Development of Integrated Project Delivery and Last Planner System Concepts as a Waste Minimization Technique in Ethiopian Road Construction Projects

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A Thesis Submitted to the department of Civil Engineering,

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Civil Engineering (Specialization in Construction Engineering and Management)

Office of Graduate Studies
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DECLARATION

I hereby declare that this Master Thesis entitled "Development of Integrated Project Delivery and Last Planner System concepts as a Waste Minimization Technique in Ethiopian Road Construction Projects" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

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I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "Development of Integrated Project Delivery and Last Planner System concepts as a Waste Minimization Technique in Ethiopian Road Construction Projects" prepared under my/our guidance by Mihireteab Melkamu submitted in partial fulfillment of the requirements for the degree of Mater's of Science in construction engineering and management. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

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APPROVAL SHEET

I, the advisors of the thesis entitled "Development of Integrated Project Delivery and Last Planner System concepts as a Waste Minimization Technique in Ethiopian Road Construction Projects" and developed by Mihireteab Melkamu; 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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Major Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Mihireteab Melkamu have read and evaluated the thesis entitled "Development of Integrated Project Delivery and Last Planner System concepts as a Waste Minimization Technique in Ethiopian Road Construction Projects" and examined the candidate. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in construction engineering and management.

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Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

AHP	Analytic hierarchical process
CL	Commitment Level
CI	Consistency Index
CR	Consistency Ratio
CPM	Critical path method
DB	Design Build
DBB	Design Bid Build
ENVA	Essential non value adding activities
PFP	Frequency of Plan Failures
IPD	Integrated project delivery system
LC	Lean Construction
LPS	Last planar system
MV	Milestone Variance
NVA	Non value adding activities
NVAW	Non value added waste
PPC	Plan percentage completed
PRC	Percentage Required Complete
RI	Random Consistency Index
TA	Task Anticipated
TMR	Task Made Ready
TPS	Toyota production System
VA	Value adding activities
VAW	Value added waste
WWP	Weekly work plan

ABSTRACT

Every nation's socioeconomic progress is significantly influenced by the construction industry. But the construction industry also significantly depletes resources through waste generation. There is a proof that these wastes lower productivity in the construction industry. Additionally, construction wastes are one of the major reasons for cost overrun and delay. The aim of the study is to develop the concepts of Integrated Project Delivery and Last Planar System as a Waste Minimization technique in Ethiopian Road Construction Projects. This research contains both quantitative and qualitative, with a descriptive nature based on comparison judgment (prioritization) aiming to build an analytical hierarchical model for the implementation of Last Planner System and Integrated Project Delivery System. The study defines road construction projects which are currently on progress under the authority of Ethiopian Road Administration as a total population. In this study both primary and secondary data are used. The study mainly uses Analytic Hierarchical Process to prioritize the sources of construction waste and also it uses site observation to get better understand about waste generating activities in road construction projects. Based on the questionnaire data analysis; design change, poor workmanship, use of incorrect material (replacement), improper planning and lack of information on the drawing are the highest waste generating sources. From the result it is identified as operational wastes are the most waste generative sources followed by design wastes and material and handling wastes respectively. And also, activities which are considered as waste generating activities are identified from site observation. After that, explanation of the concepts of last planer system and integrated projects delivery system as waste minimization is discussed. On the discussion it is briefly explained that only the important concepts of these two lean construction tools towards waste minimization are taken for framework development. Next, based on the data analysis, site observation and literature review, conceptual framework is developed to support waste minimization. And finally, conclusion about the result obtained and recommendation on future research work is given.

Key Words: *Last planar System, Integrated Project Delivery, Lean Construction, Waste minimization, Construction Waste*

CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

As one of the largest sectors of the global economy, the construction sector has experienced remarkable growth, particularly in developing countries. Every nation's socioeconomic progress is significantly influenced by the construction industry. The modern construction sector is expanding quickly due to a number of factors, including changes in consumer patterns, the need for infrastructural projects, rising living standards, and population growth (Nagapan et al., 2012).

While the construction sector does play a significant role in the overall socioeconomic development of any nation, it also significantly depletes natural non-renewable resources and pollutes the environment through resource depletion, energy consumption, air pollution, and waste generation during the raw material acquisition process (Ayalew et al., 2016).

Because waste quantities are only increasing, waste poses a challenge to global society on all fronts environmental, economic, social, and political. For instance, the European Commission says that massive volumes of waste (900 Mt/a) are produced in industries like manufacturing and construction, which have a negative influence on the environment and contribute to material losses and climate change (Koletnik et al., 2012).

Global assessments conducted in 2010 revealed that the building sector was responsible for 50% of the world's water use and 45% of its energy consumption. In addition, construction projects are responsible for 23% of air pollution, 40% of water pollution, and 40% of waste generated (Ayfokru, 2021).

The majority of countries now lack awareness of resource-efficient construction techniques. Construction sites frequently experience excessive material waste, poor site management, and a lack of awareness on the importance of waste reduction. It should be noted, however, that in recent decades, a number of developed nations have made significant progress in making use of building debris. Developed nations including the United Kingdom, the United States of America, France, Denmark, Germany, and Japan have been successful in creating commercially viable technologies that recycle as much as 80–90% of construction waste.

However, the use of construction waste in developing nations has received the least attention(Singh Sardar et al., 2018).

Ethiopia, one of the developing nations, does not have effective waste minimization procedures on the site. Although site workers have initiated the implementation of these principles, we lack an effective approach that can be applied to the process. The goals of construction waste management include waste minimization, prevention, and appropriate disposal. In addition to having major economic benefits, efficient waste management protects the environment and public health. To maximize material utilization, boost resource efficiency, reduce costs, and create sustainability, proper construction waste management is important. Reducing the need for virgin material is accomplished by depending increasingly on recycled and repurposed materials. The growth of waste management has the ability to reduce environmental pollution and bring financial rewards to building businesses, waste contractors, material manufacturers, and other stakeholders. In poor nations, companies sometimes disregard sustainable waste management development in favor of more immediate financial rewards (Mladenov, et al., 2021).

The lean concept can be viewed as a collection of instruments for improving production efficiency and reducing and eliminating waste. Lean construction methods boost production while lowering inventories and defects. Every task should contribute value to the project, which is the cornerstone of the lean approach. Giving the customer the best product they require in this case, the project's completion as planned is the foundation of the lean philosophy (Elkherbawy et al., 2019).

Integrated Project Delivery System (IPD) and Last Planar System (LPS) are categorized under lean construction tools and believed to be an excellent way of minimizing construction waste on different types of construction sectors. Using this experience as starting point, we have developed a way to use these tools in Ethiopian road construction projects.

1.2 Statement of the Problem

Waste accounts for a sizable portion of manufacturing expenses in construction industry. according to studies conducted in different nations (Raval et al., 2017), There is a proof that these wastes lower productivity in the construction industry. Additionally, these wastes may have a detrimental impact on people's social lives and the environment. As an example construction projects could generate wastes up to 15% of the resource needed to accomplish the project in developing countries (Sci, 2021). One of the well-known industries in Ethiopian is the construction industry. And the main part of the construction industry is construction of roads (Infrastructures). During the construction process, road construction projects frequently produce excessive amounts of waste. And also construction wastes are one of the major reasons of cost overrun and delays (Ayalew et al., 2016). Hence, clients and construction companies are being forced to invest additional budget as a result. We require efficient measurement if we are to eliminate this issue or reduce it to the minimum possible extent. This makes the creation of novel, cutting-edge techniques essential.

1.3 Objectives of the Study

1.3.1 General Objective

- The general objective of the study is to develop the concepts of Integrated Project Delivery (IPD) and Last Planar System (LPS) as a Waste Minimization Technique in Ethiopian Road Construction Projects

1.3.2 Specific Objectives

- To assess major sources of wastes in road construction projects.
- To investigate the way of using the concepts of Integrated Project Delivery and Last Planar System in road construction activities
- To develop conceptual framework to minimize wastes in road construction projects by implementing Integrated Project Delivery and Last Planar System

1.4 Research Question

1, what are the major sources of waste in road construction industry?

2, what types of activities can be listed as waste generative in road construction industry?

3, how can lean construction tools be implemented in road construction industry?

4, can a conceptual frame work be set to use lean construction tools in real world road construction works?

1.5 Significance of the Study

Currently in Ethiopia, we don't have that much effective waste reduction solution so we need to find effective way to reduce the waste. Specially, in road construction, high amount of waste is shown throughout the project. To overcome this problem, we need to develop an approach suited for this purpose. This paper is believed to show the relevant way that can be successfully implemented in construction projects.

Lean construction tools are widely used in other countries like United States, United Kingdom, Denmark, Finland, Indonesia, Australia, Venezuela, Brazil, Chile, Ecuador, and Peru (Ballard & Tommelein, 2021). Since the impact they have on the construction could bring significant change on the qualities of road construction projects. Some countries have developed systems which allow them to use these tools effectively and they are beneficiary (Ballard & Howell, 2003a). So this research tries to show how we can interpret the concepts of these tools towards our own countries condition

Furthermore, lean building concepts are in some ways modern techniques. There is still too much to be done, particularly in developing nations like Ethiopia, to bring these ideas to the table. There have been some researches on lean construction technologies for residential and other buildings, but it appears to be nonexistent for road construction projects. Thus, this work might serve as a reference for future investigations and provide insightful suggestions for construction roads in Ethiopia.

1.6 Scope of the Study

The scope of this research ranges from defining, categorizing and ranking construction wastes to setting out framework which helps the decision process of minimizing construction wastes. Defining and categorizing the construction wastes as well as understanding various types of lean construction tools like IPD and LPS are conducted through literature review. Ranking the impacts of sources of wastes is achieved by questionnaires through Analytic Hierarchal Process. And other activities like identifying waste generating activities are identified by site observation. There are some types of wastes like material wastes, cost overrun and time overrun and all of them have relation with each other. But this research mainly focuses on the material wastes and their impacts on the rest kinds of wastes. Due to the current situation in the country, this study tries to get essential information from selected projects.

1.7 Limitation of the Study

Due to limitation of time and current situation of Ethiopia which is lack of peace in some areas, this research focuses on collecting data from selected projects. And also since road construction covers vast area by its nature it is not easy to observe the entire area with in the given time. Most of the time, the road construction work is done by worker who gained the knowledge more by experience than academically. In this case the researcher couldn't get technical answers from the workers during site observation time.

1.8 Organization of the Study

This research has included five main chapters to convey the study that is conducted during study time. These chapters are presented below.

Chapter One: This chapter talks about the general introductory part, the objectives (general and specific) and significance, scope and limitation of the study.

Chapter Two: The second chapter describes about the literatures which are reviewed on the topic of construction wastes and lean construction tools.

Chapter Three: This chapter is about the research methodologies used in the research. The research design, sampling method, data collection method and data analysis method is briefly explained in this chapter

Chapter Four: On the forth chapter the results obtained from the analysis and site observation is presented. And also about the frame work which is developed from the analysis and literature review is discussed.

Chapter Five: The fifth chapter talks about the conclusion drawn from the research. And the recommendation given for further researches is also included in this chapter

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

On this chapter, major concepts which must be clearly understood by any of researcher are explained in a clear manner so that any reader could understand it. The topics chosen to be discussed are defined in a way keeping the chronology. Therefore the readers will have clear image on the entire paper easily.

2.2 Construction Waste

Unwanted material created either intentionally or accidentally by the construction or industries is referred to as construction waste. Waste from demolition processes, rubble, earth, concrete, steel, timber, and mixed site clearance construction materials are examples of construction wastes in any project. These wastes can arise from a variety of project activities, such as site preparation or excavation, civil and building construction materials, site clearance waste, demolition activities waste, roadwork waste, and building renovation waste.

2.2.1 Definition of Construction Waste

Various views exist among researchers and writers on the meaning of construction waste, and multiple definitions have been offered in the pertinent literature. Materials or products that require "transportation elsewhere from the construction site or be used in-situ for other applications than the intended specific purpose of the project due to damage, excess or non-use, or which cannot be used due to non-compliance with the specifications, or which is a by-product of the construction process" are classified as construction waste (Ayfokru, 2021).

Any material or item that the holder discards, plans to discard, or is compelled to discard is defined as waste. Every industrial production method produces waste. Different manufacturing techniques result in a variety of wastes with varying mechanical, chemical, elemental, and other qualities, including the ability to be hazardous, inert, or non-hazardous (Glantz, 1991).

Waste is the needless depletion of natural resources, needless expenses, and needless harm to the environment. These things can be prevented with better waste ethics. Furthermore, any resource used during a work process that does not provide value for the stakeholders, or any non-value-adding action performed at any point in time inside a work system, can be considered waste (Workneh, 2016).

Any inefficiency that leads to the usage of machinery, supplies, labor, or money in greater amounts than those deemed necessary throughout the building process is referred to as waste. Waste encompasses both the loss of materials and the execution of work that is not necessary but adds no value to the final product. Examples of waste include long distances, unneeded transportation trips, poor constructability, lack of safety, rework, inappropriate method or equipment selection or management, and delay times (Nazech et al., 2008).

Waste is often defined as any construction operations or procedures that generate costs that do not add value to the construction project directly or indirectly. These construction activities can include value-adding & non-value adding activities (wastes, wasteful operations). Building waste may be due to structural flaws, modifications, redoing work, failures and the use of excess materials. Therefore, ensuring that waste generation is minimized in construction is important Activities and procedures. Building and demolition waste is not only defined as physical waste, but also includes waste created from construction activities such as transport, waiting times, excess materials, rework, delays, and defects (Profile, 2021).

One way to characterize construction site waste is as a non-hazardous by-product of operations related to new building and renovation. A number of factors, including site preparation, material use, material damage, material non-use, excess procurement, and human mistake, contribute to its generation during the construction process. Packaging materials, site clearance, excavation materials, and building materials such metals, gypsum, concrete, brick, insulation, wood, plastic, glass, asphalt, composites, and site sweepings are a few examples of what it contains, but is not limited to. Material waste is defined as the difference between the value of materials that are delivered and accepted on site and those that are correctly used as specified and precisely measured in the work. This difference is made after subtracting the cost-saving of substitute materials that are transferred to another location, where the waste of materials may result in additional costs and time.

2.2.2 Classification of Construction Wastes

In order to understand construction wastes based on their nature, it is important to classify based on their type, properties and other parameters. These types of classification help us to find the clear and effective way to classify them.

According to (Nazech, 2008) construction wastes are categorized in to four

Natural Waste: There is a condition where construction waste is not reduce-able as the cost to reduce it is much higher than treating the waste. In this condition, there is an acceptable tolerance to the produced waste.

Direct Waste: Direct waste is produced in every phase of construction. The waste is produced from various activities on construction site, such as: material delivery; material storage in warehouses or temporary storage; reworks; inexperience workers; poor management.

Indirect Waste: The source of indirect waste include: material changes; excess materials; contractor mistakes; possibility of waste in forms of cost of materials and labors.

Consequential Waste: Is a cost associated with delay in production or reworks to repair any product deficiency.

(Workneh, 2016) classifies construction waste in to two from point of view of necessary investment and the possibility to control the incidence of waste

Avoidable Waste: when the cost of waste is significantly higher than the cost of its prevention

Unavoidable/ natural waste: in which the investment necessary to its reduction is higher than the economy produced/ reduction of waste causes higher investment than economy produced. There are two categories of construction trash that can be distinguished: physical waste and nonphysical waste. Usually, material loss is the result of producing physical waste. It makes up a major portion of the landfill. Research indicates that the building sector generates a significant quantity of trash, with over half of it ending up in landfills. On the other hand, time and expense overruns for construction projects are the primary causes of nonphysical construction wastes. When specific construction work is stopped, these issues will worsen and eventually lead to the project's abandonment.

According to (Oza & Raval, 2017) Waste can be categorized mainly in two categories: value added waste and non-value added waste.

Value added waste (VAW): Value-added waste is defined as waste that results in additional expenses and project cost overruns. That is, material waste brought on by a flaw, waste brought on by a surplus material stock, Waste from repeated work and Waste from frequent design modifications

Material waste: A significant amount of construction waste is made up of material waste. Some of the main causes of material waste are rain-related sand waste, rain-related cement bag waste, and rain-related steel bar waste. The contractor must pay more for materials as a result of material waste, which drives up project costs.

Waste due to defect: Defective waste is another significant contributor to building waste. Occasionally, it happens that the supplied material turns out to be defective and needs to be replaced, adding to the project's expense. Since the construction work was not completed according to the plan, it must be redone, using more materials and increasing the project's cost and duration. Equipment defects can occasionally occur during construction as a result of normal wear and tear, hard handling, or other factors. These pieces of equipment need to be fixed or replaced with new ones. This element also raises additional costs and causes the project's budget to balloon.

Waste due to excessive stock of material: The excessive stock of material sometimes leads to material waste. After the job is finished, excess steel bars and cement bags that were not needed become garbage. The studies show that in the projects of higher magnitudes, a considerably huge amount of material gets wasted after the completion of the project.

Waste due to rework: Any component that needs to be redone requires additional resources and time, none of which improves the project's value. Rework might result from changes in the design. Rework may occasionally be necessary if the design is altered to accommodate a customer's request or for any other unforeseen circumstance. Rework is also necessary because of the flawed work. Any component that is discovered to be improperly constructed must be rebuilt. This adds little value to the job, but it does need more time and supplies. Unskilled workers can fail to complete the construction according to the plan. It is necessary to rebuild this kind of construction.

Waste due to frequent changes in design: Occasionally, the structural engineer or architect would modify the designs to better suit the needs and specifications of the client. In the event that the client changes his mind after a component is constructed, the design may be altered and the component must be reworked, resulting in the need for additional materials, labor, and other resources.

Non-value added waste (NVAW): It can be defined as waste that uses additional resources but doesn't improve the quality of the finished output. For example, a waste of time, Motion waste, transportation waste, Waste from over processing and excess inventories.

Transportation waste: The primary waste on the construction site is time wasted traveling and experiencing delays, both of which add no value to the project. Time is lost until the newly ordered material is delivered to the location when the stock runs out. The time it takes to transport the equipment from the other location to the building site is what causes the time waste. If the necessary equipment is being used at another location, it must wait until it becomes available.

Waste of time: One significant consequence of the project's delay is the loss of time resulting from multiple sources. When rain starts to fall during the rainy season, work is suspended until the rain stops. One important factor is the time wasted during this waiting period. It takes time for the material to be delivered to the site after it is ordered. The cause for the time wastage is also related to this period. There are situations where starting an action requires finishing the one before it. Time overruns are also impacted by the time lost since the task was not started. Because to encroachment, time is lost trying to acquire the land needed for the project. This is an additional explanation.

Motion waste can also be a reason for time waste on the construction site. The unnecessary movement of people and equipments on the site also leads to waste of time. Over processing can also be a reason of time waste on the construction site. The time gets wasted on site due to re processing of a process. Double handling and double checking are also the reason of time waste on site. Another factor contributing to time loss on the construction site may be excess inventory. Extra handling time and room are required for excess inventory in order to handle the inventory. This could lead to visitors wasting time on the site.

2.2.3 Sources of Construction Waste

Waste generated during construction comes from renovation, repair, and building projects. Throughout the design and construction phases, a lot of inefficient things can happen that take up time and energy without benefiting the client.

According to (Kulatunga & Haigh, 1987) sources of construction wastes are categorized under three categories these are natural waste, direct waste, indirect waste.

Natural Sources: Waste classified as "natural" is waste that, even with prevention efforts, would still end up costing more. Material waste can be avoided, but only to a limited extent. Any attempt to stop waste will become unfeasible at that point since the cost of saving will exceed the cost of the materials spared. Natural waste is therefore permitted in the tenders. The quantity of natural waste depends on how economically viable the management strategies are. The methods and the amount of natural waste differ depending on the situation. For example, a project with an effective material management policy will have lower waste prevention costs than a project without one. Consequently, in the first case, a lower permissible level of natural waste will exist than in the latter.

Direct Sources: Direct waste is defined as "waste that can be prevented and involves the actual loss or removal and replacement of material." The majority of the time, the expense of removing and disposing of direct waste comes after the cost of material. Therefore, it is possible to reap clear financial rewards by avoiding direct waste. Before materials are delivered to the construction site and after they are incorporated into the building, direct waste can occur at any point in the construction process.

Indirect Sources: In this type of waste, the material does not get waste physically, but the payments for the material are wasted partly or wholly.

Table 2.1 Indirect waste types and examples (Kulatunga & Haigh, 1987)

Category	Reason	Example
Substitution waste	Substitution of materials in work, which will incur losses to either contractor or client	Use of facing bricks for common bricks
Production waste	Contractor does not receive any payments for the work he has carried out	Use of excess plastering to rectify the uneven surfaces of brick walls
Negligence waste	Site errors because of the condemned work or use of additional material	Over excavation of foundation, resulting in the use of additional concrete
Operational waste	Unavailability of proper quantities in the contract document / the material that are left in the site	Shutter plates, Scaffolds

According to researchers who have conducted their research in Ethiopia and throughout the world, the following sources of wastes are selected as one of the most significant ones. Even though there are limited amount of researches conducted in Ethiopia, these sources are the most frequently seen sources of construction wastes

Poor Workmanship

Incompetent workmanship is characterized by the workers' incapacity to do their jobs on construction sites. These kinds of incidents can occur to a variety of workers, from daily laborers to heavy machinery operators. Additionally, surveyors, foremen, and other employees can also show this type of incapability. Given that the worker may stay on the project for an extended length of time and may produce waste while it is being built, this circumstance could be highly important. (Alemayehu et al, 2020.).

Poor Communication

In an organizational context, construction communication refers to giving instructions to influence others' actions or behaviors. It can also involve exchanging information or making requests for information while a construction project is underway (Suleiman et al., 2023). Within the context of an organization, construction communication is the act of providing directives to affect the activities or behaviors of others. While a construction project is under progress, it may also entail information sharing or requests for information.

When managing construction projects, one of the main issues that workers encounter could be a breakdown in communication. In order to tackle inadequate communication within the construction sector, it is imperative to create unambiguous and regular communication pathways among involved parties, and guarantee that these parties are cognizant of their respective obligations concerning communication. (Borku & Yenialem, 2022).

Use of incorrect material thus requiring replacement

The needless effort of recreating a procedure or activity that was initially carried out improperly is known as replacement in construction projects. Replacement in construction projects can be caused by a variety of things, including mistakes, omissions, failures, modifications, inadequate coordination, and poor communication (Alemayehu et al., 2020.). The performance, productivity, and eventually the profit margins could all suffer from replacement. Any replacement is primarily viewed in project-based transactions as an extraneous or superfluous non-value-adding item that should be avoided rather than completely removed. Furthermore, replacement has a significant role in schedule overruns and time wastes, which subsequently affect quality, cost, and resource availability. Overtime, the additional hiring of labor and plant workers, timeline slippage, and a reduction in project scope and quality are examples of replacement. (Al et al., 2023.)

Improper Planning

In construction projects, poor planning can result in a variety of waste kinds and quantities. The rate of wastes can be greatly influenced when adequate management is used throughout the project. For instance, a disagreement, waiting periods, and disruptions to other trades result from poorly planned planning with subcontractors. The work also stops due to poor equipment selection and planning (Haftu, 2016). In addition, if subcontractors' progress is not monitored or if site workers are not motivated, the job will eventually be delayed. Therefore, the primary supervisory role that should be employed to effectively eliminate these non-physical and physical elements is proper planning and regulating. These aspects of waste generation should be the focus of increased attention for all management leaders. To monitor the various project operations and guarantee a smooth workflow, project managers must carefully choose the management team and site supervisors. Additionally, thorough planning minimizes waste in projects by outlining every task and designating a supervisor to make sure no waste is produced. Therefore, thorough planning is essential to removing waste sources and their effects if done correctly. (Soharu et al, 2022).

One of the main issues that cause waste in building projects is said to be the frequent changes made to the project plan. It typically happens when the client makes multiple last-minute alterations while the project is underway. The inability of project participants to communicate with one another and to comprehend the needs of the client also contributes to this issue. Consequently, alterations to the project's design will necessitate the reconstruction and modification of designs and requirements, resulting in financial and temporal costs. It is imperative to pay close attention to reducing waste throughout the design stage in order to prevent this source of waste (Sahlu et al, 2021).

Lack of Information on the Drawing

A drawing's lack of information is when there is not enough detail to provide information about the cross sections, the quantity of material required to complete the job, particularly when working with concrete, or other items that have been sketched carelessly. These designs will be used on the building site, and when they are used there, a number of issues may arise, one of them being the production of construction waste since we are unable to determine how much material will be required for the job due to a lack of knowledge. (Adams et al., 2018).

Complexity of the Drawing

This idea discusses employing intricate graphics that are challenging to comprehend when carrying out tasks. Using drawings to carry out construction work is a common practice for foremen and engineers. Occasionally, instead of asking what a complicated drawing means, they attempt to decipher it on their own. They are going to make costly blunders during these times. One of them is the waste of building materials since the right amount might not be known (Ayfokru, 2021).

Inappropriate stocking

The products or supplies that a business uses for manufacturing or selling are referred to as stocking. Unnecessary or excessive stocks are known as stocking, and they lead to financial losses due to capital being tied up, as well as material waste (losses from deterioration, vandalism, robbery, and inadequate stock conditions at the site). Since there is no value activity involved in stocking inventory, inappropriate stocking is viewed as waste. In addition, inventory incurs expenses, takes up space, and negatively impacts capital (Workneh, 2016).

Coordination of material availability, management, usage, and procurement is referred to as inventory control. It is a course that includes exercises to get to the appropriate inventory in the appropriate location at the appropriate time, in the appropriate quantity, and with a direct link to any project's production operations (Makebo, 2019)

Damages Due to Transportation in Construction

Certain construction components, such as segments of concrete, are cast in the precast yard and then moved to the site by various transportation methods. In order to avoid damage and damaged segments, the must be brought carefully to the site during this period. They currently require additional concrete to be used in their rehabilitation, failing which they will be refused for the task, resulting in wasteful construction on both sides. These kinds of situations might arise in various types of tasks. Therefore, careful consideration must be paid to material transportation. (Kulatunga & Haigh, 1987).

2.3 Lean Construction Principles

As the idea develops, lean construction has been defined in a number of ways. Lean construction, according to(Li & Fan, 2019) , is the application and modification of the fundamental ideas and methods of lean manufacturing as a novel production philosophy for the building industry. This manufacturing model has been adopted by the industry in an effort to boost productivity and cut down on waste, which is common in the construction sector.

Construction projects activities were identified to be three main types,

Essential Non-Value Adding activities (ENVA): These tasks cannot be stopped even though they don't improve the project. As an illustration, consider machine maintenance. Although it does not directly advance the project, it is nevertheless necessary to keep the work flow going and prevent delays. As a result, in order to avoid affecting production, these kinds of tasks must be completed effectively. Referring back to the machine maintenance example, this involves performing maintenance off-site when the machine is not in use.

Non-Value Adding activities (NVA): Although these tasks are deemed wasteful and do not contribute to the project's value, they ought to be stopped. This is applicable, for instance, when skilled labor is being held back until the shop drawing is updated due to design modifications. This wastes money and time, but it may be avoided with careful planning and effective administration.

Value Adding activities (VA): These are the only activities contributing to the project's value. This mostly refers to all project-related tasks required to produce the desired end result. This includes, for example, excavation of the sub-base layer, filling with aggregate, applying asphalt layer, etc. in road projects.

The two primary tenets of the lean philosophy, according to academics, are respect for employees and continuous development. The lean philosophy implements continual improvement by including every project participant from the outset. The difficulty lies in correctly applying the five guiding principles of continuous improvement, which are described below, in order to improve the activities related to construction projects. Since each construction work is distinct and unlike any other, it is seen as a challenge.

According to (Sahlu et al., 2021) there are five lean construction principles which must be kept in order to get progress on the construction work

Value: is the process of figuring out what the project needs. Early on in the project, it is important to appropriately identify this principle. It is regarded as a crucial idea since it is the site of origin.

Value Stream: refers to figuring out the project's present workflow. This idea serves as the standard for locating wastes and figuring out how to get rid of them.

Flow: is the method by which the wastes are removed. Ensuring effective information flow is the goal of this principle (at the design stage). To facilitate the removal of the trash, it is imperative that individuals in power are involved throughout the application of this approach.

Pull: the timely delivery of materials to the construction project is the goal of this approach. This principle's instrument, which reduces inventory, is what makes it important.

Perfection/Continuous improvement: throughout the project's building phase, the preceding four principles are continuously improved upon.

2.4 Last Planner System and Integrated Project Delivery System

2.4.1 Last Planner System

In order to increase construction productivity, Dr. Glenn Ballard and Greg Howell created the last planner system in the 1980s based on their study. This collaborative, commitment-based planning system combines weekly work planning based on dependable promises, constraint analysis, learning based on analysis of PPC (Plan Percentage Completed) and variance reasons, and should-can-will-did planning (Pull Planning, Make-Ready plan, Look-ahead plan) (Onyango, 2016).

The Last Planner System (LPS) is a workflow technique created by the Lean Construction Institute that uses meticulous group planning and strict scheduling to boost worker accountability and efficiency. The Last Planner is regarded as a managerial strategy for effectively managing a building project.

Based on short-term planning and management of operations, the Last Planner System (LPS) system is a popular application of lean construction principles and methodologies. It has been one of the most widely utilized models in the construction industry ever since it was introduced (Daniel et al., 2006). By lowering dependencies and variations to identify and eliminate waste (non-value adding activities), it could improve construction management practices in many ways and bring about a host of benefits that will make construction projects more stable and less stressful for all involved stakeholders.

According to (Elkerbawy, 2019), last planar system has five general ideas. First, Make sure that as the execution week of the working activity gets closer, enough information about its details is available. Second, make sure that those who are doing the activity's planning will execute it. Third, determine the constraints (or risks) that should be removed from the activity. Then ensure that the plan developed by the engineers is reliable and accurate. Finally, learn from the failure that occurred in the past to avoid repeating mistakes.

The critical path method (CPM) methodology, which has mostly been used for planning and control in construction projects with traditional delivery models, prompted the development of the last planner system. The final planner system, according to (Moradi & Sormunen, 2023), consists of five components: learning (DID), look ahead planning (CAN be done), daily/weekly work planning (CAN be done), master scheduling (SHOULD be done) and phase scheduling (SHOULD be done).

In general we can see the steps of last planner system in to six parts. These steps can help us achieve our progress in our day to day activities

Master plan or Milestone planning: this includes the project's milestones. This first long-term planning is done to determine the project's general information and milestones.

Collaborative programming or Phase planning: This deals with the early project stage cooperation of all project stakeholders.

Look-Ahead planning: It includes recognizing and getting rid of wastes as well as breaking down actions into more specific information. It is a medium-term planning document that provides more specific project task identification. The various resources' availability is ascertained using this approach. It normally happens three or six weeks prior to the week of execution (Hamzeh, 2004).

Make ready process: It seeks to locate and eliminate waste from the operations in order to have them ready for action.

Production planning and evaluation or Weekly Work Planning (WWP): is the stage in which the Percentage of Plan Complete (PPC) of the activities which took place in the previous week is calculated. This level is considered short-term planning (weekly planning). WWP aims to protect projects from variability and as the PPC increases; this means the reliability increases. Weekly Work Planning (WWP) is also used to determine the reason of the failure of non-complete activities.

$$\text{PPC}=\frac{Total\ numbers\ of\ activities\ completed}{Total\ numbers\ of\ activites\ Promised}\times 100\% \quad \ldots\ldots\ \text{Equation 2.1}$$

First run studies: is used to understand the construction process before starting the execution process. It focuses on understanding the critical activities and finding ways to improve them.

2.4.2 Advantages of using LPS as a Waste Minimization Approach

The Last Planner System (LPS) focuses on enhancing communication and workflow to minimize construction waste. This is how;

Collaboration and Root Cause Analysis: LPS planning sessions let designers, project managers, and subcontractors communicate with one another. This makes it possible to have a common awareness of waste problems and makes it easier to come up with creative ways to deal with them head-on (Bayer, 2016).

Reliable Planning: Making realistic plans is a fundamental component of LPS. The project team can minimize waste by creating realistic plans that lower the possibility of errors and rework by cooperatively identifying constraints and limitations.

Better Flow: LPS places a strong emphasis on a seamless job transfer between teams. As a result, there are fewer delays and idle moments, which might result in material waste from incorrect handling or storage.

Identifying and Eliminating Waste: LPS uses collaborative planning sessions to identify potential waste sources like excess material ordering, rework due to errors, or waiting due to unavailable resources. By proactively addressing these issues, the plan can be tailored to minimize waste generation.

Constant Improvement: Regular progress assessments are part of the LPS process. This promotes continual development in waste management by enabling the team to pinpoint areas where waste reduction efforts are effective and those that require more focus.

2.4.3 Challenges of Applying LPS in Road Construction

Although there are several advantages to using the Last Planner System (LPS) in construction, there are drawbacks as well. These are a few of the primary obstacles. The first on is Change Management. New techniques may encounter resistance in the construction sector. To overcome the mindset of "we've always done it this way" and inertia, strong leadership support and stakeholder training are necessary. The other one is People and Culture. LPS values open communication and teamwork. Establishing a culture of trust and cooperation is essential, particularly if employees and subcontractors are accustomed to isolated workplaces. Training and Knowledge Gaps can also be seen as challenges. The LPS process requires a good understanding of lean construction principles. Investing in training for project managers, planners, and field personnel is essential for successful implementation. Contracting and Incentives: Conventional construction agreements frequently place a premium on speed over planning and quality. It might be difficult to get project contracts and incentive programs to match LPS objectives (Ballard & Howell, 2003).

Partial Implementation is also another challenge. LPS must be fully embraced in order to be effective. The efficacy of the method may be limited if weekly planning meetings are the exclusive focus and look ahead planning, continuous improvement, and collaborative elements are not included. And finally, Integration with Current Systems can be taken as another challenge. It may be necessary to make workflow improvements and make additional upfront investments in order to successfully integrate LPS with current project management software and data collection techniques (Salo, 2022).

Notwithstanding these difficulties, it is still worthwhile to get past them because LPS has the potential to enhance workflow, cut waste, and increase project predictability. Through the implementation of excellent leadership, training, and cultural transformation, construction businesses can achieve substantial benefits from the Last Planner System.

2.4.4 Integrated Project Delivery system

The term "Integrated Project Delivery System" (IPD) refers to a delivery method that enhances communication among project participants by primarily incorporating stakeholders in the early stages of the project.

The American Institute of Architects defines Integrated Project Delivery system (IPD) is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste and minimize efficiency through all phase of design, fabrication and construction” (Jørgensen, 2006).

According to (Girma., 2022) The most important benefits for project employers/clients are the improved project control accuracy, higher product quality, faster construction, improved leadership, etc. The IPD strategy offers these and other benefits. From the owner's perspective (less time and money spent, better quality and safety), as well as the designers' and contractors' perspective (more profit and profit velocity, better safety, and happier workers), the Integrated Agreement for Lean Project Delivery improves project performance. Although the results are preliminary, they seem quite promising.(Sahlu et al., 2021)

While the IPD Contractual Relationships are relational and include contractual principles like key players tied together as equals, the IPD Project Organization features integrated governance, an integrated project team, and early involvement of key participants. Characteristics of IPD include shared financial risk and reward based on project outcome, liability waivers between key players, fiscal transparency between key players, early key participant involvement, intensified design, jointly developed project target criteria, and collaborative decision-making(Program et al., 2022).

(Elkherbawy et al., 2019) tried to show the differences between the Integrated Project Delivery (IPD), Design-Build (DB), and Design-Bid-Build (DBB) systems. The percentage of the design that was completed when stakeholders were involved is the main topic of this comparison. In a Design-Bid-Build (DBB) project, the owner/client contracts with the general contractor following a 100% completion of the design. While in Design-Build (DB), the client makes the contract with the general contract after 20% of the design is finished. By using Integrated Project Delivery system (IPD), all the stakeholders are involved in all the project stages, including before starting the design phase. Using Integrated Project Delivery system (IPD) reduces the projects' cost and ensures having higher quality in shorter duration.

From the beginning of the design phase to the conclusion of the construction phase, Integrated Project Delivery (IPD) unites all project participants. Through integration, there is an improvement in stakeholder communication, risk sharing, and the development of stakeholder trust. Furthermore, it has been discovered that poor teamwork results in decreased production. Because it involves project stakeholders early on and shares reward and risk, Integrated Project Delivery (IPD) is an ideal Lean tool. When compared to Design-Bid-Build (DBB), Design-Build (DB), it was discovered that the Integrated Project Delivery System (IPD) reduced the number of project design modifications. Certain general dangers can be recognized and minimized with the help of IPD. Construction projects have lower overall costs when they use the Integrated Project Delivery System (IPD). The timetable will be fulfilled and the owner will be happy with the project's end outcome thanks to the implementation of the Integrated Project Delivery system (IPD).

2.4.5 Benefits of Using IPD as a Waste Minimization Technique

IPD offers a number of benefits for cutting waste in building projects. It is briefly discussed below. Early Planning and Collaboration: IPD involves all project participants from the outset, including contractors, architects, engineers, and subcontractors. This makes it possible to detect waste problems early on, such as material conflicts, mistakes in design, or ineffective building techniques. The project team may reduce waste generation during construction by making educated decisions by tackling these issues together up front (Yee et al., 2017).

Standardized Communication and Processes: IPD places a strong emphasis on creating uniform data environments and communication standards. This lessens miscommunications and mistakes that can result in material waste or additional work. With access to the most recent information, all parties involved may make smarter decisions and are less likely to order the incorrect materials or use antiquated plans.

Emphasis on Whole-Life Value: IPD takes into account a building's whole lifecycle rather than just the expenditures associated with construction. This promotes the use of long-lasting, environmentally friendly materials that produce the least amount of trash during use and upkeep (Jørgensen, 2006). Furthermore, reducing overall waste creation is achieved by designing for deconstruction or material repurposing at the end of the building's life.

Supply Chain Optimization: More precise material ordering and just-in-time delivery are made possible by early planning collaboration with subcontractors. This lessens the requirement for extra items on-site, which could get wasted, ruined, or run out of date.

Techniques for invention and Waste Reduction: IPD's collaborative atmosphere encourages invention. When all parties are involved, the team can investigate and apply innovative technologies and building techniques like prefabrication, modular construction, or energy-efficient building envelope systems that reduce waste production (Mossman, 2018).

Performance Measurement and Continuous Improvement (IPD): IPD places a strong emphasis on establishing precise project objectives, including waste reduction goals. Throughout the project lifecycle, the team can identify areas for improvement and put corrective steps into place by routinely monitoring performance against these (Kassab, 2020).

2.4.6 Challenges of Using IPD in the Road Construction

Integrated Project Delivery (IPD) offers a collaborative approach to construction projects, but it's not without its hurdles. Here are some of the main challenges to consider:

New legal ground**:** IPD contracts differ from traditional models. They require a shared risk/reward structure, which can be complex to craft and may not be supported by existing legal frameworks in all regions. Traditional roles are upended in IPD. A party used to managing a specific risk silo may now be responsible for project outcomes beyond their initial purview.

Industry inertia**:** The construction industry can be slow to adopt new methods. IPD requires a significant shift from traditional adversarial contracting to a collaborative mindset. Many players in the construction industry may not be familiar or experienced with IPD principles. This can lead to confusion and hinder effective collaboration.

Early project collaboration: IPD success hinges on getting all stakeholders involved early. This can be challenging for some project owners who are accustomed to a more sequential approach. IPD projects require strong leadership that can foster trust, open communication, and shared decision-making among traditionally separate entities.

Technology Adoption: IPD often relies on digital tools and BIM (Building Information Modeling) for information sharing and collaboration. Implementing and using these effectively can require additional investment and training.

While these challenges exist, they can be addressed through proactive measures. By carefully crafting IPD contracts, educating project participants, and building a strong collaborative culture, the benefits of IPD can be achieved.

2.5 Summary of Literature Review

The literature review is conducted by extracting useful information from different types of books, Journals, Research Papers, Thesis Papers and others. This literature review comprises of two main concepts. These are construction wastes and Lean construction tools. In the construction wastes section, the definition of construction wastes specially related to road construction wastes is briefly explained. Next we have seen the types of construction wastes and tried to classify them according to different scholars. And finally in this section we have understood the major sources of wastes and used them to generate analytic hierarchal process.

The next section is about lean construction tools. First we have reviewed literatures about the historical development of lean tools. Then we have seen lean construction tools in general and saw the processes and principles of lean construction tools. After that we have reviewed literatures on last planner system and integrated project delivery separately. Detail review about definition, processes, stages and barriers of implementing LPS is briefly discussed. And also successful review is conducted about IPD. The definition, stages of IPD and detailed comparisons between DB, DBB and IPD is reviewed.

2.6 Research Gap

In order to get sufficient knowledge about important concepts to conduct this thesis many literatures are reviewed. Most of literatures reviewed about lean construction tools are from other developed countries (Ballard & Tommelein, 2021), (Bayer, 2016), (Hamzeh, 2004) and other. It is known that some local researchers; (Sahlu, 2021) and (Ayfokru, 2021) have conducted their researches on the lean construction tools in general and tried to give general implementation techniques to minimize wastes and improve productivity. And also they have tried to implement the tools on building construction projects. When we come to road construction projects, it seems nonexistent to find researches conducted on improving waste minimization methods. So this research tries to fill the gap of implementing these tools separately and integrating them together to minimize construction wastes created during construction time. This research has taken some road construction projects to study the sources and waste generating activities.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Introduction

This chapter introduces the research tools and procedures used. The first section, the research methodology, describes the five main components leading to the completion of the research objectives. The first of these components is the research design. Then the sample criteria and the means of calculating the sample size are explained. The third and fourth components describe the data collection methods and the procedure for the formulation of the research questionnaire. The final component is the methodology of the data analysis, which provides the framework for the subsequent chapter.

Research projects synthesize and analyses existing theory, ideas, and findings of other research, in seeking to answer a particular question or to provide new insights. Once the problem statement has been formulated, it should become evident what kind of data will be required to study the problem, and also what kind of analysis would be most appropriate to analyze the data.

3.2 Research Design

This research contains both quantitative and qualitative, with a descriptive nature based on comparison judgment (prioritization). This study aims to build an analytical hierarchical model for the implementation of LPS and IPD on the reduction of construction waste in Ethiopian road construction projects. An integrated approach was used to compile and analyze the quantitative and qualitative data that were obtained through surveys and interviews, respectively. The mixed strategy was modified for the study in order to use instruments like questionnaires and site observation to gather data from pertinent sources.

This research follows the structure of starting from mentioning the problems to ending by preparing a model which can help us implement the lean techniques in road construction projects. First, we have drawn our research objective. Then we have tried to understand sources of road construction wastes and lean construction techniques through literature review. After that, questionnaire is developed to understand the sources of wastes and site observation is conducted to gain sufficient information on how road construction projects are operating and how road construction activities are generating wastes. Finally using all information gathered analyzed and interpreted, construction frame work for lean tools implementation is developed.

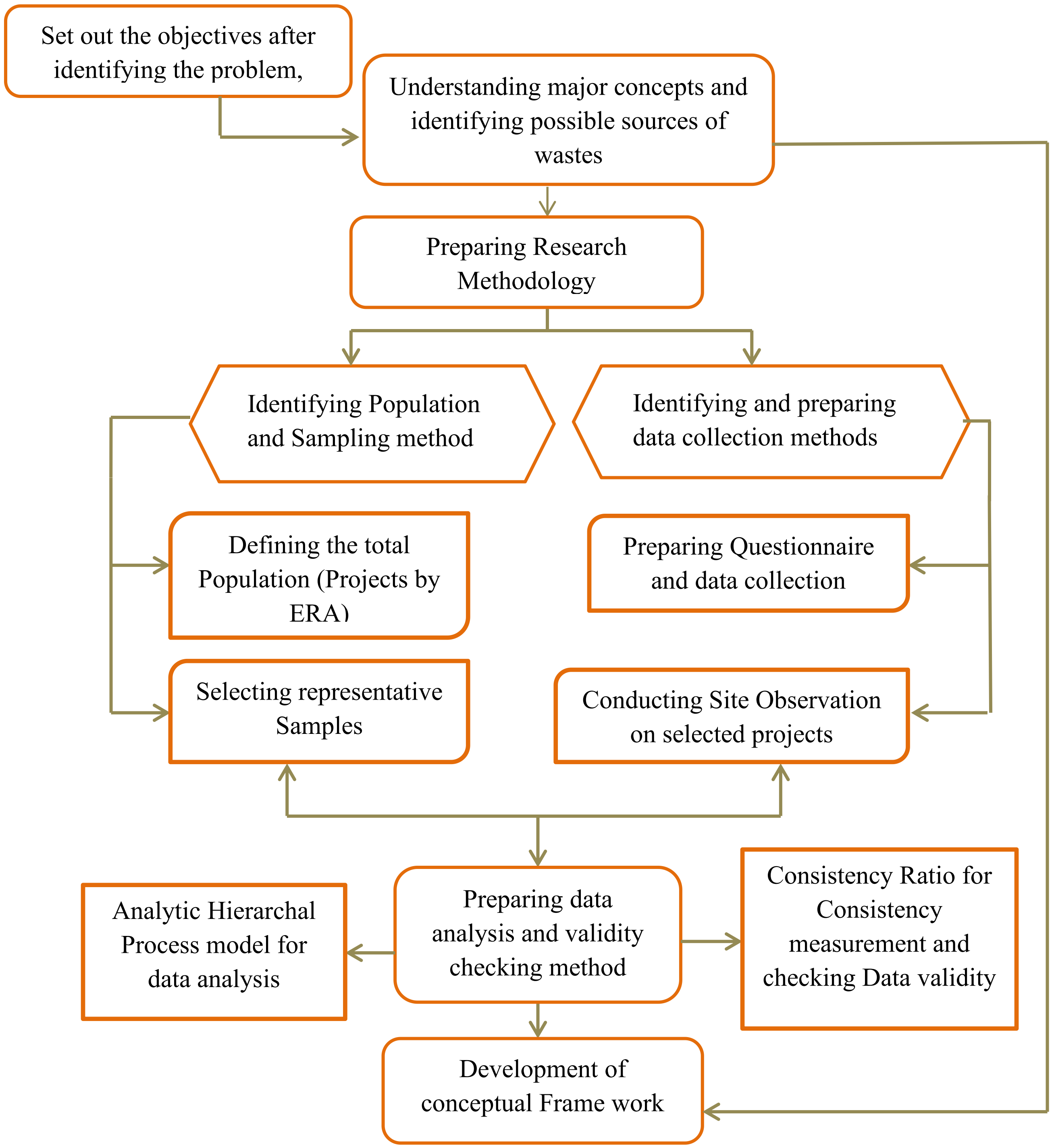

Figure 3.1 Research Design

3.3 Population and Sampling

3.3.1 Population

The study population is a group of respondents from whom the required information to find answers to a research question of a specific research is obtained. Since the objective of the study is to develop implementation plan for lean construction tool taking Ethiopian Road Authority projects, only projects by ERA will be selected as a population. Currently there are 200 road construction projects which are being executed under the control of Ethiopian Road Administration. So, these construction projects are taken as total population.

3.3.2 Sampling

The numbers of projects which are going to be selected as samples in this study are minimized due to many reasons. Prior to every reason, they need to meet with two crucial requirements. The first on is they should include. Second, they should be on the progress of executing or finishing the execution process off these layers so that the respondents will have good insight about the activities and respond with representative data for our data analysis.

In order to deliberately pick the pertinent sample units for the problem among the respondents, a purposive sampling technique is used. We have mentioned the main reasons to select the representative samples. First, from the construction projects which are taken as total population; some of them are only maintenance works which are not representative according to the requirement. Some of them are on the way of starting the projects so the layers are not on the level of execution. Some of them are on the way of finishing the project (only paper works left) so the contractors and consultants have released most of the workers. Hence, we won't get the required respondents. The other one is some of the projects haven't included the required types of layers in their design to be taken as representative.

There are also some additional reasons to select the sample size. First, the current situation in the country (lack of peace) causes many construction companies to stop projects. And also, this problem will not allow us to move freely from place to place in order to collect the relevant data from the construction projects. The second one is due to the reason that road construction projects occupy vast area; it is not going to be possible to collect the relevant data from many projects with in short period of time.

Due to the above reasons, the researcher has been forced to choose six road construction projects which are selected based their activeness and range of including each type of works from the bottom layers up to the top one.

3.4 Data collection Technique

Both primary and secondary data were included in this research. Primary data were gathered from observation and questionnaire with study participants such as client (ERA workers), consultants and contractors. And also site observation is included as a primary data. Secondary data used include literature, reference books, journals, previous studies, etc. written on the thesis topic.

3.4.1 Questionnaire

The purpose of the questionnaire is to create an AHP decision support model. A literature review is used to identify prevalent sources of waste in the construction industry in order to implement lean strategies on waste. Based on a comparison of these identified sources, the survey was carried out using an approach that uses AHP.

The purpose of the questionnaire is to rate, on a ratio scale, the relative importance of a particular source of construction waste and lean procedures as an alternative, based on the expertise of the construction industry. For every element in the same level as well as every level below it, a pairwise comparison matrix has been created, with a single matrix for every element in the level right above it. The researcher has personally delivered each questionnaire and addresses them in person. Although it could take more time, this alternative has a good response rate. Additionally, the research will have a combination of closed-ended and open-ended questions. Open ended questions are only used in the first part of the questionnaire. Close ended question is drawn for the data use in the AHP process. So they can easily choose the significant answer based on their knowledge and priority.

Based on the previous researches passes through similar cases (Teferi, 2017,), (Alemayehu et al., 2018.), (Ayfokru, 2021) and others, the respondents are chosen as follows. From era: Project Managers, project engineers, team leaders for construction department and Lead Engineers and are selected as respondent. From consultants: Resident engineers, material engineers, work inspectors, and office engineers are included. From contractors: construction engineers, site engineers, material engineers and office engineers are selected as a respondent. And since the purpose of the thesis is integrating stake holders, representing the main stake holders in similar number is tried. In order to make the research more professional, workers with experiences are appreciated to participate as a respondent.

3.4.2 Site Observation

This technique of gathering data involves observation; as construction wastes are typically invisible to the unaided eye, it is simple to ignore them. The use of observation as a data gathering strategy is preferred because it provides researchers and other learners with precise observations, which aid in their comprehension of the world around them. The observer has the chance to watch and listen to others while using the observation data collection approach. This can help detect constraints and provide insight into the accessibility of basic facilities as well as consumer response.

3.5 Data Analysis Method

3.5.1 The Analytic Hierarchal Process (AHP)

One general theory of measuring is the Analytic Hierarchy Process (AHP). Ratio scales can be derived from discrete and continuous paired comparisons using this method. These comparisons can be made using real measures or a basic scale that shows how strongly preferences, sentiments, and measurements relate to one another. The AHP is particularly concerned about deviations from consistency as well as their reliance within and across the structural element groups. Its broadest uses have been in multi criteria decision making, resource allocation and planning, and dispute resolution (Ayfokru , 2019).

It is among the most well-known and popular multi criteria analysis strategies. It enables users to intuitively evaluate the relative weight of several criteria or options in relation to specified criteria. Policy makers or assessors can nevertheless determine which criterion is more significant than another even in the absence of quantitative assessments. Pairwise comparisons are therefore desirable to users.

The basic procedure to carry out the AHP consists of the following steps (Nadja & Karlheinz, 2004):

1. Putting together a decision problem and choosing criteria

Breaking down a decision problem into its component elements is the first step. The most basic version of this structure has alternatives at the lowest level, criteria (and sub criteria) at the intermediate levels, and a goal or focus at the top. Putting all the parts in a hierarchy gives the decision-maker a broad overview of the intricate linkages and aids in determining if the components in each level are similar enough to be fairly compared. It is not necessary for an element in one level to serve as a standard for every element in the level below it. The hierarchy does not have to be complete because each level may reflect a distinct approach to the problem. (Saaty, 1990) When creating hierarchies, it's critical to take into account the context of the problem, pinpoint the problems or characteristics that lead to the solution, and list all parties involved in the problem

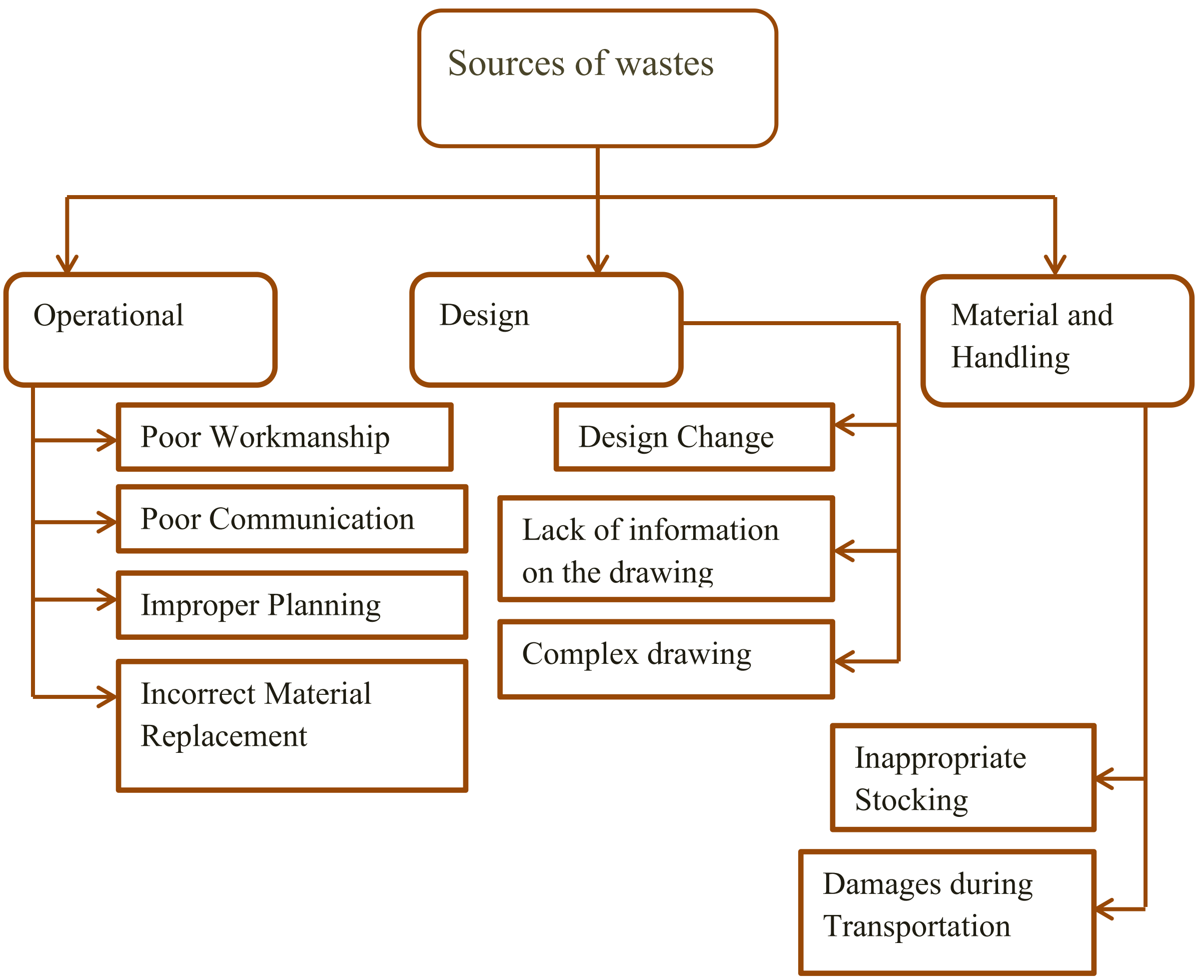

Figure 3.2 Hierarchical Example on sources of wastes (Goal, Criteria and Alternatives)

Creating a decision hierarchy is the first stage in an AHP analysis. This is also known as decision modeling, and it basically entails constructing a hierarchy in order to assess the choice. Our objective is the hierarchy; in this case, identifying the waste' sources. The standards by which we shall determine the problem's origin make up the second tier of the hierarchy. Three criteria have been highlighted in our example: material and handling waste, design waste, and operational waste. Multiple choices make up the third level. Here, among other things, are subpar construction and inadequate supervision.

And the alternatives are driven from the following literatures

Table 3.1 Causes of Construction Waste

Source	Causes of Waste	Referential Sources
Operational Waste	Poor workmanship	(Alemayehu et al., 2020.), (Sci, 2021)
	Poor communication with in the organization	(Suleiman et al., 2023) & (Borku & Yenialem, 2022)
	Use of incorrect material thus requiring replacement	(Alemayehu et al., 2021), (Al et al., 2023), (Singh Sardar et al., 2018)
	Improper Planning	(Haftu, 2016), (Soharu et al., 2022), (Septiani, 2017)
Design Waste	Design change during the construction Period	(Sahlu et al., 2021), (Ayfokru, 2021), (Raval et al., 2017)
	Lack of information on the drawing	(Adams et al., 2018) & (Suleiman et al., 2023)
	Complexity of the drawing	(Gulghane & Khandve, 2015) & (Kulatunga & Haigh, 1987)
Material and handling waste	Inappropriate stocking	(Workneh, 2016), (Makebo, 2019)
	Damages during transportation	(Kulatunga & Haigh, 1987) & (Haile Mariam, 2021)

2. Establishing the criteria's priority through pairwise comparison

The decision-maker must answer questions like "How important is criterion A relative to criterion B?" for each pair of criteria. The more significant criterion is given a weight between 1 (equal importance) and 9 (extreme importance), and the other criterion in the pair receives the reciprocal of this value to indicate the relative "priority" of the criteria. After that, the weights are averaged and normalized to determine the average weight for each criterion.

Table 3.2 the fundamental scale of absolute numbers in AHP

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2 **3**	Weak or slight Moderate importance	Experience and judgment slightly favor one activity over another
4 **5**	Moderate plus Strong importance	Experience and judgment strongly favor one activity over another
6 **7**	Strong plus very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8 **9**	Very, very strong Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation

3. Option comparisons on each criterion in pairs

Within each criterion pairing, the superior option is given a rating equal to the reciprocal of this value, with the other option in the pairing receiving a score ranging from 1 (equally good) to 9 (extreme). Every score indicates how effectively option "x" satisfies criterion "Y." The ratings are then averaged and adjusted. When comparing items in pairs, they must be similar or homogeneous with regard to the shared characteristic; otherwise, substantial mistakes could be introduced into the measuring process.

Creating the pairwise comparison matrix is the next stage. Based on the responses of a decision-maker or an expert, who rates the significance of each criterion for each decision objective(s) on a scale from 1 to 9, a pairwise comparison is performed.

4. Determining the proportional overall score for every choice

The option scores and the criterion weights are combined in the last stage to generate an overall score for each option. The relative relevance of the criteria determines how much the options satisfy the requirements. Simple weighted summation is used to do this (see the preceding chapter). Eventually, the less significant aspects may be carefully removed from further consideration due to their relatively little impact on the overall goal, once decisions have been made regarding the impact of each element and priorities have been calculated for the hierarchy as a whole. After that, the priorities can be recalculated throughout, with or without the judgments altered. The compensability among criteria might provide challenges, particularly when dealing with complicated sustainability issues

1, First addition of the values in the pairwise matrix's columns; $A_{ij} = \sum_{i=1}^{n} Aij \quad \ldots \; I$

2. Next, create a normalized pairwise matrix by dividing each element in the matrix by the total number of columns; $Nij = \frac{Aij}{\sum_{i=1}^{n} Aij} \begin{pmatrix} W11 & W12 & W13 \\ W21 & W22 & W23 \\ W31 & W23 & W33 \end{pmatrix} \ldots\ldots\ldots\ldots\ldots\ldots II$

3, To create a weighted matrix, divide the total of the normalized column of the matrix by the number of alternatives (n) which is priority vector; $Wij = \frac{\sum_{i=1}^{n} wij\,j}{n} \begin{Bmatrix} w11 \\ w22 \\ w33 \end{Bmatrix} \ldots\ldots III$

The Eigenvalue and Eigenvector are derived as the final step. This step involves normalizing the values in the comparison matrix and computing the average of each line in the normalized comparison matrix to get the Eigenvector. These means provide us a notion of the options' relative priority to one another. Multiplying the Eigenvector by the comparison matrix yields the Eigen matrix.

3.6 Data Validity and Reliability

Validity and reliability of data are important components of research methodology that include survey accuracy and consistency. In order to determine the first face validity measure for this study, academicians with subject-matter expertise complete the questionnaire to assess the content; the questionnaire is then changed in light of their assessment and feedback. Subsequently, a pilot study is carried out on the projects, distributing 72 questionnaires for stakeholders to complete. Once the questionnaires are filled out accurately, the data is gathered and its reliability is assessed using the consistency ratio.

We can derive the comparative weights by finding the eigenvector w with respective λmax that satisfies Aw = λmax, where λmax is the largest eigenvalue of the matrix A, i.e., find the eigenvector w with respective λmax for (A – λmaxI)w=0.

To ensure the consistency of the subjective perception and the accuracy of the comparative weights, two indices, including the consistency index (C.I.) and the consistency ratio (C.R.) are suggested

C.I=(λmax-n)/(n-1) …………………..IV :where λmax is the largest eigenvalue, and n denotes the numbers of the attribute

$CR = \frac{CI}{RI}$…………V : Saaty (1980) suggested that the value of the C.I. should not exceed 0.1 for a confident result

The term "R.I." stands for random consistency index, which is obtained by applying the scale to a sizable sample of randomly produced reciprocal matrices. 1/9, 1/8,...,1,...,8, 9

Table 3.3 RI value

n	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***
RI	***0.52***	***0.89***	***1.11***	***1.25***	***1.35***	***1.4***	***1.45***	***1.49***	***1.52***	***1.54***	***1.56***

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Introduction

In this chapter, some analyses used to understand about road construction wastes are prepared. And also some discussion and interpretation are presented in order to achieve our main goal which is developing conceptual frame work used to minimize wastes in road construction projects. AHP calculation on the sources of construction wastes, site observation detail reports and another important parameter are deeply discussed in this chapter.

4.2 Profile of Respondents

Generally, 72 questionnaires were distributed to professionals and 58 questionnaires are successfully responded which is 80.56% of the total number. From these 21 of them are responded by contractors, 17 of them are responded by ERA workers and 20 of them are answered by consultants.

From the questionnaires which aren't taken for analysis, most of them are from the side of clients. And the rest are from consultants and contractors respectively. Since most of construction wastes are generated on the site, we can consider the amount of questionnaires not taken from the clients as acceptable since consultants and contractors are major role players on the site work.

Table 4.1 Information of the Respondents

Respondents	Questionnaires Given	Successfully Responded	Incomplete and Incorrect Response	Not Responded	Response Rate (%)
Client (ERA)	24	17	3	4	70.8
Consultants	24	20	1	3	83.3
Contractors	24	21	2	1	87.5

Educational Background

The educational background of the respondents is discussed below. As it is shown below most of the respondents (46 respondents) have gotten their bachelor degree and considerable amount of the respondents (16 respondents) hold their master's degree in the construction sector. And the rest of them have diploma (7 respondents).

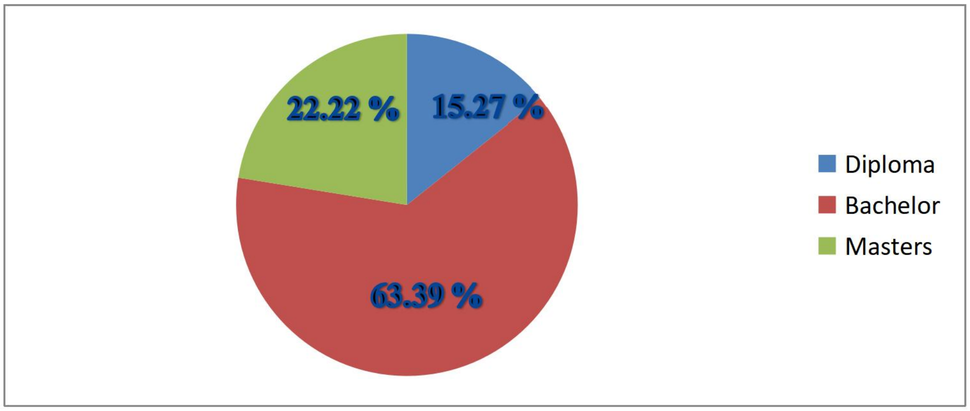

Figure 4.1 Educational Background f the respondents

Work Experience

The other thing is respondents experience in the construction industry, 36.11% of the respondents have the experience between 1-5 years (26 respondents). 31.9% of the respondents have 6-10 years of experience (23 respondents), 19.4% of the respondents have experience of 11-20 years (14 respondents) and the rest 12.5% of the respondents have experience of more than 20 years (9 respondents).

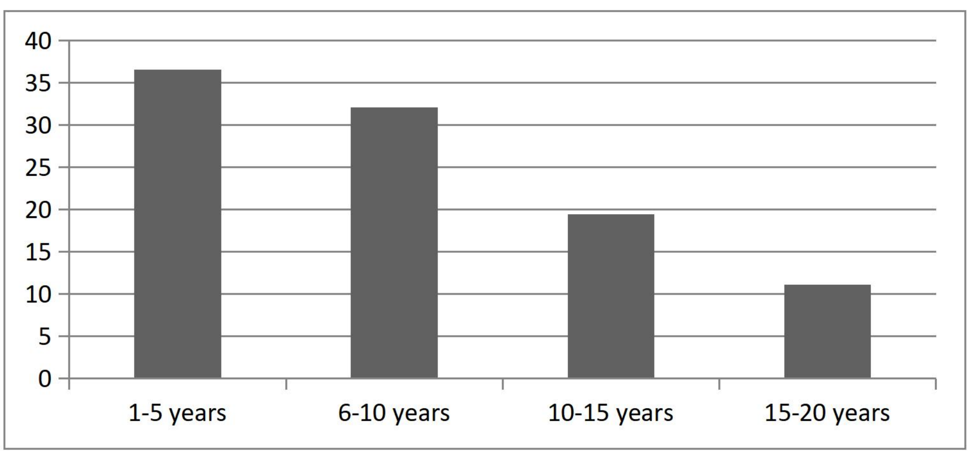

Figure 4.2 Experience of the respondents

4.3 Sources of Road Construction Wastes

4.3.1 AHP Analysis

According to (Saaty, 2002)**,** in using the AHP to model a problem, one needs a hierarchic or a network structure to represent that problem, as well as pairwise comparisons to establish relations within the structure. Sources of Construction waste, which are identified through literature review, are set to be compared with each other by construction professionals. These identified sources are 9 in number and then turned into a questioner which includes 36 paired comparison questions, for each alternatives to be prioritized.

Table 4.2 Categorization of Sources of Construction Wastes

No	Sources of Wastes	Symbols
1	**Poor workmanship**	**A1**
2	**Poor communication**	**A2**
3	**Use of incorrect material (replacement)**	**A3**
4	**Improper Planning**	**A4**
5	**Design change during the construction Period**	**A5**
6	**Lack of information on the drawing**	**A6**
7	**Complexity of the drawing**	**A7**
8	**Inappropriate stocking**	**A8**
9	**Damages during transportation**	**A9**

To perform the pairwise comparison you need to create a comparison matrix of the criteria involved in the decision, as shown in Table 4.3. Cells in comparison matrices will have a value from the numeric scale shown in Table 3.2 to reflect our relative preference (also called intensity judgment or simply judgment) in each of the compared pairs. For example, if we consider that Poor workmanship is moderately more important than the Improper Planning, the comparison cell (i.e., the intersection of the row 'Poor workmanship' and column 'Improper Planning) will contain the value 3 as shown in Table 4.3. Mathematically this means that the ratio of the importance of Poor workmanship versus the importance of Improper Planning is three (Poor workmanship / Improper Planning'= 3). Because of this the reciprocal of this value (Improper Planning / Poor workmanship = 1/3) as shown in the Poor workmanship- Improper Planning cell in the comparison matrix in Table 4.3. The rationale is intuitively obvious.

On the next table the result obtained from the questionnaires is put. The results are calculated based on the calculation on summation of the numbers assigned on each comparison multiplied with their respective repetition and divided by total number of questionnaire.

Table 4.3 Pairwise Comparison of the Matrix

Alternatives	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	1	1	1	3	1/3	1	1	3	1
A2	1	1	1	1	1/3	1	1	1	1
A3	1	1	1	1	1	1	1	3	1
A4	1/3	1	1	1	3	1	1	1	1
A5	3	3	1	1/3	1	1	1	1	1
A6	1	1	1	1	1	1	3	1/3	1
A7	1	1	1	1	1	1/3	1	1	1
A8	1/3	1	1/3	1	3	3	1	1	1
A9	1	1	1	1	1	1	1	1	1

The next step is to compute a vector of priorities, or weighting of matrix members, after collecting the pair-wise judgments in table 4.3. This is equivalent to adding the members of each column to determine the total when calculating the matrix's priority vector, or eigenvector, in terms of matrix algebra. Divide each column's elements by the column total and sum them up to normalize each column to sum to 1.0 or 100%. Scores were first adjusted before we saw the step-by-step process to determine priority. This step involves adding up all of the integers in each column to normalize the matrix.. For the matrix of the pairwise matrix (Table 4.4)

Next, create a normalized pairwise by dividing each element in the matrix by the sum of its columns. (Table 4.5): $N_{ij} = \frac{Aij}{\sum_{i=1}^{n} Aij} \begin{pmatrix} W11 & W12 & W13 \\ W21 & W22 & W23 \\ W31 & W23 & W33 \end{pmatrix}$

Table 4.4 Pair-wise Comparisons

Alternatives	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	1	1	1	3	0.33	1	1	3	1
A2	1	1	1	1	0.33	1	1	1	1
A3	1	1	1	1	1	1	1	3	1
A4	0.33	1	1	1	3	1	1	1	1
A5	3	3	1	0.33	1	1	1	1	1
A6	1	1	1	1	1	1	3	0.33	1
A7	1	1	1	1	1	0.33	1	1	1
A8	0.33	1	0.33	1	1	3	1	1	1
A9	1	1	1	1	1	1	1	1	1
Sum	**7.40**	**11.00**	**12.33**	**16.87**	**9.40**	**16.33**	**23.00**	**16.01**	**18.14**

To create a normalized pairwise matrix, divide each matrix member by the sum of its columns.

Table 4.5 Normalized Pairwise Matrix

Alternatives	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	0.103	0.091	0.120	0.290	0.034	0.097	0.091	0.243	0.11
A2	0.103	0.091	0.120	0.097	0.034	0.097	0.091	0.081	0.11
A3	0.103	0.091	0.120	0.097	0.103	0.097	0.091	0.243	0.11
A4	0.034	0.091	0.120	0.097	0.310	0.097	0.091	0.081	0.11
A5	0.310	0.273	0.120	0.032	0.103	0.097	0.091	0.081	0.11
A6	0.103	0.091	0.120	0.097	0.103	0.097	0.273	0.027	0.11
A7	0.103	0.091	0.120	0.097	0.103	0.032	0.091	0.081	0.11
A8	0.034	0.091	0.040	0.097	0.103	0.290	0.091	0.081	0.11
A9	0.103	0.091	0.120	0.097	0.103	0.097	0.091	0.081	0.11
Sum	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

To create a weighted matrix (priority vector), divide the total of the matrix's normalized column by the number of Alternatives. in table 4.6;

Table 4.6 Weighted Matrixes

Alternatives	A1	A2	A3	A4	A5	A6	A7	A8	A9	Priority
A1	0.10	0.09	0.12	0.29	0.03	0.10	0.09	0.24	0.11	**0.1312**
A2	0.10	0.09	0.12	0.10	0.03	0.10	0.09	0.08	0.11	**0.0917**
A3	0.10	0.09	0.12	0.10	0.10	0.10	0.09	0.24	0.11	**0.1174**
A4	0.03	0.09	0.12	0.10	0.31	0.10	0.09	0.08	0.11	**0.1147**
A5	0.31	0.27	0.12	0.03	0.10	0.10	0.09	0.08	0.11	**0.1354**
A6	0.10	0.09	0.12	0.10	0.10	0.10	0.27	0.03	0.11	**0.1136**
A7	0.10	0.09	0.12	0.10	0.10	0.03	0.09	0.08	0.11	**0.0922**
A8	0.03	0.09	0.04	0.10	0.10	0.29	0.09	0.08	0.11	**0.1043**
A9	0.10	0.09	0.12	0.10	0.10	0.10	0.09	0.08	0.11	**0.0994**

As it is shown in the above table, the major sources of construction wastes are identified and listed based on their rank on the table below (table 4.7).

Table 4.7 Sources of construction waste based on their priority

No	Sources of Wastes	Symbol	Weight (%)
1	Design changes during construction	A5	13.54
2	Poor workmanship	A1	13.12
3	Use of incorrect material (replacement)	A3	11.74
4	Improper Planning	A4	11.47
5	Lack of information on the drawing	A6	11.36
6	Inappropriate stocking	A8	10.43
7	Damages during transportation	A8	9.94
8	Complexity of the drawing	A7	9.22
9	Poor Communication	A2	9.17

In general we have classified road construction wastes in to three main categories. From the sources, 45.5% of waste is occurred due to operational sources 34.12% is occurred by sources related to design works and 20.38% is originated from material and handling sources

4.3.2 Checking for Consistency

Prior to accepting the criterion weight of the computation above, we must verify if the data is consistent. When a decision-maker's judgment is taken into account in the pairwise comparison matrices, consistency is linked to their internal coherence. It is the most significant measurement of the AHP pairwise comparison results. By reducing the consistency index for the set of judgments by the index for the matching random matrix, one can get the true consistency ratio.

There will inevitably be some discrepancies in the final matrix of evaluations because the numerical values are based on people's subjective choices. How much inconsistency is allowed is the question. AHP uses the consistency index (CI) of the matrix in question—the one containing our judgments—as well as the consistency index of a random-like matrix (RI) to compute a consistency ratio (CR) for this purpose. Since the judgments in a random matrix are input at random, it is normal for the matrix to be extremely inconsistent. RI is the average CI of 500 randomly filled-in matrices, to be more precise.

Because it allows for the comparison of each possibility with the others, the AHP technique is frequently selected. As a result, the outcome is stronger when ranking the criterion. The consistency ratio in AHP is expressed as CR, where CR is equal to CI/RI. According to Saaty (2012), the AHP analysis can proceed with a consistency ratio (CR) of 0.10 or below. In order to identify and fix the source of the discrepancy, the judgments must be revised if the consistency ratio is higher than 0.10. We restrict ourselves to generating an estimate of the consistency ratio here because computer algorithms can readily calculate this value as follows:

1, Start with Table 4.8, which is a copy of Table 4.2 for convenience, which displays the matrix of judgment comparisons and resulting priorities. And preparation of pairwise priorities for the next calculations can be taken from the above analysis.

Table 4.8 Pairwise Matrixes

Alternatives	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	1	1	1	3	1/3	1	1	3	1
A2	1	1	1	1	1/3	1	1	1	1
A3	1	1	1	1	1	1	1	3	1
A4	1/3	1	1	1	3	1	1	1	1
A5	3	3	1	1/3	1	1	1	1	1
A6	1	1	1	1	1	1	3	1/3	1
A7	1	1	1	1	1	1/3	1	1	1
A8	1/3	1	1/3	1	1	3	1	1	1
A9	1	1	1	1	1	1	1	1	1

2, Use each column's priority as a multiplier by using them as factors (weights).

Table 4.9 Matrixes with priorities as factors

	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	0.131	0.092	0.117	0.344	0.045	0.114	0.092	0.313	0.099
A2	0.131	0.092	0.117	0.115	0.045	0.114	0.092	0.104	0.099
A3	0.131	0.092	0.117	0.115	0.135	0.114	0.092	0.313	0.099
A4	0.044	0.092	0.117	0.115	0.406	0.114	0.092	0.104	0.099
A5	0.394	0.275	0.117	0.038	0.135	0.114	0.092	0.104	0.099
A6	0.131	0.092	0.117	0.115	0.135	0.114	0.277	0.035	0.099
A7	0.131	0.092	0.117	0.115	0.135	0.038	0.092	0.104	0.099
A8	0.044	0.092	0.039	0.115	0.135	0.341	0.092	0.104	0.099
A9	0.131	0.092	0.117	0.115	0.135	0.114	0.092	0.104	0.099

3, Now compute the total of the weight value and ratio for each of the options.

Table 4.10 Summation of the Weight Value and Ratio

Alternative	A1	A2	A3	A4	A5	A6	A7	A8	A9	weighted sum	Ratio
A1	0.13	0.09	0.12	0.34	0.05	0.11	0.09	0.31	0.10	**1.35**	**10.27**
A2	0.13	0.09	0.12	0.11	0.05	0.11	0.09	0.10	0.10	**0.91**	**9.92**
A3	0.13	0.09	0.12	0.11	0.14	0.11	0.09	0.31	0.10	**1.21**	**10.29**
A4	0.04	0.09	0.12	0.11	0.41	0.11	0.09	0.10	0.10	**1.18**	**10.32**
A5	0.39	0.28	0.12	0.04	0.14	0.11	0.09	0.10	0.10	**1.37**	**10.11**
A6	0.13	0.09	0.12	0.11	0.14	0.11	0.28	0.03	0.10	**1.11**	**9.82**
A7	0.13	0.09	0.12	0.11	0.14	0.04	0.09	0.10	0.10	**0.92**	**10.02**
A8	0.04	0.09	0.04	0.11	0.14	0.34	0.09	0.10	0.10	**1.06**	**10.17**
A9	0.13	0.09	0.12	0.11	0.14	0.11	0.09	0.10	0.10	**1.00**	**10.06**

4, The consistency index (C.I) requires the largest eigenvalue of the matrix, lambda max (λ max), to be calculated. By dividing the total of all ratios by the priority factor and averaging the results, we can now determine λ max. Additionally, table 4.11's consistency ratio can be readily determined after the number is obtained.

Table 4.11 Consistency Calculation

λ_{max}=AVG of sum of weight value of Ratio	**10.1085**
C.I=(λmax-n)/(n-1)	**0.1386**
Random Index (RI for 9)	**1.45**
CR= CI/RI	**0.0956**

Since the value of consistency ratio is less than 0.1, we can say that the judgment is consistent and we can take the results to remove the sources based on their priority in our preparation of framework.

And also comparison of sources of construction wastes with other researches is discussed. Even if the preparation methods of the questionnaire and data analysis method are different with each other, comparison of the rank of sources of wastes in different researches is compared with this one. The source of wastes identified by researchers differs in many researches. (Kulatunga & Haigh, 1987) tries to classify construction wastes in to four parts. From these classifications Poor workmanship, Design change during construction, inappropriate storage and incorrect procurement are the first sources of wastes from each classifications. From these sources two of them are the highest waste generator of wastes in our case (Design change and poor workmanship).

(Soharu et al., 2022) has tried to study and analyzed the sources of construction wastes and found that complex design is the most waste generative source and design change and poor experience (workmanship) second and third respectively which is close with our result. (Fadiya et al., 2014) has founded that data error, design changes, material handling and operation wastes are the major classifications of sources of wastes respectively. Replacement, waiting for results and design changes are the most waste generative source according to (Al et al., n.d.).

As we have seen earlier, researchers analyzed sources of construction wastes in different perspectives. Some of them has tried to group the wastes in to major categories and analyzed them. And some of them have used another types of sources or left sources we used in our study. Others have classified the types of wastes and studied the sources of them by analyzing each of them differently. But most of them have gained the same results especially operational wastes are major sources of wastes in most of studies. And also we have observed that design changes during construction, poor workman ship and use of incorrect material (Replacement) are major source of wastes in different researches. Since each researches use different formats for sources of wastes it is difficult to put the similarity of our results with others in percentage but in general we have compared our most waste generative sources with other researches.

4.4 Waste Generating Activities

4.4.1 Site Observation

This chapter's primary goal is to provide an explanation of the site observation employed in this study. In this study, site observation is quite important. For instance, it allows the researcher to observe how road construction projects are carried out at the location. And also it ensures the researcher is aware of the tasks involved in the study on a daily basis. Consequently, the researcher gains familiarity with the tasks and planning methods involved in the project, which enhances his understanding of the construction process and aids in the creation of a stronger conceptual framework.

Project definition

The site observation is conducted on the project named Adama – KM 60 Expressway. This project is one of the largest road construction projects in Ethiopian. And currently holds the activities embankment work, capping layer. Sub base layer, base course layer, asphalt layer and structural works under construction. So the researcher can get good insight about the activities on each layer. This project is of the projects which is a part of Ethiopia – Djibouti Transport Corridor Project. The contract amount is 6,688,456,565.74 in ETB. The starting point is Adama and the end point is Melkajilo. The project duration is 4.5 years. The completion date is 09/01/2026 GC. African Development Bank is the Financier of this project. The Engineer of the project is LEA Associates South Asia PVT. LTD, India In Sub Consultancy With United Consulting Engineers P.L.C. The Contractor of the projects is Kalpatharu Power International Limited (KPIL) with L.R.B.C.

This project is one of the few projects which are currently being constructed without significant external influences. The activities which are executed during road construction (earth work, capping layer work, sub-base work, base-course work and asphalt work) and some structural works (Culverts and Bridges) were on progress during site observation time. The site observation lasted from 2nd February 2024 to 15th May 2024 (104 days).

The main purpose of displaying this is to provide detailed information about the real life activities and sub activities of the project, based on which the conceptual framework is modeled. After the data is gathered from field observation, the main activities in the construction work which are waste generative are pointed out. These activities are beneficial during frame work developing time to lead us using the best solution included in the process of removing the wastes from the site. And also some data gathering about hierarchy of the management system, the project delivery system, planning techniques and work approval systems are gathered during site observation time. In order to make it more reliable, some pictures are included which show waste generated due to some activities.

4.4.2 Embankment work (Earth Work)

The embankment work cover from preparation of road bed or undercut replacement up to the accomplishment of subgrade top layer which is the upmost layer below capping layer. This work majorly comprises of soil material works and sometimes uses granular and boulder materials.

The asphalt road is constructed through layer by layer construction method. These layers could be among some of or all of the layers shown in the figure below. These layers could be included or neglected based on the necessity of the role they are playing. But the layers which can be used in the road construction are shown on the figure below.

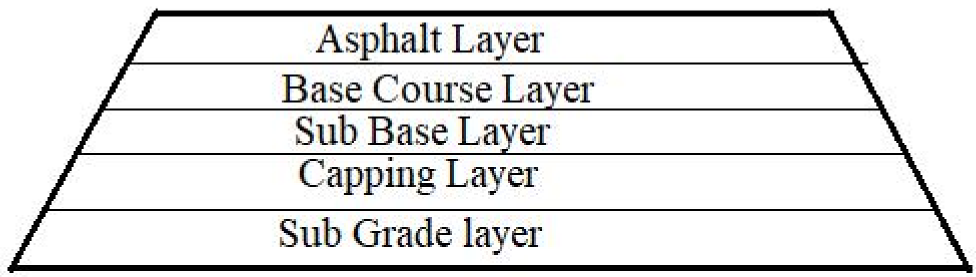

Figure 4.3 Layers of Asphalt Road

One of the activities which can cause high amount of waste during our site visit time is incorrect estimation of amount of material need for the work to be done. Most of the time, the estimated amount of quantity is more which can lead to over consumption of material. In addition to over consumption, it causes time waste in order to remove the excess material. This situation is shown the figure below (Fig 3.1a).

The other factor can be described as leaving tasks without completing them so they have to be reconditioned in order to continue the next work. As an example the figure shown below (Fig 3.1b) indicates that from 25+300 to 25+800 was left without completing the embankment work so during rainy time it was eroded so they had to be reconditioned before continual of the next work.

An act of not executing the next activity is also a cause for construction wastes. For example after the road bed is prepared, it should be covered at least one layer otherwise grass and another plants can grow easily. If they grow they have to be removed and it can be considered as rework.

Figure 4.4 Wastes on Embankment Layer work

4.4.3 Capping Layer:

Capping layer is a layer which is found between sub base layer and embankment top layer (sub grade top. This layer is used as a separation layer between soil and granular material. So it should be placed properly.

There are some wastes observed during site observation time. The first one was improper calculation of capping material needed for the execution. Due to this, huge amount of material became waste. The second one is related to poor workman ship. During elevation point taking time, the elevation was not correctly read so it results with fill layer. This caused using additional amount of material on the next layer (sub base layer) which is going to be more than 20cm

4.4.4 Sub Base Layer

The sub-base is an important load spreading layer which enables traffic stresses to be reduced to acceptable levels on the subgrade. This layer comes after capping layer. And it is executed using granular material. There are some waste generation activities observed during site observation time. The first one is related to poor elevation taking skills. Due to this problem the required elevation for sub base layer becomes lower and it makes next layer (Base Course) way thicker. The second activity is estimating incorrect amount of sub base material so it will be excess material on the site which becomes waste later (Fig 4.1A). And also, inappropriate usage of sub base material for another work which could be done by low cost materials is also observed (Fig4.1 B).

Figure 4.5 Wastes on Sub Base Layer work

4.4.5 Base Course Layer

This is the layer under the asphalt courses. It may unbounded or stabilized. It provides a level surface for laying the surface layer. It prevents intrusions of the fine subgrade soils into the pavement structure. This layer is one of the most important layers in the road construction. And also it is one of the most expensive. Waste generating on this layer means costing too much amount of money. During our visit, we have seen some waste generating activities. The first one is inappropriate estimation of base course material which leads excess material. Additionally, incorrect level taking of base course offsets is observed. And this action could lead to using high amount of material on the next layer (Asphalt Layer) which is more expensive.

4.4.6 Asphalt Layer

It is the top course of an asphalt pavement. It is constructed by dense graded hot-mix asphalt. It must be tough to resist distortion under traffic and provide a smooth and skid-resistant riding surface & waterproof. Since it is the most expensive one, more focus is given to this layer than other. But there are some activities which can lead to waste generation. It is known in the construction project that asphalt plants use too much fuel in order to gain the required amount of energy for the heater. So it is advised to work long distances once since it doesn’t need high amount of energy after it is heated.

During site observation time, execution of this layer for shorter distances has been observed and this leads to ineffective usage of fuel which is waste. The other one is related to preparation of asphalt layer at joint making place. At this time, cutting of paved layer is needed to join it with the new pavement to be laid. During this time it is seen that the paved layer is cut in a way that it can be considered as waste generative. And also significant amount of excess material is shown during site observation time

4.4.7 Structural Wastes

Another part of road construction is structural construction works. This work includes the construction of culverts (boxes and pipes) and bridges (under passes and over passes). This works can be classified in to two places as precast and cast in-situ works. The construction wastes observed under this categorization is related to poor workmanship. For example we can mention the preparation of steel bars for the work. After the needed part is prepared, the rest part is not going to be used for another work (). But this case doesn't work all the time. The second one is related to calculation of the amount of concrete need for one work. In order not to face shortage of concrete amount is going to be increased with higher amount. This could cause higher amount of concrete waste which is expensive can be occurred. These and another construction wastes are observed during site visit.

Figure 4.6 Wastes on Structural Works

Generally, activities which are considered as waste generative are presented in a tabular form below. These activities are only the observed waste generating activities during site observation time. It is believed that there will be other activities which generate construction wastes in the construction world. But most of the major waste generating activities are included in the table below

Table 4.12 Waste Generating Activities in Each Layer

Work	Waste Generating Activities
Embankment Layers	Idleness of machines
	Exaggerated amount of the estimation of material need in the work
	Usage of material which is more expensive and could be used on the other layer (Capping)
	Poor operator skill
	Extra work done on the offset which is wider than required.
	Reworks on unprotected works which were already completed
Capping Layer	Wastage of important material on unnecessary offset
	Incorrect estimation of quantity of material which is excess
	Usage of capping material for embankment works
	Idleness of machines during working time
	Incorrect elevation point taking which leads to excess amount of material usage on next layer
Sub Base Layer	Inappropriate usage of sub base material on other works
	Incorrect estimation of material for the required work (more than required)
	Poor elevation taking skill
	Poorly crushed sub base material (Boulders) which will be removed from the site

Base Course Layer	Incorrect estimation of material for the required work (more than required)
	Poor elevation taking skill
Asphalt Layer	Poor joint cutting activities
	Incorrect estimation of asphalt material needed
	Incorrect setup of leveling points
Structural Wastes	Incorrect estimation of amount of concreter needed for a single work
	Improper preparation of reinforcements so the rest part cannot be used for another work
	Leaving equipments on the site after finishing the work so they will be useless due to weather condition and another reasons

4.5 Interrelation of Sources of Wastes and Waste Generating Activities

As we've already seen, sources of construction waste are analyzed according to priority. Additionally, site observation is used to identify waste-generating activities. The sources of waste can be thought of as broad ideas that can arise from a variety of activities. As an illustration, our analysis shows that design change is the main source of waste. This source frequently produces wastes during structural construction, particularly when designing reinforcements. Additionally, incorrect design work done in the past may occasionally cause the cross sections on road segments to be redesigned. These periods will see a considerable increase in waste generation, which may cause further connected issues.

Poor workmanship is the next main source of waste generation. In each layer, this one is commonly observed. Poor workmanship can include miscalculating the amount of material required, reading layers' levels incorrectly, and operating machines with inexperience. The majority of incorrect material replacement occurs during embankment construction. Backfill projects should avoid using materials that have a great capacity to hold water, especially during wet seasons. Because these materials won't readily escape the moisture, using them during wet seasons may require replacing them with another material. Additionally, using materials that are unsuitable for usage in a certain layer may necessitate replacing those materials. Improper planning was evident in every kind of road building project. It could result in machines being inactive or extremely busy, it could cause weather-related disruptions to the job, it could cause stress to worker and generate more waste than expected and others.

Without proper planning overlap of work can be occurred and also inappropriate work can be executed so these works can cause wastes. Lack of information on the drawing is also another one. Many structural workers do their work based on the information on the drawing. Sometimes the drawing won't give enough information about the reinforcement placement. These time worker do the work without any help from the professionals in order to finish the work according to the plan. This time mistakes could be created which leads to generating waste. This type of source of waste also has an effect on embankment works specially related with slop cutting bench excavation.

The next source of waste is inappropriate stocking. Material like granular sub base is often stocked on the site not to wait until it is sent from stock yard. So the workers can easily use it from the site. But if it is not properly stocked it will be contaminated with soil so it will be discarded and considered as a waste. Damages during transportation mostly occurred in structural works. Parts of segments of culverts are casted at precast yard and transported to the site. During transportation the segments could fall down or hit with each other so some part of the body will be broken. This time we can't use them for the work required.

And also complexity of the drawing can be seen as a source for wastes especially in structural works. Due to complication workers might do unnecessary work which can be considered as waste. And lastly poor communication is also major type of source of waste which is seen in many activities. This source of waste is also seen in asphalt and base course activities. With out proper communication the required material cannot be delivered on the site and the required work cannot be executed.

4.6 IPD and LPS as Waste Minimization Technique in Ethiopian Road Construction Projects

4.6.1 Last Planer System

In the early 1990s, the Last Planner System (LPS) was developed as a project production control system. It's usual to distinguish between "controlling," which involves implementing plans to ensure that goals are met, and "planning," which refers to creating strategies to accomplish goals. Project controls dominated the project management toolset, while production control was considered the missing component. Setting and tracking schedule and cost goals that are in line with the project's scope is the responsibility of project controls. Production control, on the other hand, has the responsibility of guiding toward targets, taking all necessary steps to follow the intended course, and, in the event that it is not feasible, determining a different course of action to reach targets.

Both are essential. They are a coin's two sides. Driving with your eyes in your rearview mirror is the equivalent of project controls lacking production control. It would be equivalent to driving without a goal, unaware of the amount of fuel left in the tank, or production control without project controls.

The identification of consistently poor workflow reliability in construction projects served as the impetus for LPS. As a result, the first stage in its development was to raise the match between DID and WILL and enhance workflow reliability—that is, to learn how to accomplish what we say we're going to do. The process of creating coordinated weekly work plans began in the early 1990s and involved meetings with front line supervisors. The weekly work plans adhered to the rule that only tasks that were clearly defined, sound, sequenced, and sized to performer capabilities could be included. That worked out well. Both worker productivity and the percentage of plans completed (PPC) increased. However, it soon became clear that even with 100% PPC and exceptional productivity, a project may still be running behind schedule. A look-ahead planning process was added to LPS in recognition that project progress toward anticipated completion dates rises and falls with PPC only when activities are made available in the proper sequence and rate. This allows for the completion of what SHOULD be done when needed. LPS's initial production control functions were superseded by this.

As was previously said, LPS is an adaptable technique for enhancing a project's performance from a variety of angles. When considered as a whole, it can produce many kinds of solutions for many problems; but, if we wish to use it for a particular goal, we can choose the right phrases only and avoid taking on needless, complicated duties as essential labor. In our instance, we have picked key ideas to minimize building work because we are attempting to build a framework for waste minimization.

Note on terminology: It is important to be explicit about how we are using the terms system, process, operation, and method in this research article because they are frequently used interchangeably in everyday speech and are used in a variety of ways. This can assist us in comprehending the nature of each stage of LPS.

The Last Planner is referred to be a "system" since it is designed to carry out particular tasks in order to fulfill the planning and control objectives. A process is a sequence of actions and events that result in a certain conclusion; in other words, a process is used to carry out a specific function, such choosing which scheduled activities in weekly work plans are released for commitment. We refer to phases inside processes that are assigned to a single trade or discipline (or to an integrated team) as operations. A method is an approach to carrying out the tasks involved in a process.

LPS has six steps needed to be followed to exercise it. These are; Project execution planning, Master (milestone) planning, Phase planning, Look ahead planning, Weekly work planning (commitment planning) and learning (continuous improvement) respectively (Ballard & Tommelein, 2021). Project execution plans are created to set the project objectives, assess the feasibility of successfully completing a given project and finish the projects within acceptable risk. Master and phase schedules outline what SHOULD to be done, when, and by whom to accomplish project goals. Master planning also serves the purpose of determining phase durations and overlaps. Phases are used to express the master timetable. Phase planning includes defining handoffs and conditions of satisfaction between processes within phases. Processes are used to express phase schedules.

Since they address other significant challenges, all of the aforementioned actions are conducted generally. However, it is expected that by modifying our planning under look ahead planning, we can reduce construction wastes. The purpose of look-ahead planning is to ensure that activities are prepared so they CAN be completed on time. The look-ahead schedule is first stated in terms of processes, but operations make up the task breakdown. Steps that need to be completed by people or teams are specified in operations designs, which specify how work is to be done in order to meet predetermined expectations. Only jobs in the feasible backlog—i.e., those that have been marked as critical or non-critical, screened for constraints, and declared constraint-free—can be committed to.

Finally In order to see what will become available for them to select, last planners should be involved in look ahead planning. This will enable them to identify critical tasks and devote their capacity to them first, as well as assist in deciding how to distribute scarce capacity. Choosing ready work and articulating what WILL be done throughout the plan period constitute the basis of commitment plans. Commitment plans include duties that are related to operations. The front-line supervisor, Last Planner, and the workers themselves oversee the execution of operations in compliance with their design. Plan failures are determined by comparing DID to WILL, such as unfulfilled promises or noteworthy accomplishments. After that, if there has been a negative deviation, the failure is examined for ways to make it happen again; if there has been a positive deviation, the analysis looks for ways to make it happen again and considers incorporating the practice into a new norm that sets a higher bar.

Some key phrases are created to compare our progress with the planned one in order to manage the production and learn from past mistakes. These phrases are applied both generally to the overall framework and particularly to each layer's details.

Milestone Variance (MV): The state of the project relative to its schedule target is assessed using the metric milestone variance defined as the number of days early or late a milestone is expected to be reached.

Percent Required Complete (PRC): gives the necessary information to determine if a day is early or late; that is, it indicates which necessary chores were not finished the week before. Metrics unique to each aim are used to evaluate progress toward it, such as cost, material consumption, or other

Commitment Level (CL): It has to do with allocating capacity to necessary jobs first. Studies have indicated that necessary or vital tasks are not always given priority when allocating capacity. There are multiple possible reasons for this. It's possible that front line supervisors, or last planners, are unaware of which activities are crucial, and their superiors aren't checking preliminary weekly work plans to make sure this guideline is being followed. As a result, it's essential to evaluate CL weekly with supervisors.

Percent Plan Complete (PPC): PPC tracks workflow reliability, or the consistent distribution of work throughout work groups. It is often done once a week, but it can be done at any period that is suitable for the task at hand.

Tasks Made Ready (TMR): Comparing the weekly work plan (Week0) to an earlier week in the look ahead window (Weekn), TMR is the same measurement as PPC but is carried out earlier in the look ahead process. TMR assesses the team's capacity to recognize and eliminate obstacles prior to the planned commencement of designated work assignments.

Tasks Anticipated (TA): TA calculates the proportion of a target week's tasks that were predicted in a prior plan for that target week. This indicator's goal is to give a reasonable assessment of the team's ability to influence the project's real course of events during the coming weeks. This capacity for planning is essential since without it, the appropriate task cannot be prepared.

Frequency of Plan Failures (FPF): As explained (see Percent Plan Complete (PPC)), activities are annotated during execution with a note indicating whether or not they were completed on schedule. Those that are not finished on time are categorized into a group that provides a general explanation of the reason for the deviation or failure of the plan. These categories, which are frequently referred to as "Reasons for Variance," are helpful in locating flaws in particular support systems or flows. For instance, persistent material issues could indicate a breakdown in the supplier/site coordination or the materials management information system. Through analysis, the true cause of plan failures must be found.

4.6.2 Integrated Project Delivery

IPD often focuses on improving projects as a whole by integrating people, processes, and tools into a system. Early in the project lifecycle, it has strong cooperation in integrated interdisciplinary skills, ensuring that successful design decisions are met. The introduction of the IPD strategy aims to improve project performances by revolutionizing project delivery and management. Whether the integration principles be applied within the current project delivery methodologies or with a new delivery system will determine how they are taken into consideration; both are thought to result in better modifications and higher returns on investment.

The acceptance of IPD in the construction sector is questionable, despite the fact that many professional institutes have supported its growth and highlighted its merits. Other industrialized nations have witnessed IPD development in the construction industry in recent years, although construction workers' awareness and understanding are still at a low level. To increase appreciation, it is necessary to highlight the requirements and degree of IPD integration.

We must adhere to the principles that can direct us toward our goal in order to apply IPD in our situation. Scholars and nations that have adopted the IPD system claim that several methods are employed to lay out the guiding principles. Nonetheless, we are able to drive the IPD concepts and group them into four categories: technological, structural, behavioral, and contractual principles. The formal arrangement principles that will be used in IPD initiatives are known as contractual or legal principles. Project participants are required to adhere to and carry out these legally binding principles. Through the establishment of reciprocal risk and reward systems, trust-based relationship contracting, and other mechanisms, the multi-party agreement approach will strengthen project teams' contractual ties, optimize effective project integration, and ultimately lower project risk.

Regardless of backgrounds and knowledge, members' performances have a direct impact on how well a partnership works. Therefore, the project team's actions will determine how effective the integration is. The term "behavioral principle" in IPD refers to programs that enhance team integration performances through informal relationships and focus on participant mindsets and attitudes. Project teams must implement these IPD principle aspects in order to achieve the success of IPD in actual practices.

The arrangements and connections between the components that make up the entire complex are referred to as structural. The system and process management used to manage the IPD project is a structural principle. In essence, structural principles are subject to change and can continuously incorporate lessons discovered during the course of projects. The cooperative decision-making processes, shared accountability, and cooperative organizational cultures are the traits of structural principles. The term "technological principle" describes the application of ICT as an interface tool to raise the degree of project team integration. While the technology and delivery mechanisms are in place, team members must make an effort to implement the IPD principles as a means of fostering excellent teamwork and unleashing the creative potential of an integrated team.

IPD Implementation

The level of integration that we must implement for the project determines how we will implement IPD. The degree of integration between stakeholders and the kinds of principles applied determine how different the integration levels are from one another. Different projects use one of four types of integration levels. The first is referred to as Lean Delivery or Level One Integration. At this stage, the willingness of the project participants to work together determines whether or not a contract is necessary for integration. Level Two Integration, or IPD-ish, is the second one. The second level of integration illustrates how IPD collaboration is implemented using conventional contract formats (without establishing multi-party contracts).At this stage, projects are officially encouraged to begin earlier for sequence designs, include BIM into the preconstruction phase, and produce shop drawings and submittal stages earlier. "Pure" and "Real" IPD refer to levels three and four, respectively. Projects that meet the standards of other IPD principles and are contractually bound on multi-party contracts are classified as level 3 or 4 integration. "Pure" IPD necessitated legally binding cooperation, sharing of risks and rewards, and access to each party organization's financial data.

In our situation, material wastes are primarily produced on site following the signing of all contracts. Additionally, trash is produced during building, which is typically the contractor's problem. Therefore, it is not appropriate to change the project delivery system just for waste minimization purposes as this could result in needless effort. However, this does not negate the necessity of other stakeholders' involvement in the site. For instance, some wastes are produced when consultants disagree with the completed work. And the improper plan for carrying out the work could be the cause. Waste may never be produced if the contractor and consultant, who are the two stakeholders, agree on the strategy initially. Thus, for all these reasons lead us to use level one integration of IPD or lean delivery.

At this level, there is very little integration, little team sharing, and minimal client, consultant, and contractor collaboration—all of whom are ultimately in charge of the building projects from start to finish. This calls for the participants to be trusted, dependable, honest, and respectful of their expertise and opinions. At this stage, the most important thing to adopt is the behavioral concept. IPD principles, integration level, and implementation barriers in relation to LPS are all considered in the development of the IPD theoretical framework. This work added to the corpus of knowledge by providing an extensive literature review on the IPD philosophy. The research on the reclassification of IPD principles has enhanced our understanding of the concepts needed to produce excellent IPD works. In addition to helping industry personnel better understand the requirements and relationships of IPD principles implemented concurrently with level of integration and barriers in order to mitigate Ethiopia's construction waste, this study is significant because it proposes a benchmark of conceptual review in IPD principles for future research.

4.7 Framework of Waste Minimization in Road Construction Projects

The data analysis, site observations, and literature reviews on construction wastes, last planner systems, and integrated projects delivery systems served as the foundation for the development of this framework. In order to achieve a major improvement in the process, the framework integrates LPS and IPD in an effort to reduce waste. There are three components to this framework. The first is a broad overview of how LPS and IPD are implemented throughout a project, from inception to completion. The second section discusses the steps that must be taken during the stage of forward planning, while the third section addresses the commitment plan and ongoing improvement (learning).

Planning for waste minimization should not always begin at the outset when it comes to waste reduction. Once the overall goals have been established and milestone plans have been created, we can use our waste minimization technique to the middle planning. Therefore, the majority of the plans, schedules, and work for our framework will be completed during the look ahead planning stage. Following the look-ahead planning phase, we will oversee, administer, and modify the plan during the following two phases. We try to learn from our mistakes after the plan is executed and attempt to fix any issues that arose during planning and execution on the following planning, beginning with look ahead planning. So first the general framework is developed then the detail strategies and methods to be followed in the look ahead planning, commitment planning and continuous improvement is drawn in the next three framework drawings.

Last planner system is in general about planning and production control which gives an opportunity to learn from previous faults and lead us to perfection through continuous improvement. So we have used these concepts in our planning and production phase. When we come to Integrated Project Delivery; it is about integrating systems, stake holder, tools and others to achieve a desired objective effectively. And we have tried to integrate the stake holder starting from look ahead planning up to continuous improvement and coming back to look ahead planning again in our case. This is how we used these two systems to overcome the problem of generation of road construction wastes.

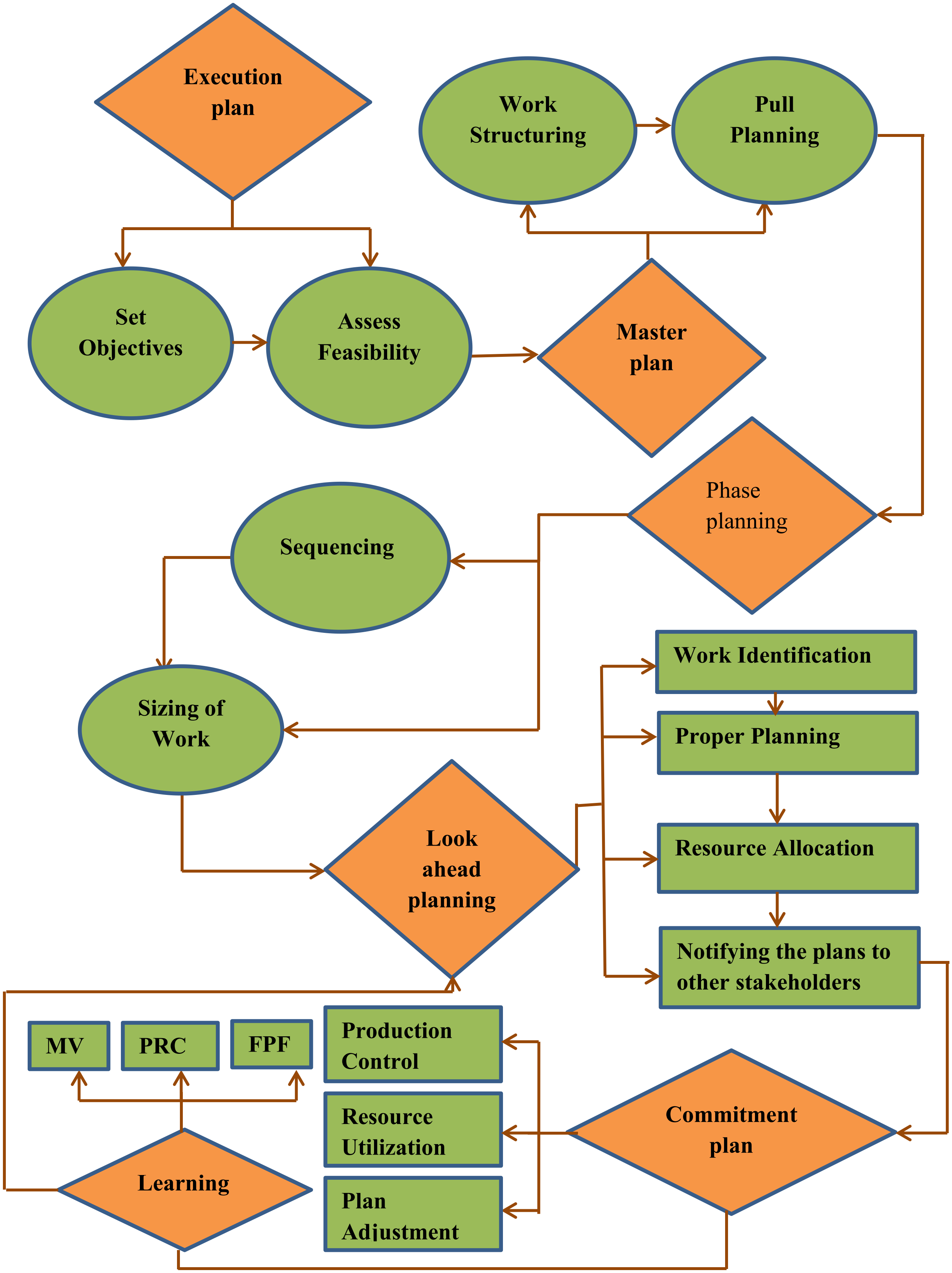

Figure 4.7 General Structure of the Frame work

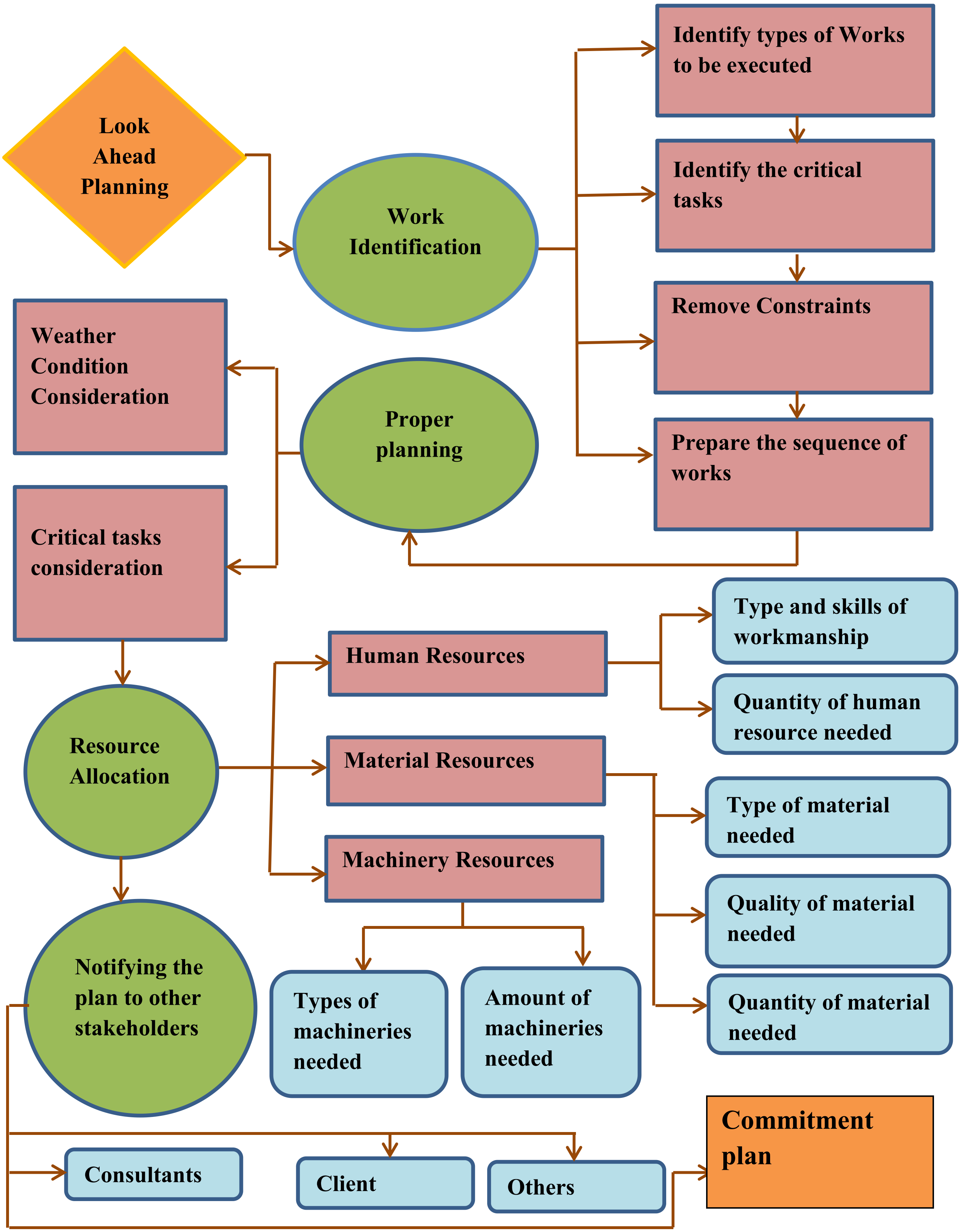

Figure 4.8 Look Ahead Planning

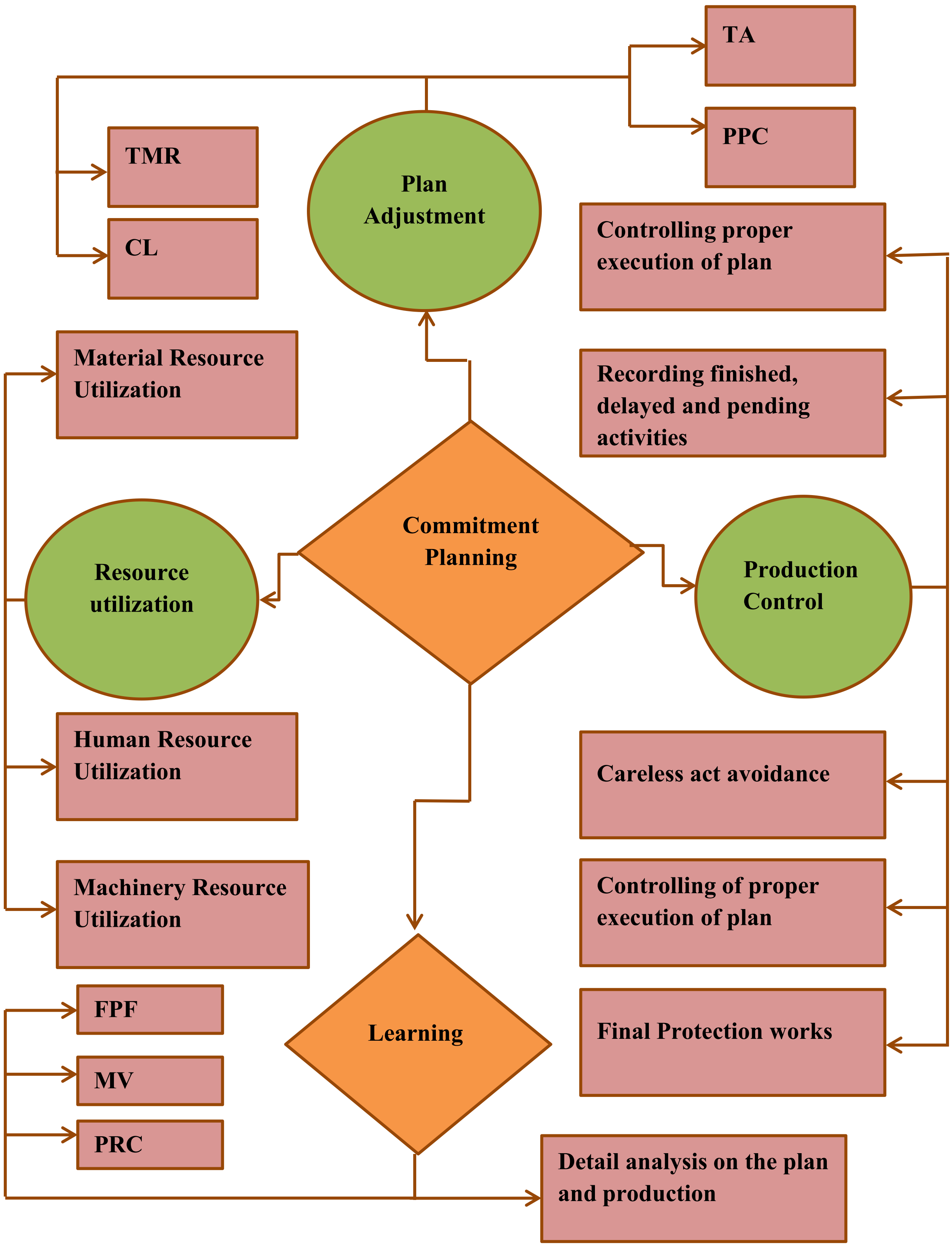

Figure 4.9 Commitment Planning and Learning Stage

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The conclusions are made below depending on the data analyzed on the previous chapter, the data collected from the site observation and from the literature review which are integrated and discussed in a chronological way to address each objective.

- Based on the analysis conducted in the previous section, design changes, poor workmanship, improper material replacement, improper planning and lack of on the drawing are the major types of sources of wastes in the road construction projects with the generation rate of 13.54%, 13.12%, 11.74%,11.47% and 11.36% respectively. And also, we can generally classify road construction wastes in to three categories; operation waste design wastes and material and handling wastes. From the sources, 45.5% of waste is occurred due to operational sources 34.12% is occurred by sources related to design works and 20.38% is originated from material and handling sources. This implies that most of the sources are originated during the execution of activities to construct the road rather than design time or material handling time.
- Waste generating activities differ with each other base on the layer to be constructed. On the soil works which are embankment work and capping layer work (optional), most of the sources are generated from poor workman ship and material replacement. On the sub base layer poor workman ship and inappropriate stocking are highly shown during site observation time. Poor communication, improper planning and poor workmanship are observed on the base course and asphalt layer activities. Design wastes (design change, lack of information on the drawing and complexity of the drawing) are highly shown on the structural works specially, on the reinforcement bars. Damages during transportation are also slightly seen on the concrete delivery related to loss of workability and if the amount is small.
- Based on the discussion made, sources of wastes analyzed in the research are shown in the waste generative activities observed on the site. Some activities indicate more than one source during execution. Sometimes some groups of wastes related to single type

of activities. For example design wastes are mostly related to concrete and reinforcement works and material and handling wastes are moderately related to soil works.

- Interpretation of the concepts LPS and IPD on the case of waste minimization of road construction in Ethiopian context is successfully executed. And the researcher has found that there is high opportunity of minimizing wastes using these concepts. And also it is identified that these concepts can be easily implemented with commitment from each stake holders and including members of the construction projects on both planning and execution times.
- Conceptual frame work is developed to implement the concepts of LPS and IPD to apply them in the construction projects. The frame work is developed in a way to facilitate the planning phase on each layer individually. This will allow the planners to plan a plan which is compatible the execution of each layer. And also it allows planners to learn from previous plans by calculating weekly worked plan and checking what should be improved from previous plans.

5.2 Recommendation

The following recommendation are suggested from the researcher

- Lean construction tools can bring a lot of changes in the construction industries if they are successfully implemented. So construction industries can apply them easily and could gain the benefit.
- The major sources of wastes are arrived during execution time. So during construction, appropriate focus should be given to each work.
- Most of road construction wastes can be removed with proper preparation of workers at lower levels. So allowing lower class workers in a planning session could make a big difference.
- Many other countries are using these lean construction tools for waste minimization purposes including developed countries. So it is reliable that we can get what we deserve from implementing these concepts effectively.

- Integrating every stake holder can simplify most of the works and allows workers to work in a well-organized manner. Therefore stake holders should work as one to overcome any problems raised in a construction projects.
- Contractors are the one who are going to be benefited from applying these tools. So they are expected to develop these ideas in their plans, schedules processes and principles.

5.3 Recommendation for Further Research Works

This research has tried to develop framework on the construction wastes using lean construction tools. But another many types of improvement can be made using these tools. Hence the following recommendation are suggested to future researchers

- These concepts can be improved to software models. So software developers can develop the concepts as a model so they can be easily implemented in different areas.
- Lean construction tools can be developed as performance improver, cost minimizer, quality assurance and on other important parameters. Hence professionals can participate on this kinds of researches
- Lean construction tools can be deeply studied for each layer to increase their effectiveness on the work. So developers can study these concepts and apply them on the most important layers.

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APPENDIX

Appendix A

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF CIVIL ENGINEERING AND ARCHITECTURE CONSTRUCTION ENGINEERING AND MANAGEMENT

Questionnaire survey for thesis paper on

Development of Integrated Project Delivery and Last Planner System concepts as a Waste Minimization Technique in Ethiopian Road Construction Projects

This research survey is designed to fulfill an academic requirement for MSc program in Construction Engineering and Management at the Adama science and technology university. Those who involve in the road construction projects controlled by Ethiopian Road Administration are kindly requested to contribute to this research work.

The result of this survey is intended to serve only for academic purpose and will be treated with strict confidentiality. The name of institutions participated will be recorded confidentially. Thank you in advance for your willingness to fill the questionnaires and returning them back on time.

Mihireteab Melkamu

0937861758

Email:- mihireteabmelkamu@gmail.com

Advisor: Bahiru Beweket (PhD)

Part One: General Information

1, Name of the respondent (optional)

____

2, Respondent's Organization on the project

☐ Client ☐ Consultant ☐ Contractor

3, Level of education of the respondent

☐ Below BSc degree ☐ Master's Degree

☐ BSc Degree ☐ Ph.D

4. Relevant working experience

☐ 1-5 years ☐ 11-15 years

☐ 6- 10 years ☐ more than 15 years

5 Current Position in the Organization

____

Part Two: Sources of Construction Wastes

Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) is a general theory of measurement. It is used to derive ratio scales from both discrete and continuous paired comparisons. These comparisons may be taken from actual measurements or from a fundamental scale which reflects the relative strength of preferences and feelings.

The sources listed on the survey table are commonly mentioned sources of wastes on road construction. The respondent is required to compare these criteria according to their importance.

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one activity over another
5	Strong importance	Experience and judgment strongly favor one activity over another
7	very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
9	Very, very strong Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation

Example

Some respondents might believe that poor workman ship is more waste generating source rather than poor communication. Hence they can choose poor workman ship based on the importance it has. For example they can choose no 7 if it is very strongly important.

No	**Alternatives**	Extremely Important	Very strong Importance	Strong Importance	Moderate Importance	Equal Importance	Moderate Importance	Strong Importance	Very strong Importance	Extremely Important	**Alternatives**
1	Poor Workmanship	9	7	5	3	1	3	5	7	9	Poor Communication

Hence, please wisely choose the one which has relatively high importance with the appropriate degree listed below !

No	Alternatives	Extremely Important	Very strong Importance	Strong Importance	Moderate Importance	Equal Importance	Moderate Importance	Strong Importance	Very strong Importance	Extremely Important	Alternatives
1	Poor Workmanship	9	7	5	3	1	3	5	7	9	Poor Communication
2	Poor Workmanship	9	7	5	3	1	3	5	7	9	Use of incorrect material replacement
3	Poor Workmanship	9	7	5	3	1	3	5	7	9	Improper Planning
4	Poor Workmanship	9	7	5	3	1	3	5	7	9	Design change
5	Poor Workmanship	9	7	5	3	1	3	5	7	9	Lack of Information on the Drawing
6	Poor Workmanship	9	7	5	3	1	3	5	7	9	Complexity of the Drawing
7	Poor Workmanship	9	7	5	3	1	3	5	7	9	Inappropriate Stocking
8	Poor Workmanship	9	7	5	3	1	3	5	7	9	Damages during transportation
1	Poor Communication	9	7	5	3	1	3	5	7	9	Use of Incorrect Material (replacement)
2	Poor Communication	9	7	5	3	1	3	5	7	9	Improper Planning
3	Poor Communication	9	7	5	3	1	3	5	7	9	Design change
4	Poor Communication	9	7	5	3	1	3	5	7	9	Lack of Information on the Drawing
5	Poor Communication	9	7	5	3	1	3	5	7	9	Complexity of the Drawing
6	Poor Communication	9	7	5	3	1	3	5	7	9	Inappropriate Stocking
7	Poor Communication	9	7	5	3	1	3	5	7	9	Damages during transportation
1	Use of Incorrect Material (replacement)	9	7	5	3	1	3	5	7	9	Improper Planning
2	Use of Incorrect Material (replacement)	9	7	5	3	1	3	5	7	9	Design change
3	Use of Incorrect Material (replacement)	9	7	5	3	1	3	5	7	9	Lack of Information on the Drawing
4	Use of Incorrect Material (replacement)	9	7	5	3	1	3	5	7	9	Complexity of the Drawing

5	Use of Incorrect Material (replacement)	9	7	5	3	1	3	5	7	9	Inappropriate Stocking
6	Use of Incorrect Material (replacement)	9	7	5	3	1	3	5	7	9	Damages during transportation
1	Improper Planning	9	7	5	3	1	3	5	7	9	Design change
2	Improper Planning	9	7	5	3	1	3	5	7	9	Lack of Information on the Drawing
3	Improper Planning	9	7	5	3	1	3	5	7	9	Complexity of the Drawing
4	Improper Planning	9	7	5	3	1	3	5	7	9	Inappropriate Stocking
5	Improper Planning	9	7	5	3	1	3	5	7	9	Damages during transportation
1	Design change	9	7	5	3	1	3	5	7	9	Lack of Information on the Drawing
2	Design change	9	7	5	3	1	3	5	7	9	Complexity of the Drawing
3	Design change	9	7	5	3	1	3	5	7	9	Inappropriate Stocking
4	Design change	9	7	5	3	1	3	5	7	9	Damages during transportation
1	Lack of Information on the Drawing	9	7	5	3	1	3	5	7	9	Complexity of the Drawing
2	Lack of Information on the Drawing	9	7	5	3	1	3	5	7	9	Inappropriate Stocking
3	Lack of Information on the Drawing	9	7	5	3	1	3	5	7	9	Damages during transportation
1	Complexity of the Drawing	9	7	5	3	1	3	5	7	9	Inappropriate Stocking
2	Complexity of the Drawing	9	7	5	3	1	3	5	7	9	Damages during transportation
1	Inappropriate Stocking	9	7	5	3	1	3	5	7	9	Damages during transportation

Appendix B

Pictures captured during site observation time which are helpful for understanding the activities of road construction

Fig1 Excess Capping Material

Fig 2 Rework of Road Bed and Undercut Replacement

Fig 3 Using sub base material which is excess (using1m width but 0.4m needed)

Fig 4 Removed excess material from the site

Fig 5 Sub base waste material

Fig 6 Reinforcement Wastes

Fig 7 Concrete Wastes

Appendix C

Calculation for Analytic Hierarchal Process (AHP)

Alternative	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	1.00	1.00	1.00	3.00	0.33	1.00	1.00	3.00	1.00
A2	1.00	1.00	1.00	1.00	0.33	1.00	1.00	1.00	1.00
A3	1.00	1.00	1.00	1.00	1.00	1.00	1.00	3.00	1.00
A4	0.33	1.00	1.00	1.00	3.00	1.00	1.00	1.00	1.00
A5	3.00	3.00	1.00	0.33	1.00	1.00	1.00	1.00	1.00
A6	1.00	1.00	1.00	1.00	1.00	1.00	3.00	0.33	1.00
A7	1.00	1.00	1.00	1.00	1.00	0.33	1.00	1.00	1.00
A8	0.33	1.00	0.33	1.00	1.00	3.00	1.00	1.00	1.00
A9	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Sum	9.67	11.00	8.33	10.33	9.67	10.33	11.00	12.33	9.00

Alternative	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	0.103	0.091	0.120	0.290	0.034	0.097	0.091	0.243	0.11
A2	0.103	0.091	0.120	0.097	0.034	0.097	0.091	0.081	0.11
A3	0.103	0.091	0.120	0.097	0.103	0.097	0.091	0.243	0.11
A4	0.034	0.091	0.120	0.097	0.310	0.097	0.091	0.081	0.11
A5	0.310	0.273	0.120	0.032	0.103	0.097	0.091	0.081	0.11
A6	0.103	0.091	0.120	0.097	0.103	0.097	0.273	0.027	0.11
A7	0.103	0.091	0.120	0.097	0.103	0.032	0.091	0.081	0.11
A8	0.034	0.091	0.040	0.097	0.103	0.290	0.091	0.081	0.11
A9	0.103	0.091	0.120	0.097	0.103	0.097	0.091	0.081	0.11
Sum	1	1	1	1	1	1	1	1	1

Alternative	A1	A2	A3	A4	A5	A6	A7	A8	A9	Priority
A1	0.10	0.09	0.12	0.29	0.03	0.10	0.09	0.24	0.11	0.1312
A2	0.10	0.09	0.12	0.10	0.03	0.10	0.09	0.08	0.11	0.0917
A3	0.10	0.09	0.12	0.10	0.10	0.10	0.09	0.24	0.11	0.1174
A4	0.03	0.09	0.12	0.10	0.31	0.10	0.09	0.08	0.11	0.1147
A5	0.31	0.27	0.12	0.03	0.10	0.10	0.09	0.08	0.11	0.1354
A6	0.10	0.09	0.12	0.10	0.10	0.10	0.27	0.03	0.11	0.1136
A7	0.10	0.09	0.12	0.10	0.10	0.03	0.09	0.08	0.11	0.0922
A8	0.03	0.09	0.04	0.10	0.10	0.29	0.09	0.08	0.11	0.1043
A9	0.10	0.09	0.12	0.10	0.10	0.10	0.09	0.08	0.11	0.0994
									1	

Alternative	A1	A2	A3	A4	A5	A6	A7	A8	A9	Priority	Sum	Weight
A1	0.13	0.24	0.10	0.23	0.03	0.18	0.06	0.25	0.21	0.17	1.44	8.55
A2	0.04	0.08	0.10	0.08	0.03	0.06	0.06	0.08	0.21	0.10	0.75	7.84
A3	0.13	0.08	0.10	0.08	0.03	0.06	0.06	0.25	0.07	0.08	0.86	10.48
A4	0.04	0.08	0.10	0.08	0.31	0.18	0.06	0.25	0.01	0.12	1.11	8.89
A5	0.39	0.24	0.29	0.03	0.10	0.18	0.18	0.03	0.07	0.19	1.51	8.07
A6	0.04	0.08	0.10	0.03	0.03	0.06	0.18	0.03	0.07	0.06	0.62	10.28
A7	0.13	0.08	0.10	0.08	0.03	0.02	0.06	0.02	0.07	0.05	0.59	11.59
A8	0.04	0.08	0.03	0.03	0.31	0.18	0.29	0.08	0.21	0.14	1.26	9.03
A9	0.04	0.03	0.10	0.38	0.10	0.06	0.06	0.03	0.07	0.09	0.87	9.44
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	9.00	84.18

Alternative	A1	A2	A3	A4	A5	A6	A7	A8	A9
A1	1.00	1.00	1.00	3.00	0.33	1.00	1.00	3.00	1.00
A2	1.00	1.00	1.00	1.00	0.33	1.00	1.00	1.00	1.00
A3	1.00	1.00	1.00	1.00	1.00	1.00	1.00	3.00	1.00
A4	0.33	1.00	1.00	1.00	3.00	1.00	1.00	1.00	1.00
A5	3.00	3.00	1.00	0.33	1.00	1.00	1.00	1.00	1.00
A6	1.00	1.00	1.00	1.00	1.00	1.00	3.00	0.33	1.00
A7	1.00	1.00	1.00	1.00	1.00	0.33	1.00	1.00	1.00
A8	0.33	1.00	0.33	1.00	1.00	3.00	1.00	1.00	1.00
A9	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Sum	9.67	11.00	8.33	10.33	9.67	10.33	11.00	12.33	9.00

Alternative	A1	A2	A3	A4	A5	A6	A7	A8	A9	weighted
A1	0.131	0.092	0.117	0.344	0.045	0.114	0.092	0.313	0.099	1.348
A2	0.131	0.092	0.117	0.115	0.045	0.114	0.092	0.104	0.099	0.910
A3	0.131	0.092	0.117	0.115	0.135	0.114	0.092	0.313	0.099	1.209
A4	0.044	0.092	0.117	0.115	0.406	0.114	0.092	0.104	0.099	1.183
A5	0.394	0.275	0.117	0.038	0.135	0.114	0.092	0.104	0.099	1.369
A6	0.131	0.092	0.117	0.115	0.135	0.114	0.277	0.035	0.099	1.115
A7	0.131	0.092	0.117	0.115	0.135	0.038	0.092	0.104	0.099	0.924
A8	0.044	0.092	0.039	0.115	0.135	0.341	0.092	0.104	0.099	1.061
A9	0.131	0.092	0.117	0.115	0.135	0.114	0.092	0.104	0.099	1.000

Priority	weighted s	Ratio
0.131	1.348	10.268
0.092	0.910	9.917
0.117	1.209	10.294
0.115	1.183	10.315
0.135	1.369	10.112
0.114	1.115	9.815
0.092	0.924	10.022
0.104	1.061	10.172
0.099	1.000	10.061

Avg	10.10848226
CI	0.138560283
RI	1.45
CR	0.095558816