your answer is a contractor for question number 1, What is the grade of the company?

_______________________________.

8. What is your position in the firm/project?

_______________________________.

9. What is the highest level of education you have received?

Ph.D. ☐ MSc. ☐ BSC. ☐ Diploma/level ☐

10. Years of experience in the construction industry

0-5years ☐ 6-10 years ☐ 11-15years ☐ 16-20years ☐ >20 years ☐

2. Section Two

➢ **Define the importance level.**

In this section, there are the top 13 factors affecting construction labor productivity. Therefore, respondents compare the importance level (pair-wise comparison) of factors by ticking (X or √). The comparison scales are 1,3,5,7 and 9.

Definition of scales

Intensity of importance	Fuzzy no	Linguistic variables	Membership function (TFN)
1	$\tilde{1}$	Equally Important/ preferred	(1,1,3)
3	$\tilde{3}$	Weak Important/preferred	(1,3,5)
5	$\tilde{5}$	Strong Important/preferred	(3,5,7)
7	$\tilde{7}$	Very strong Important/preferred	(5,7,9)
9	$\tilde{9}$	Extremely strong Important/preferred	(7,9,11)

2.1. In this section, respondents compare a group of factors with another group of factors affecting construction labor productivity.

The left factor is affecting more					Equal	The right factor is affecting more				
	9	7	5	3	1	3	5	7	9	
Management related factors										Finance related factors
Management related factors										Labor related factors
Management related factors										Material related factors
Management related factors										Equipment and tools related factors
Management related factors										Safety and health related factors
Management related factors										Project environment factors
The left factor is affecting more	9	7	5	3	1	3	5	7	9	**The right factor is affecting more**
Finance related factors										Labor related factors
Finance related factors										Material related factors
Finance related factors										Equipment and tools related factors
Finance related factors										Safety and health related factors
Finance related factors										Project environment factors
The left factor is affecting more	9	7	5	3	1	3	5	7	9	**The right factor is affecting more**
Labor related factors										Material related factors
Labor related factors										Equipment and tools related factors
Labor related factors										Safety and health related factors
Labor related factors										Project environment factors
The left factor is affecting more	9	7	5	3	1	3	5	7	9	**The right factor is affecting more**
Material related factors										Equipment and tools related factors
Material related factors										Safety and health related factors
Material related factors										Project environment factors
The left factor is affecting more	9	7	5	3	1	3	5	7	9	**The right factor is affecting more**
Equipment and tools related factors										Safety and health related factors
Equipment and tools related factors										Project environment factors
The left factor is affecting more	9	7	5	3	1	3	5	7	9	**The right factor is affecting more**
Safety and health related factors										Project environment factors

2.2. In this section, respondents compare factors affecting construction labor productivity within the same categories.

A Management related factors

The left factor is affecting more					Equal	The right factor is affecting more				
	9	7	5	3	1	3	5	7	9	
Poor planning and scheduling										Poor site management
Poor planning and scheduling										Delay in decision making
Poor site management										Delay in decision making

B. Finance related factors

The left factor is affecting more					Equal	The right factor is affecting more				
	9	7	5	3	1	3	5	7	9	
Payment delay										Low labor wage

C. Labor related factors

The left factor is affecting more					Equal	The right factor is affecting more				
	9	7	5	3	1	3	5	7	9	
Lack of skilled and specialized labor										Lack of motivation of workers

D. Material related factors

The left factor is affecting more					Equal	The right factor is affecting more				
	9	7	5	3	1	3	5	7	9	
Shortage of construction material										Poor quality of construction materials

E. Equipment and tools related factors

The left factor is affecting more					Equal	The right factor is affecting more				
	9	7	5	3	1	3	5	7	9	
Shortage of tools and equipment										Old and inefficient equipment

F. Safety and health related factors

The left factor is affecting more					Equal	The right factor is affecting more				
	9	7	5	3	1	3	5	7	9	
Lack of Safety tools										Violation of safety precautions

G. Project environment and external factors

The left factor is affecting more					Equal	The right factor is affecting more				
	9	7	5	3	1	3	5	7	9	
Incomplete facilities (water, power supply, and sanitary)										Confined working space

3. Section three

In this section, respondents compare the importance level of 65 management practices to overcome each factor affecting construction labor productivity by writing "HV," "H," "M," "L," and "HL" on the space provided. Management practices are categorized into preconstruction management, site management and construction method, human resources management, construction materials management, equipment and tools management, safety and health management, and stakeholder management practices.

Variables	Fuzzy no defined	Membership functions (TFN)
VH	Very high	(7,9,11)
H	High	(5,7,9)
M	Medium	(3,5,7)
L	Low	(1,3,5)
VL	Very Low	(1,1,3)

- **Factors affecting labor productivity and their codes**

Code	Factors affecting construction labor productivity
1	Poor planning and scheduling
2	Poor site management
3	Delay in decision making
4	Payment delay
5	Low labor wage
6	Lack of skilled and specialized labor
7	Lack of motivation of workers
8	Shortage of construction material
9	Poor quality of construction materials
10	Shortage of tools and equipment
11	Old and inefficient equipment
12	Lack of Safety tools
13	Violation of safety precautions
14	Incomplete facilities (water, power supply, and sanitary)
15	Confined working space

1. **Management practices to overcome factors affecting labor productivity.**

Management practices	Factors affecting construction labor productivity														
I. Preconstruction phase management	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Use of software in planning work packages															
Appointed experienced designer															
Well-Defined scope of work															
Complete and approval of construction drawing before the commencement of construction															
Realistic work schedule															
Collaborative procurement															
Project Start-up Plan															
Project Completion Plan															
Short Interval Plan															
Fulfill Regulatory Requirement															
II. Site management and construction method	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Proper site administration															
Provide necessary site facilities															
Proper construction site layout															
Dynamic Site Layout Plan															
Site Security Plan															
Traffic Control Plan															
Adoption of advanced technologies															
Effective supervision and quality control															
III. Human resource management	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Detailed Workforce Plan															
Hiring skilled workers															
Training of workers															
Incentive/bones															
Increase labors wage/salary															
Timely payment															
Proper arrangement of labors															
Clear delegation of responsibility															
Worker’s participation in decision making															
Skill assessment and Evaluation															
Correct bad labor characteristics															
Team building															
Good communication															
Good relation between labor and superintendents															
Shift-based working hours															

Hold regular meetings with labors about schedule and remaining tasks															
Giving workers breaks time and day off for holidays															
IV. Materials management	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Procurement plans for materials															
Provide materials on time															
Just-in-time materials delivery															
Proper materials handling systems															
Long-lead materials identification															
Materials status database															
Post receipt preservation and maintenance															
On-site materials tracking															
V. Equipment and tools Management	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Equipment procurement plans															
Provide tools and equipment on time															
Just-in-time equipment															
Equipment maintenance															
Equipment productivity analysis															
VI. Safety and health management	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Safety and Health plan															
Assign safety engineer															
Safety and Health Training															
Implement safe work method statement															
Provide hygienic site conditions															
Toolbox Safety Meetings															
Frequent housekeeping															
Keep workplace safety signs facility															
Proper maintained PPE															
Effective site communication															
Anticipating problems and planning for them in advance															
VII. Stakeholders' management	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Coordination between stakeholders															
Regular and effective communication on construction status															
Enhancing leadership and decision making for the supervisors															
Proper project financing															
Stable organizational structure															

APPENDIX B
WEIGHTED FUZZY NORMALIZED MATRIX, F-TOPSIS

Table B.1- Weighted Fuzzy normalized matrix

	MF1	MF2	MF3	FF1	FF2	LF1	LF2	MTF1	MTF2	ETF1	ETF2	SHF1	SHF2	PEF1	PEF2
	0.008	0.001	0.001	0.054	0.025	0.017	0.007	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.003
	0.025	0.002	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
SPPM1	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.008	0.005	0.001	0.054	0.025	0.017	0.007	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.003
	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
SPPM2	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.008	0.001	0.000	0.023	0.025	0.017	0.007	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.003
	0.025	0.002	0.002	0.043	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
SPPM3	0.025	0.005	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.008	0.001	0.001	0.054	0.025	0.017	0.007	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.003
	0.025	0.002	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
SPPM4	0.025	0.005	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.004	0.001	0.000	0.054	0.025	0.017	0.007	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.003
	0.020	0.002	0.002	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
SPPM5	0.025	0.002	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.003	0.001	0.000	0.015	0.025	0.017	0.007	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.003
	0.008	0.002	0.001	0.026	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
SPPM6	0.025	0.005	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.002	0.001	0.000	0.015	0.025	0.017	0.007	0.032	0.023	0.019	0.021	0.010	0.007	0.003	0.003
	0.004	0.002	0.002	0.024	0.076	0.050	0.021	0.146	0.070	0.091	0.064	0.029	0.020	0.017	0.010
SPPM7	0.008	0.005	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.002	0.001	0.000	0.015	0.025	0.017	0.007	0.032	0.010	0.019	0.021	0.010	0.007	0.003	0.001
	0.004	0.002	0.001	0.026	0.076	0.050	0.021	0.042	0.040	0.078	0.064	0.029	0.020	0.018	0.002
SPPM8	0.008	0.005	0.003	0.162	0.076	0.050	0.021	0.097	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.008	0.005	0.001	0.054	0.025	0.017	0.002	0.027	0.008	0.019	0.009	0.010	0.007	0.010	0.003
	0.025	0.016	0.003	0.162	0.076	0.050	0.010	0.102	0.033	0.060	0.028	0.029	0.020	0.031	0.010
SPPM9	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.008	0.001	0.001	0.054	0.008	0.017	0.007	0.097	0.010	0.045	0.021	0.010	0.007	0.010	0.003
	0.025	0.002	0.003	0.162	0.030	0.050	0.021	0.292	0.056	0.136	0.064	0.029	0.020	0.031	0.010
SPPM10	0.025	0.005	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.002	0.005	0.000	0.023	0.008	0.005	0.003	0.027	0.008	0.015	0.007	0.003	0.002	0.003	0.003
	0.003	0.016	0.000	0.093	0.023	0.008	0.012	0.044	0.051	0.021	0.014	0.004	0.003	0.004	0.010
SSM1	0.005	0.016	0.001	0.162	0.076	0.017	0.021	0.097	0.070	0.045	0.064	0.010	0.007	0.010	0.010
	0.002	0.005	0.001	0.054	0.025	0.006	0.003	0.097	0.023	0.045	0.021	0.010	0.007	0.003	0.003
	0.003	0.016	0.003	0.162	0.076	0.008	0.017	0.292	0.070	0.136	0.064	0.029	0.020	0.004	0.010
SSM2	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.010	0.010
	0.002	0.005	0.001	0.054	0.025	0.006	0.007	0.097	0.023	0.045	0.021	0.010	0.002	0.010	0.001
	0.003	0.016	0.003	0.162	0.076	0.008	0.021	0.292	0.070	0.136	0.064	0.029	0.003	0.031	0.001
SSM3	0.025	0.016	0.003	0.162	0.076	0.017	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.001
	0.002	0.001	0.001	0.054	0.025	0.017	0.007	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.001
	0.003	0.002	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.001
SSM4	0.025	0.005	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.003

	MF1	MF2	MF3	FF1	FF2	LF1	LF2	MTF1	MTF2	ETF1	ETF2	SHF1	SHF2	PEF1	PEF2
	0.002	0.002	0.001	0.054	0.025	0.017	0.007	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.003
	0.004	0.003	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
SSM5	0.025	0.005	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.002	0.001	0.001	0.054	0.025	0.017	0.007	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.001
	0.004	0.003	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.001
SSM6	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.002
	0.008	0.005	0.001	0.023	0.025	0.017	0.007	0.097	0.008	0.012	0.006	0.010	0.007	0.010	0.003
	0.025	0.016	0.003	0.130	0.076	0.050	0.021	0.292	0.051	0.016	0.012	0.029	0.020	0.031	0.010
SSM7	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.045	0.064	0.029	0.020	0.031	0.010
	0.002	0.001	0.000	0.015	0.008	0.005	0.004	0.027	0.010	0.045	0.021	0.010	0.002	0.003	0.003
	0.003	0.002	0.000	0.023	0.030	0.009	0.015	0.043	0.047	0.136	0.064	0.029	0.003	0.016	0.010
SSM8	0.025	0.016	0.001	0.054	0.076	0.050	0.021	0.097	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.008	0.001	0.001	0.032	0.008	0.017	0.002	0.097	0.023	0.045	0.006	0.010	0.007	0.010	0.001
	0.025	0.002	0.003	0.108	0.023	0.050	0.003	0.292	0.070	0.136	0.009	0.029	0.020	0.031	0.002
SHRM1	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.008	0.005	0.001	0.054	0.025	0.017	0.002	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.003
	0.025	0.016	0.003	0.162	0.076	0.050	0.003	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
SHRM2	0.025	0.016	0.003	0.162	0.076	0.050	0.004	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.008	0.005	0.001	0.054	0.025	0.017	0.002	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.003
	0.025	0.016	0.003	0.162	0.076	0.050	0.003	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
SHRM3	0.025	0.016	0.003	0.162	0.076	0.050	0.007	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.008	0.005	0.001	0.054	0.007	0.005	0.007	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.003
	0.025	0.016	0.003	0.162	0.010	0.007	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
SHRM4	0.025	0.016	0.003	0.162	0.025	0.017	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.008	0.005	0.001	0.054	0.007	0.017	0.007	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.003
	0.025	0.016	0.003	0.162	0.009	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
SHRM5	0.025	0.016	0.003	0.162	0.025	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.008	0.005	0.001	0.015	0.025	0.005	0.007	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.003
	0.025	0.016	0.003	0.019	0.076	0.006	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
SHRM6	0.025	0.016	0.003	0.032	0.076	0.017	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.002	0.005	0.001	0.054	0.025	0.017	0.002	0.097	0.023	0.045	0.006	0.010	0.007	0.010	0.001
	0.003	0.016	0.003	0.162	0.076	0.050	0.003	0.292	0.070	0.136	0.008	0.029	0.020	0.031	0.001
SHRM7	0.025	0.016	0.003	0.162	0.076	0.050	0.007	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.002
	0.008	0.005	0.001	0.054	0.007	0.017	0.002	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.003
	0.025	0.016	0.003	0.162	0.051	0.050	0.003	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
SHRM8	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.003	0.005	0.000	0.054	0.007	0.005	0.007	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.003
	0.018	0.016	0.000	0.162	0.025	0.008	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
SHRM9	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
SHRM10															
	0.008	0.005	0.001	0.054	0.025	0.017	0.002	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.003
	0.025	0.016	0.003	0.162	0.076	0.050	0.003	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.025	0.016	0.003	0.162	0.076	0.050	0.007	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010

	MF1	MF2	MF3	FF1	FF2	LF1	LF2	MTF1	MTF2	ETF1	ETF2	SHF1	SHF2	PEF1	PEF2
	0.008	0.005	0.001	0.054	0.008	0.017	0.007	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.003
	0.025	0.016	0.003	0.162	0.055	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
SHRM11	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.008	0.005	0.001	0.054	0.008	0.005	0.002	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.003
	0.025	0.016	0.003	0.162	0.028	0.007	0.008	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
SHRM12	0.025	0.016	0.003	0.162	0.076	0.017	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.003	0.005	0.000	0.054	0.011	0.005	0.003	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.003
	0.018	0.016	0.000	0.162	0.041	0.007	0.011	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
SHRM13	0.025	0.016	0.003	0.162	0.076	0.010	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.008	0.005	0.001	0.054	0.025	0.017	0.007	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.003
	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
SHRM14	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.008	0.005	0.001	0.054	0.025	0.017	0.007	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.003
	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
SHRM15	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.008	0.005	0.001	0.054	0.011	0.005	0.007	0.097	0.023	0.045	0.007	0.010	0.007	0.010	0.002
	0.025	0.016	0.003	0.162	0.061	0.008	0.021	0.292	0.070	0.136	0.030	0.029	0.020	0.031	0.007
SHRM16	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.003	0.005	0.000	0.032	0.011	0.006	0.002	0.097	0.008	0.019	0.006	0.003	0.002	0.003	0.003
	0.018	0.016	0.000	0.108	0.034	0.008	0.003	0.292	0.016	0.078	0.012	0.015	0.003	0.016	0.010
SHRM17	0.025	0.016	0.001	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.007	0.031	0.010
	0.008	0.005	0.001	0.054	0.025	0.005	0.007	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.003
	0.025	0.016	0.003	0.162	0.076	0.008	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
SHRM18	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.002	0.001	0.001	0.054	0.025	0.017	0.007	0.027	0.006	0.045	0.021	0.010	0.007	0.010	0.003
	0.004	0.002	0.003	0.162	0.076	0.050	0.021	0.038	0.010	0.136	0.064	0.029	0.020	0.031	0.010
SMM1	0.025	0.005	0.003	0.162	0.076	0.050	0.021	0.097	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.002	0.005	0.001	0.054	0.025	0.005	0.007	0.027	0.023	0.045	0.021	0.010	0.007	0.010	0.003
	0.003	0.016	0.003	0.162	0.076	0.007	0.021	0.038	0.070	0.136	0.064	0.029	0.020	0.031	0.010
SMM2	0.025	0.016	0.003	0.162	0.076	0.017	0.021	0.097	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.008	0.005	0.001	0.054	0.025	0.017	0.007	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.001
	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.001
SMM3	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.002
	0.002	0.005	0.001	0.054	0.025	0.017	0.007	0.097	0.006	0.045	0.021	0.010	0.007	0.010	0.003
	0.004	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.012	0.136	0.064	0.029	0.020	0.031	0.010
SMM4	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.097	0.07	0.136	0.064	0.029	0.020	0.031	0.010
	0.003	0.005	0.001	0.054	0.025	0.017	0.007	0.027	0.023	0.045	0.021	0.010	0.007	0.010	0.003
	0.004	0.016	0.003	0.162	0.076	0.050	0.021	0.033	0.070	0.136	0.064	0.029	0.020	0.031	0.010
SMM5	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.042	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.003	0.005	0.001	0.054	0.025	0.017	0.007	0.097	0.006	0.045	0.021	0.010	0.007	0.010	0.003
	0.005	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.008	0.136	0.064	0.029	0.020	0.031	0.010
SMM6	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.008	0.005	0.001	0.054	0.025	0.017	0.007	0.097	0.006	0.045	0.021	0.010	0.007	0.010	0.003
	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.012	0.136	0.064	0.029	0.020	0.031	0.010
SMM7	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010

	MF1	MF2	MF3	FF1	FF2	LF1	LF2	MTF1	MTF2	ETF1	ETF2	SHF1	SHF2	PEF1	PEF2
	0.003	0.005	0.001	0.054	0.025	0.017	0.007	0.027	0.010	0.045	0.021	0.010	0.007	0.010	0.001
	0.004	0.016	0.003	0.162	0.076	0.050	0.021	0.037	0.056	0.136	0.064	0.029	0.020	0.031	0.001
SMM8	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.097	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.008	0.001	0.001	0.054	0.025	0.017	0.007	0.097	0.008	0.012	0.006	0.010	0.007	0.010	0.003
	0.025	0.002	0.003	0.162	0.076	0.050	0.021	0.292	0.051	0.019	0.009	0.029	0.020	0.031	0.010
SETM1	0.025	0.005	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.045	0.021	0.029	0.020	0.031	0.010
	0.008	0.005	0.001	0.054	0.025	0.006	0.007	0.097	0.023	0.045	0.006	0.010	0.007	0.010	0.003
	0.025	0.016	0.003	0.162	0.076	0.007	0.021	0.292	0.070	0.136	0.008	0.029	0.020	0.031	0.010
SETM2	0.025	0.016	0.003	0.162	0.076	0.017	0.021	0.292	0.070	0.136	0.013	0.029	0.020	0.031	0.010
	0.008	0.005	0.001	0.054	0.025	0.017	0.007	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.001
	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.001
SETM3	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.003
	0.008	0.005	0.001	0.054	0.025	0.017	0.007	0.097	0.008	0.012	0.006	0.010	0.007	0.010	0.003
	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.051	0.018	0.009	0.029	0.020	0.031	0.010
SETM4	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.027	0.064	0.029	0.020	0.031	0.010
	0.008	0.005	0.001	0.054	0.025	0.017	0.007	0.097	0.008	0.012	0.021	0.010	0.007	0.010	0.003
	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.051	0.018	0.064	0.029	0.020	0.031	0.010
SETM5	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.027	0.064	0.029	0.020	0.031	0.010
	0.008	0.001	0.001	0.054	0.025	0.017	0.007	0.097	0.023	0.045	0.021	0.003	0.002	0.010	0.001
	0.025	0.002	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.004	0.003	0.031	0.001
SSHM1	0.025	0.005	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.010	0.007	0.031	0.010
	0.002	0.005	0.001	0.054	0.025	0.017	0.007	0.097	0.023	0.045	0.021	0.003	0.002	0.010	0.003
	0.005	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.009	0.003	0.031	0.010
SSHM2	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.007	0.031	0.010
	0.008	0.005	0.001	0.054	0.025	0.017	0.007	0.097	0.023	0.045	0.021	0.010	0.002	0.010	0.003
	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.002	0.031	0.010
SSHM3	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.007	0.031	0.010
	0.008	0.005	0.001	0.054	0.025	0.017	0.007	0.097	0.023	0.045	0.021	0.003	0.007	0.010	0.003
	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.012	0.020	0.031	0.010
SSHM4	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.002	0.005	0.001	0.054	0.025	0.005	0.007	0.097	0.023	0.045	0.021	0.003	0.002	0.003	0.003
	0.004	0.016	0.003	0.162	0.076	0.008	0.021	0.292	0.070	0.136	0.064	0.012	0.003	0.004	0.010
SSHM5	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.007	0.010	0.010
	0.008	0.005	0.001	0.054	0.025	0.017	0.007	0.097	0.023	0.045	0.021	0.003	0.002	0.010	0.003
	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.007	0.003	0.031	0.010
SSHM6	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.002	0.005	0.001	0.054	0.025	0.006	0.007	0.097	0.023	0.045	0.021	0.010	0.002	0.010	0.001
	0.004	0.016	0.003	0.162	0.076	0.008	0.021	0.292	0.070	0.136	0.064	0.029	0.003	0.031	0.001
SSHM7	0.025	0.016	0.003	0.162	0.076	0.017	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.002	0.005	0.001	0.054	0.025	0.017	0.007	0.097	0.023	0.045	0.021	0.003	0.002	0.003	0.003
	0.004	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.004	0.003	0.023	0.010
SSHM8	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.010	0.007	0.031	0.010
	0.008	0.005	0.001	0.054	0.025	0.005	0.007	0.097	0.023	0.045	0.021	0.003	0.002	0.010	0.003
	0.025	0.016	0.003	0.162	0.076	0.007	0.021	0.292	0.070	0.136	0.064	0.003	0.003	0.031	0.010
SSHM9	0.025	0.016	0.003	0.162	0.076	0.017	0.021	0.292	0.070	0.136	0.064	0.006	0.007	0.031	0.010

	MF1	MF2	MF3	FF1	FF2	LF1	LF2	MTF1	MTF2	ETF1	ETF2	SHF1	SHF2	PEF1	PEF2
	0.002	0.005	0.001	0.054	0.025	0.017	0.007	0.097	0.023	0.045	0.021	0.003	0.002	0.010	0.003
	0.004	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.005	0.003	0.031	0.010
SSHM10	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.007	0.031	0.010
	0.002	0.001	0.001	0.054	0.025	0.017	0.007	0.097	0.023	0.045	0.021	0.003	0.007	0.010	0.003
	0.004	0.002	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.012	0.020	0.031	0.010
SSHM11	0.025	0.005	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.002	0.001	0.000	0.018	0.007	0.006	0.007	0.032	0.008	0.015	0.007	0.003	0.007	0.003	0.003
	0.004	0.002	0.000	0.025	0.025	0.009	0.021	0.049	0.014	0.021	0.010	0.005	0.020	0.004	0.010
SSTM1	0.025	0.005	0.003	0.054	0.076	0.050	0.021	0.292	0.070	0.045	0.064	0.010	0.020	0.010	0.010
	0.002	0.001	0.000	0.015	0.025	0.006	0.007	0.027	0.008	0.015	0.007	0.010	0.007	0.003	0.001
	0.004	0.002	0.000	0.025	0.076	0.009	0.021	0.044	0.013	0.020	0.011	0.029	0.020	0.005	0.002
SSTM2	0.008	0.005	0.001	0.162	0.076	0.050	0.021	0.292	0.070	0.045	0.064	0.029	0.020	0.031	0.010
	0.008	0.005	0.001	0.054	0.025	0.017	0.007	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.003
	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
SSTM3	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
	0.002	0.005	0.000	0.054	0.025	0.005	0.002	0.097	0.006	0.012	0.006	0.003	0.002	0.003	0.001
	0.003	0.016	0.000	0.162	0.076	0.009	0.003	0.292	0.010	0.016	0.012	0.004	0.003	0.005	0.002
SSTM5	0.005	0.016	0.001	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.010	0.020	0.031	0.010
	0.002	0.005	0.001	0.015	0.007	0.017	0.007	0.027	0.006	0.012	0.021	0.010	0.007	0.010	0.003
	0.004	0.016	0.003	0.021	0.012	0.050	0.021	0.052	0.037	0.020	0.064	0.029	0.020	0.031	0.010
SSTM6	0.025	0.016	0.003	0.032	0.076	0.050	0.021	0.292	0.070	0.045	0.064	0.029	0.020	0.031	0.010
	0.002	0.001	0.000	0.015	0.007	0.017	0.004	0.032	0.008	0.012	0.007	0.003	0.007	0.003	0.003
	0.003	0.002	0.001	0.022	0.011	0.050	0.014	0.045	0.051	0.020	0.026	0.005	0.020	0.012	0.010
SSTM7	0.008	0.005	0.001	0.032	0.025	0.050	0.021	0.097	0.070	0.045	0.064	0.029	0.020	0.031	0.010
	0.002	0.001	0.000	0.015	0.007	0.005	0.002	0.027	0.006	0.012	0.006	0.003	0.002	0.003	0.001
	0.003	0.002	0.000	0.019	0.009	0.006	0.003	0.033	0.008	0.016	0.008	0.003	0.002	0.004	0.001
A+	0.005	0.002	0.001	0.032	0.025	0.020	0.004	0.190	0.070	0.027	0.013	0.006	0.007	0.010	0.001
	0.008	0.005	0.001	0.054	0.025	0.017	0.007	0.097	0.023	0.045	0.021	0.010	0.007	0.010	0.003
	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010
A-	0.025	0.016	0.003	0.162	0.076	0.050	0.021	0.292	0.070	0.136	0.064	0.029	0.020	0.031	0.010