INFLUENCE OF CONSTRUCTION MECHANIZATION ON THE QUALITY OF WORK LIFE AND THE PERFORMANCE OF CONSTRUCTION WORKERS IN KENYA

DENNIS MUMO NDOLO

DOCTOR OF PHILOSOPHY IN
CONSTRUCTION PROJECT MANAGEMENT

JOMO KENYATTA UNIVERSITY
OF
AGRICULTURE AND TECHNOLOGY

2026

Influence of Construction Mechanization on the Quality of Work Life and the Performance of Construction Workers in Kenya

Dennis Mumo Ndolo

A Thesis Submitted in Partial Fulfilment of the Requirements for the Degree of Doctor of Philosophy in Construction Project Management of the Jomo Kenyatta University of Agriculture and Technology

2026

DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

Signature……………………………………………… Date………………………….

Dennis Mumo Ndolo

This thesis has been submitted for examination with our approval as the University Supervisors.

Signature……………………………………………… Date………………………….

Prof. Stephen Diang'a, PhD

JKUAT, Kenya.

Signature……………………………………………… Date………………………….

Prof. Oswald Gwaya, PhD

JKUAT, Kenya.

DEDICATION

I dedicate this thesis to my parents Mr and Mrs John Ndolo Maungu.

ACKNOWLEDGEMENT

The accomplishment of this thesis was realized through the input and support of different organizations and individuals. First of all, I forever remain indebted to God for the gift of life, sound health, and resources to work on this thesis. Secondly, to my supervisors, Prof. Stephen Diang'a, and Prof. Oswald Gwaya, I appreciate your guidance, support, insight, and time throughout the study. I must admit that your patience with me has been outstanding. I also take this time to appreciate the valuable input received from the postgraduate committees, both at the department and school levels. The critique from the various seminars attended was key in shaping the course of this study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACRONYMS AND ABBREVIATIONS

AR:	Augmented Reality
BIM:	Building Information Modelling
CAD:	Computer-Aided Design
CVR:	Content Validity Ratio
GDP:	Gross Domestic Product
GST:	General Systems Theory
KNBS:	Kenya National Bureau of Statistics
MIAT:	Mechanization Index Assessment Tool
MIBCP:	Mechanization Index for Building Construction Projects
NACOSTI:	National Commission for Science, Technology & Innovation
OST:	Open Systems Theory
SPSS:	Statistical Package for Social Sciences
STS:	Socio-technical Systems
VR:	Virtual Reality

ABSTRACT

Mechanization in the construction sector significantly impacts both the quality of work life and the performance of workers in Kenya. This study aimed to investigate the influence of construction mechanization on the quality of work life and the performance of workers on construction sites in Kenya. The specific objectives of the study included: (i) to establish the level of quality of work life and the performance of workers on construction sites in Kenya, (ii) to establish the extent of mechanization in construction projects in Kenya, (iii) to establish the effect of mechanization on the quality of work life and the performance of construction workers on sites, and (iv) to formulate a framework for optimizing the level of mechanization and manpower in construction projects in Kenya. The theoretical foundations draw from the human capital theory, the theory of capitalism, theory of induced innovation, and the socio-technical systems theory, emphasizing the interplay between technology and human factors in construction project management. This research was guided by the philosophy of positivism. A quantitative research strategy and survey research design were adopted. Both quantitative and qualitative data were collected using questionnaires administered on construction sites. The findings revealed that labour efficiency in the studied construction projects ranged between 64.8% and 69.6%. The quality of work ranged between 59.6% and 62.8%. The overall level of the extent of training, skillset, and development among the construction workers was found to be 67.2%. The findings indicated that the qualitative aspect (effectiveness) of construction worker performance was lower than the quantitative aspect (labour efficiency) by 4 percentage points. The overall extent of fairness of compensation and reward systems, quality of working conditions, quality of health and safety, and the quality of welfare and social integration was 64.4%, 72.6%, 72.6%, and 71.0% respectively. Findings on the level of mechanization show that more than half (53%) of the activities in the building construction sector in Kenya are carried out using hand tools. None of the activities in construction are robotized. The overall mechanization level for Kenya's construction industry was found to be 47%, indicating a substantial reliance on manual methods. Correlation analysis showed no significant relationship between mechanization and labour efficiency. Regression analysis revealed three predictors with a significant relationship with construction worker performance. The study found that mechanization positively impacts the quality of working conditions for construction workers, but negatively affects compensation and rewards systems, health and safety, welfare and social integration. The study recommends that construction workers need to be regularly trained through comprehensive training programs that focus not only on new methods of construction but also on their career growth opportunities. This will help them not only improve their performance while utilizing machines but also improve their work-life in the modern construction workplace.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

The construction industry in any part of the world is an important sector of the economy in terms of its contribution to economic growth. According to Clough *et al*. (2000), any economic development is partly and significantly characterized by construction activities. Further, Giang, and Pheng (2011) state that the global construction industry contributes about 13% of the world's Gross Domestic Product (GDP) but there are significant variations between developed and developing countries. For example, in Ghana, the construction sector contributed about 13.7% of the GDP in the year 2016/17 (Ghana Statistical Service, 2017). However, in developed countries like the USA, the construction industry contributes about 4% to the GDP (Statista Research Department 2023).

According to the Kenya National Bureau of Statistics (KNBS), the level of building activities in the country is an indicator of the general economic performance due to linkages with most other sectors with corresponding demands for material and labour (KNBS, 2023). According to the economic survey of 2022/23, the construction and building industry in Kenya contributed to 5.6 percent of the Gross Domestic Product (GDP), and this illustrates the economic significance of the industry in the country's growth. During the same period, the sector's Compounded Annual Growth Rate (CAGR) increased by 13.8% from USD 3.1 billion in 2015 to USD 5.2 billion (KNBS, 2023). This is mostly depicted in large-scale building and construction projects including roads, dams, stadia, and government housing projects among others. Notably, all these projects are characterized by heavy dependence on mechanization, and therefore, it is logical to consider including mechanization as a function of the fraction of GDP contributed by the construction industry.

Mechanization in a broad sense is the process of adopting the use of machines in carrying out tasks that would otherwise be done by manual labour (Hwang et al., 2020). From this perspective, mechanization can be understood as the process of substitution or complementing human labour with machines to make work easier. Mechanization thus implies a complete or partial replacement of human labour with machines that could either be automated, or operated by just one or a few experts. Where the machine is automatic, a computerized system is used to instruct the machine on which operation to undertake (Vadukkumchery & Myneni, 2023).

While the level of mechanization depends on the extent to which machines have been incorporated to replace human labour, automation is a dimension of mechanization which means the total replacement of human labour with machines that use Artificial Intelligence (AI) to perform an activity (Kamaruddin et al., 2016). Automated machines work but under the instruction of a programme that controls the behaviours of the machines. Understandably therefore, mechanization can be applied at the design level, and in actual construction processes such as digging trenches, earth moving, paving, lifting, and hoisting, bar cutting machines, bar straightening machines, concrete making machines, core drill, plastering and painting and 3D printing (Calvetti et al., 2020). Computer-aided design (CAD) for instance, has contributed to a digital way of operation. CAD is software used by engineers, architects, and project managers who create drawings of not only the plans but also all aspects of a building or civil engineering work. There are many other Artificial Intelligence (AI) technologies used by Engineers and Architects in different countries to facilitate the planning process. To architects, CAD has become extremely important in the design process and because it allows for design, planning, costing with 2-D 3-D, 4D and 5B models in a very efficient way (Calvetti et al., 2020).

Mechanization has created a paradigm shift that has changed the way managers handle construction projects. Managers in the construction sector have had to contend with the realities that mechanization comes with. Among the realities include costs and skills management. None of the realities are insignificant if any success in the industry is anything to take into account (Kamaruddin et al., 2016). Managers have therefore had to adopt a paradigm shift on how to manage and deliver construction works. Mechanization comes with heavy capital demand which must be met. It is critical to note that some civil construction works as well as commercial and building construction works cannot succeed without the use of machines. Hoisting and lifting heavy materials like steel and pre-cast concrete can only succeed with the use of cranes and hydraulic lift machines (Calvetti et al., 2021). Therefore, the cost of mechanization is something that managers must face. Managers have to carry out informed cost-benefit analysis between purchasing or renting the machines needed. According to Zhadanovsky and Sinenko (2018), while conducting the analysis other aspects such as maintenance, and depreciation costs have to be factored in so that a more informed decision is made. A Construction Project Manager is thus compelled to carry out comprehensive analyses because the project in question relies on mechanization.

Besides management's indulgence with cost-benefit analysis induced by the need of mechanization, managers have equally to contend with skills and experiences of handling and maintaining the machines. Various machines used in the mechanization process require different skills and experiences to operate and maintain (Iheama et al., 2017). The manager therefore needs to adopt best practice standards such as strategic workforce planning. The emergence and adoption of mechanization in construction has sealed the need for strategic workforce planning to ensure that there are seamless operations while at the same time balancing and managing the workforce not only in terms of the numbers but also capacity building them for better delivery of mechanized construction processes (Grover & Solanki, 2023).

Strategic workforce planning involves a scenario-based approach that promotes sustainability. Mechanization forces managers to take a long-term view of workforce demand, for example, skills requirements in the mechanization space or the need for local market experts, but also expected productivity gains through technological advances. Additionally, the managers must simulate the supply of workforce accordingly based on existing staff profiles; consider, for example, shifts in age profiles and capacity losses through attrition. Furthermore, managers have to identify gaps and risks and devise, on that basis, an executable workforce plan, including mitigation measures to address any over- or under-supply of staff and any skills gaps. Managers can achieve this through recruiting, training, transfers, in-/outsourcing or lay-offs, and enhanced retention (Sharmila et al., 2018). These scenarios point to the fact that adoption mechanization means that Construction Project Managers have to go an extra mile. It is therefore the interest of this study to establish the effects of mechanization on the management of construction.

Although the construction industry creates labour market, the adoption of mechanization introduced a dilemma of labour displacement. Increased mechanization often causes job displacement because machines and automation can perform tasks that were previously done by human workers. Certain manual and repetitive jobs, such as bricklaying, excavation, or material handling, can easily be taken over by machines, resulting in fewer job opportunities for workers in those specific areas (De Stefano, 2019). Additionally, while some construction processes may be taken over by machines, the adoption of machines would require that construction workers acquire new sets of skills. As construction processes become more mechanized, the workers are compelled to have the skills to operate and maintain the machines. This could create a shift in the labour market, requiring workers to acquire new technical skills and adapt to changing job requirements. The situation necessitates additional expenditure on training either at an individual level or corporate level (Iheama et al., 2017).

The Malaysian economy, for example, has been a fast-growing and industrialized economy since the 1980s. In the last decade, the Malaysian construction industry has contributed heavily towards the growing national economy. Through its value addition to the national GDP, it has had a positive impact on the development of social-economic infrastructures thereby accounting for approximately 4.6% of the country’s GDP in 2011 (Fu et al., 2022). According to Razi et al. (2024), the construction industry which contributes around 4.5% of the country’s GDP is a great employer providing job opportunities to both local and foreign labour force accounting for more than 6 percent of the country’s workforce. Kamaruddin et al. (2018) however note that, in Malaysia, it is extremely hard for local companies to compete for opportunities with foreign competitors particularly from developed countries because more and more construction processes are becoming highly mechanized. Mechanization requires a substantial and sustainable budget, allocated time for training of labour to gain new skills and expertise in working with plants and machinery, and occupational safety. The heavily mechanized approach in the construction industry disadvantages a substantial number of the workforce. Among the issues that are perceived negatively by the workforce include their displacement by machines which renders them jobless, increased occupational hazards, and health concerns due to exposure to too much noise, dust, and emissions (Calvetti et al., 2021). Consequently, in Malaysia, workers felt their worklife and welfare were compromised by the adoption of mechanization without a framework for optimizing the relationship between mechanization and construction manpower.

In India, Sharmila et al. (2018) studied the utilization and implication of mechanization and noted that mechanization is least adopted in masonry and plastering while most utilized in excavation, reinforcement cutting, lifting and hoisting, concrete transportation, concrete batching, and mixing. The study observed that mechanization was adopted in 8.91% of the transportation of concrete, 3.60% of masonry in construction, 3.47% of plastering using wall plastering machine, spraying machine, 8.51%, of concrete batching and mixing, mechanized excavation 8.42%, mechanized reinforcement cutting 8.38% and system formwork usage comes up to 7.19%. Overall, the authors noted that mechanization was utilized in every type of project in India. Due to the adoption of mechanization, there was a significant rise in productivity. However, the use of new machines did not automatically lead to more effective and efficient construction processes and building expertise and management. On the contrary, Zhang et al. (2016) noted that mechanization can worsen the occupational health and safety performance of the industry when it is not effectively managed. Additionally, mechanization meant a surge in air and noise pollution, and construction workers were the most affected. That notwithstanding, the authors acknowledged that mechanization made construction work more efficient, thus leading to cost and time-saving in the long run. Additionally, they noted that social parameters such as increased training and skill requirements is a necessity created by mechanization and it has caused an increase in equipment manufacturing and service. In other words, the adoption of plant, equipment, and machinery in construction implies that the labourers involved must be trained on how to efficiently and effectively operate them.

The Kenyan construction industry has heavily been characterized by increased investment in infrastructure development by both the government and private entities.

These construction activities have seen an increase in the use of machinery in the following areas, earth moving and surface clearing, laser screeding, paving, plastering, steel cutting, rebar straightening, concrete making machines, core drilling, and arial platform work lifting machine (Bommet et al., 2020). In some cases, it is appreciable that the construction work could only succeed with mechanization but in other cases, the replacement of manual labour with machines is perhaps questionable.

1.2 Statement of the Problem

The construction sector in Kenya is central to national development, yet it continues to struggle with low productivity, uneven worker welfare, and limited technological adoption. While global construction industries increasingly embrace advanced mechanization, Kenya's sector remains heavily reliant on manual labour. Mechanization presents both opportunities and challenges for construction workers. On one hand, it improves working conditions by reducing physical strain and enhancing task execution. On the other hand, it negatively affects compensation systems, health and safety, welfare, and social integration. Labour efficiency averages between 65–70%, yet qualitative aspects of performance—such as effectiveness and work quality—consistently lag behind (Kuruga, 2017). These contradictions reveal that mechanization, as currently applied, does not deliver balanced improvements in worker performance or quality of work life. The construction sector lacks a coherent framework to integrate mechanization with manpower development (Hughes & Ferrett, 2012; Mučenski et al., 2018).

Kenya's construction industry faces a structural imbalance: mechanization is introduced to boost productivity, but its integration neglects the socio-technical systems that sustain worker well-being. The absence of an evidence-based strategy to balance mechanization with workforce training, fair compensation, and improved welfare systems undermines both project outcomes and long-term sectoral sustainability (Vishwakarma et al., 2022; Kamaruddin et al., 2018; Sharmila et al., 2018; Grover & Solanki, 2023; Iheama et al., 2017; Calvetti et al., 2021; Kamaruddin et al., 2016; Vadukkumchery & Myneni, 2023). Addressing this gap is critical for aligning the industry with national development agendas such as Vision 2030, the

Sustainable Development Goals, and Agenda 2063, while ensuring resilience, competitiveness, and inclusive growth.

1.3 Aim of the Study

The aim of this study was to establish a framework that can be adopted to optimize the harmony between mechanization and construction manpower.

1.4 Objectives of the Study

1.4.1 Main Objective

The main objective of the study was to investigate the influence of construction mechanization on the quality of work life and the performance of workers on construction sites in Kenya.

1.4.2 Specific Objectives

The specific objectives of the study were: -

1. To establish the level of quality of work life and the performance of workers on construction sites in Kenya.
2. To establish the extent of mechanization in building projects in Kenya.
3. To establish the effect of mechanization on the quality of work life and the performance of construction workers on sites.
4. To formulate a framework for optimizing the level of mechanization and manpower in construction projects in Kenya.

1.5 Research Hypothesis

The study hypothesized a statistically significant relationship between the two dependent variables (i.e., quality of work life and performance of construction workers) and the level of mechanization on construction projects in Kenya.

This hypothesis was tested using the multiple regression model outlined below;

$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \varepsilon$

Where:

Y_i= the i^{th} dependent variable. This study has two dependent variables as follows;

- Y_1= Quality of Work Life (QWL), measured using four proxies namely; Fairness of Compensation and Reward Systems (CRS), Quality of Working Conditions (WC), Quality of Health and Safety (HS), Quality of Welfare and Social Integration (WSI). These proxies were also further broken down into individual indicators during data collection and analysis.
- Y_2= Performance of Construction Workers (PCWs); this has been measured using two proxies namely; Labour Efficiency (LE), and Effectiveness (EF). These proxies were further broken down into individual indicators during data collection and analysis.

B_0 = Constant.

X_i = Extent of Mechanization of various construction elements as follows;

- X_1 = Site Preparation and Earthworks (M_{SPE})
- X_2 = Scaffolding and Formwork (M_{SF})
- X_3 = Concreting (M_C)
- X_4 = Walling (M_W)
- X_5 = Plastering and Flooring (M_{PF})
- X_6 = Tiling and Painting (M_{TP})
- X_7 = Building Services (M_{BS})

Therefore,

$QWL = \beta_0 + \beta_1.M_{SPE} + \beta_2.M_{SF} + \beta_3.M_C + \beta_4.M_W + \beta_5.M_{PF} + \beta_6.M_{TP} + \beta_7.M_{BS} + \varepsilon$

$PCW = \beta_0 + \beta_1.M_{SPE} + \beta_2.M_{SF} + \beta_3.M_C + \beta_4.M_W + \beta_5.M_{PF} + \beta_6.M_{TP} + \beta_7.M_{BS} + \varepsilon$

Null Hypothesis (H_0): $\beta_i = 0$ for all relationship coefficients of X_i. This means that mechanization does not affect the quality of work life and the performance of construction workers in Kenya.

Alternate Hypothesis (H_1): $\beta_i \neq 0$ for at least one of the relationship coefficients of X_i. This implies that at least one of the explanatory variables affects the quality of work life and the performance of construction workers in Kenya.

1.6 Justification of the Study

There is a lot of drastic development in the construction industry, not only worldwide, but also in Kenya. Economically, the construction industry is one of the chief contributors to the GDP of any given country. Coupled with the technological advancement of mechanization, and automation, it is projected that the productivity of the industry can get better. However, mechanization and automation could have varied impacts on the quality of life of construction workers, their effectiveness, and productivity. The use of machines in construction has been associated with increased unemployment, environmental degradation, and negative health effects on workers among other effects. However, mechanization has its benefits. When it comes to large volumes of work, machines have been reported to be more efficient and sometimes more effective. This leads to clients and contractors opting for machines instead of men. Therefore, there is a good case for both in a construction project. The findings of this study could help various stakeholders in establishing a trade-off between optimizing the level of construction mechanization and the use of labour force in construction projects.

1.7 Significance of the Study

Given the current rapid advancement in technology, this research is timely. This is because mechanization is expected to grow with the advances in technology. The study comes when the country is facing a surge in the construction industry activities as seen in mega projects being undertaken in both the private and public sectors. Kenya as a country has many projects. On the other hand, the government is continuously launching huge projects in terms of scope which attracts more mechanization. Further, foreign contractors from developed countries have continued to win big tenders thereby bringing new technologies and advanced equipment to the construction industry of Kenya. It is however notable that the mechanization disrupts construction workplace with a direct influence on construction workers' work life and welfare. This study is critical in optimizing the harmony between mechanization and construction manpower. To achieve this, the study develops a framework that is currently lacking in theory and practice.

1.8 Scope of the Study

The study was based in Kenya, and limited to the construction industry with regard to its mechanization. It therefore targeted construction workers as represented by accredited construction site supervisors. The study sought to understand the relationship between the mechanization of construction projects and processes and their influence on construction workers' performance and work life.

1.8.1 Geographical Scope

This study was based on the construction industry in Kenya and focused on building projects registered by the National Construction Authority in Nairobi County. Nairobi is the capital of Kenya and the regional economic powerhouse. It continues to experience growth both demographically and economically. At any given time, the county has the largest number of registered projects, and hence the findings were representative of all the construction projects in Kenya. The study targeted high-rise buildings worth above 100million. This is because the extent of mechanization in smaller construction projects may be comparatively low and therefore should be studied separately. Highrise buildings were selected to ensure data was collected for all the seven work categories i.e. Site Preparation and Earthworks, Scaffolding and Formwork, Concreting, Walling, Plastering and Flooring, Tiling and Painting, and Building Services.

1.8.2 Theoretical Scope

The study was based on four main theories which provide the theoretical underpinning. These include the socio-technical systems theory, human capital theory, theory of induced innovation, and the theory of capitalism. While the capitalism theory argues that market players such as contractors and developers are free to select any method of construction including the use of human labour and/or machines, the socio-technical systems theory recognizes the valuable input of these two resources and advocates for joint optimization in a bid to ensure project success. These theories provide key concepts such as human behaviour, worker performance, relationships, control, maintenance functions, human capital, innovation, interactions, effectiveness, self-interest, and market mechanisms among others. It is based on these concepts that the study's constructs and variables were formulated.

The study comprised two dependent variables namely the Performance of Construction Workers (PCW) and the Quality of Work Life of construction workers (QWL). The former was conceptualized both quantitatively (labour efficiency) and qualitatively (effectiveness of construction workers) while the latter was broken down into four constructs namely Fairness of Compensation and Reward Systems (CRS), Quality of Working Conditions (WC), Quality of Health and Safety (HS), Quality of Welfare and Social Integration (WSI). Construction mechanization was conceptualized in a multidimensional approach based on the following work elements; Site Preparation and Earthworks (M_{SPE}), Scaffolding and Formwork (M_{SF}), Concreting (M_C), Walling (M_W), Plastering and Flooring (M_{PF}), Tiling and Painting (M_{TP}), and Building Services (M_{BS}).

1.8.3 Methodological Scope

This research was deductive in nature and therefore used a quantitative research approach. The research design adopted was survey research. The data collection method utilized the use of questionnaires. The research focused on the construction projects in which a whole calendar year had passed since they were registered on the NCA portal. The aim was to find projects that were at least more than 50% complete to have a minimal number of missing values. The research focused on building projects with a contract sum of at least KShs. 100 million. This means that the findings may not apply to smaller construction projects, which tend to have a very low level of mechanization. Additionally, the research focused on mechanization during the construction phase. The preconstruction phase, which includes the project design and planning, was not considered in this study. The main reason for this was that this phase is almost completely mechanized, and due to the possibility of skewness of results, this phase needs to be studied separately. Methods of analyzing data included descriptive statistics, correlations, and multiple regression. These were selected due to their ability to bring out generalizations, which was a key element of this research.

To introduce a section on the non-statistical assumptions of the study, you can utilize the following text. This section highlights the foundational premises regarding the participants, the industry context, and the theoretical application that underpin the research.

1.9 Assumptions of the Study

The study was built upon several key assumptions that provided the necessary context for the investigation into construction mechanization in Kenya:

- **Reliability of participant experience:** it was assumed that the sampled professionals (Site Managers, Site Agents, and Clerks of Works) possessed sufficient expertise and professional experience to provide accurate data on project performance and mechanization levels.
- **Sectoral representativeness:** the study assumed that building projects with a contract sum of at least KShs. 100 million were representative of the larger mechanized construction landscape in Kenya, where such investments are more likely to involve machine-intensive processes.
- **Standardization of work categories:** it was assumed that the seven modified work categories (e.g., Concreting, Walling, and Building Services) were comprehensive enough to capture the overall level of mechanization across diverse construction sites.

- **Stability of the socio-technical environment:** under the Socio-Technical Systems (STS) theory, it was assumed that the interrelation between the social subsystem (workers) and the technical subsystem (machines) remains constant enough during the construction phase to allow for measurable impacts on the Quality of Work Life (QWL).
- **Applicability of macroeconomic linkages:** the research assumed that mechanization could be treated as a functional component of the construction industry's contribution to Kenya's GDP, following the logic that large-scale infrastructure and building projects are inherently tied to mechanical advancement.
- **Rationality in resource selection:** it was assumed that contractors and developers operate within a capitalist market where they make rational choices between human labour and machinery based on perceived project needs and economic benefits.

1.10 Limitations of the Study

The main limitation associated with this study is that the findings only apply to commercial buildings. The selection of these buildings was mainly because they have a moderate (average) usage of equipment and machinery. Residential projects have a low level of equipment usage while industrial and heavy construction projects require intense and high utilization of machinery for carrying out site works and many other special activities. Further, since commercial projects tend to be high-rise, the majority of construction activities including scaffolding are present. Therefore, the findings may not be applicable to other types of building projects. Additionally, the findings of this study do not apply to other types of construction projects such as civil engineering infrastructure.

Additionally, the cross-sectional nature of the study may not adequately capture the dynamic changes over time associated with construction mechanization. Longitudinal studies could provide deeper insights into how mechanization impacts worker performance and QWL over extended periods of time.

1.11 Outline of the Study

The study comprises five chapters organized in chronological order. The first chapter captures the background information about the economic and managerial effects of the mechanization of the construction industry from various parts of the world, organized in such a way that it begins at the global level, the continental level, and finally the national level. Also captured in chapter one includes a statement of the problem, the purpose of the study, objectives of the study, the research hypothesis, research questions, justification of the study, the significance of the study, and finally, the scope and limitations of the research.

The second chapter presents a review of the literature on the topic of mechanization and the managerial and economic effects it has. The chapter, therefore, captures the theoretical reviews in which various theories are explored in terms of their relevance to the study, empirical reviews, and the research gap being addressed by this study. Finally, the hypothesized relationships among the study variables are demonstrated in the conceptual framework.

Chapter three discusses the research methodology used to achieve the objectives of the study and thus answer the research questions. It therefore defines the research philosophy, research strategy, research design, study population, sample size, and sampling techniques. Additionally, the chapter describes the data needs, how data was collected, how validity and reliability were determined, and finally how the data collected was processed and analyzed.

The fourth chapter presents the results of the study, their corresponding analysis, and discussions. Lastly, chapter five summarizes the research findings, draws conclusions, and makes recommendations based on the findings of the study. The study's theoretical and practical implications are also presented in this chapter. The chapter concludes by discussing the study's contribution to knowledge and pointing out possible areas for further research.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter provides both an empirical and a theoretical review of relevant literature. It starts by discussing the concepts of quality of work life and the performance of construction workers. Some of the pertinent issues discussed under quality of work life include compensation and reward systems, working conditions, health and safety, and welfare and social integration. The performance of construction workers is presented in two ways, quantitatively and qualitatively. Labour efficiency and effectiveness highlight the former and the latter, respectively. The empirical review goes on to highlight the concept of construction mechanization and how it can be evaluated. In the theoretical review section, different theories are discussed, and a theoretical framework is presented. The chapter concludes by discussing the research gap and presenting the conceptual framework.

2.2 Concept of Quality of Work Life (QWL)

Throughout history, man has always looked for ways to make tasks easier and improve his well-being. However, it was not until the 18^{th} century that the scientific study of work conditions and their impact on productivity and worker morale began. This was when concepts such as task division, systematic production methods, specialized steps, centralized production, use of specialized tools and equipment, and quality control were introduced (Camarini et al., 2020). Thus, there was a major shift in industrial processes and technological advancements. On the other hand, workers' basic needs were disregarded as they endured poor living conditions, inadequate remuneration, and workdays lasting up to 18 hours (Sinval et al., 2020).

Though previous studies and experiments had explored human behaviour and needs at the workplace, the expression "*Quality of Work Life*" appeared in the early 1950s in England during which research on the work organization was developed based on the socio-technical approach which takes into account social relations in the workplace, work conditions, worker satisfaction, and technological requirements (Camarini et al., 2020). However, according to Shanmugam and Ganapathi (2017), the concept of QWL was born in the 1960s and since then, the idea has increasingly become more significant in almost all economic sectors (Jayaraman et al., 2023). According to Walton (1973), who was a major contributor during the early years, QWL refers to the human and environmental values that industries neglect in favour of technological development, productivity, and economic growth. Jerome (2013) describes QWL as a process through which organizations respond to employees' needs by developing mechanisms to include them in the decision-making process of issues that affect their lives at work. It has been defined by Vetrimani and Maheswari (2014) as the quality of the relationship between workers and the total working environment. According to Ganapathi (2016), QWL is a philosophical approach that holds people to be the most significant resource in an organization, as they are reliable, responsible, and make valuable contributions, and therefore should be treated with dignity and respect. It is therefore clear from these definitions that QWL is generally the extent of favourableness of a job environment for people. It is all about enhancing the human dimensions at the workplace by introducing inclusive problem-solving, work restructuring, improving the work environment, and introducing innovative reward systems.

QWL can be conceived as a set of methods, such as job enrichment, autonomous work groups, and high worker involvement, aimed at boosting both the productivity and satisfaction of workers (Soundarya & Anandh, 2024). It requires the commitment of workers to the organization and a working environment in which this commitment can prosper. Therefore, QWL could be seen as a comprehensive construct that not only includes an individual's job-related well-being but also the extent to which the job experience is fulfilling, rewarding, and free of stress and other negative consequences.

QWL is a highly significant issue in almost all industries. The success of any industrial sector is not just dependent on the adoption of contemporary methods; it also requires having quality workers. The concept of QWL is primarily focused on the influence of employment on the health and welfare of workers. Nowadays, every industry seeks to provide enhanced working conditions for its employees, both financially and nonfinancially. Their main aim is to retain employees for longer working durations and achieve the organization's goals. There is also an understanding that workers perform their jobs better when they are permitted to contribute to managing and being involved in the decision-making process in their work.

The working conditions of construction workers in developing countries have been termed as subpar. Shanmugam and Ganapathi (2017) argues that though the construction industry in developing countries continues to grow in leaps and bounds, the working conditions of construction workers have not drastically improved. Further, according to Samuel et al. (2022), the industry faces a number of challenges, including high levels of accidents and health problems, and it is one of the most hazardous sectors. Ganapathi (2016) pointed out that construction workers in developing countries remain the most exploited.

During the 1960's and the early 1970's, great progress was made in QWL studies due to the increased awareness of workers' and companies' social responsibility, resulting in them focusing their efforts on internal research on the organization and different ways to accomplish the work. During those early years of the development of the idea of QWL, Walton (1973) established a model for analyzing organizational experiments based on contributions from human development theories such as Maslow's Hierarchy of Needs theory. The model introduced eight conceptual categories together with their respective criteria relating to aspects of physical and mental health, social development, and integration, as shown in Table 2.1.

Table 2.1: Conceptual Categories for Analyzing Organizational Experiments

No.	Category	Criteria
1	Fair and adequate compensation	Internal and external equity, fair compensation, sharing productivity earnings, and proportionality of salaries
2	Safe and healthy working conditions	reasonable working times, safe and healthy physical environment, and absence of insalubrity
3	The opportunity to use and develop human capabilities	autonomy, relative self-control, multiple qualities, information on the whole work process
4	Opportunity for continued growth and employment assurance	possibility of career, personal growth, perspective of advancing wages and job security
5	Social integration into the organization	equality, mobility, relationship, sense of community and absence of prejudices
6	Constitutionalism in the organization	rights of worker protection, personal privacy, freedom of speech, fair treatment, and labour rights
7	Work and the total space in an individual's life	balanced role at work, stability of schedules, few geographical changes and time for leisure activities with the family
8	Social relevance of work	image of the company, corporate social responsibility, liability for products and employment practices

Source: Modified from Camarini et al. (2020)

Over the years, QWL, which was previously understood as a simple reaction to work, evolved to a new way of enhancing the work environment, of increasing productivity and worker satisfaction. Sirgy (2001) proposed that QWL involves the satisfaction of workers' basic (lower-order) and growth (higher-order) needs based on Maslow's framework. The basic needs include health and safety needs, such as protection from injury and job-related health benefits, and economic and family needs, such as adequate compensation, job security, and work-life balance. On the other hand, higher-order needs include social needs such as leisure time and social interactions at work, esteem needs such as recognition of job performance, actualization needs such as the realization of one's potential within the organization and work field, knowledge needs such as learning for continuous professional development, and aesthetic needs such as creativity at work. Further, current studies on QWL emphasize, mainly, the worker's well-being and satisfaction, valuing workers' participation in the decision-making process, and the humanistic perspective of thinking about people, work, and organization. Koonmee et al. (2010) suggested that company rules and standards that govern workers' conduct, such as incentive systems, corporate culture, promotion policies, valued behaviours, and management behaviour are some of the factors that determine QWL. It is true that, currently, companies need to be increasingly competitive and, therefore, to care about the people, as it is through their commitment to the organization's proposals that the results will be achieved successfully (Tolfo & Piccinini, 2011). The most important aspects of work life for construction workers are working conditions and environment, compensation, professional growth, and social integration (Shanmugam & Ganapathi, 2017). According to Ganapathi (2016), factors that are relevant to workers' QWL include the physical work environment, the task, the administrative system, the social environment within the organization, and the work-life balance. The author further states that QWL consists of the opportunities for active employee involvement in problem-solving or group work arrangements that are of mutual benefit to both the workers and their employers, based on a labour-management cooperation.

Some of the published instruments designed to measure QWL over the years include: the Quality of Work Life Questionnaire (Elizur & Shye, 1990), the Quality of Work Life Scale (QWLS) (Sirgy, 2001), the Quality of Work Life Measure (Zin, 2004), Quality of Working Life Systemic Inventory (Martel & Dupuis, 2006), Nurses' Quality of Working Life Questionnaire (Hsu, 2016), and the Work-Related Quality of Life Scale (Easton & Van Laar, 2018). After careful analysis of these published tools, the researcher broke down the concept of QWL into four constructs namely; compensation and reward, working conditions, health and safety, and welfare and social integration. These have been discussed in the following sections.

2.2.1 Compensation and Reward Systems

Salary and wages are output of the input of labour for their effort and work. This not only includes the physical but also the mental work done by employees (Yadav et al., 2019). Salaries and wages are known as remuneration and cover all the amenities offered by the employer, such as holidays, paid vacations, and sick leave, as well as other fringe benefits. According to Vetrimani and Maheswari (2014), QWL is associated with job satisfaction, which in turn is linked to wages, working conditions, and working hours. Swathi (2017) lists the basic elements of a good QWL as impartial wages, a safe workplace, and equal opportunities for career advancement. It is clear from these discussions that remuneration is a recurring factor in the QWL discussion. Further, many authors have also explained the importance of remuneration as a key dimension of QWL (Royuela et al., 2008; Sharma et al., 1970; Sinval et al., 2020; Sirgy, 2001; Swathi, 2017; Vetrimani & Maheswari, 2014; Yadav et al., 2019). According to Shanmugam and Ganapathi (2017) salary and remuneration affects employee's work satisfaction and performance. Workers seek to achieve secure jobs with justified salaries, which makes them feel relaxed at the workplace (Samuel et al., 2022). According to Janmohammadi et al. (2015), there should be an equitable balance between effort and reward. The pay should be able to help the worker maintain a socially desirable standard of living and should also be comparable to the reward and compensation for similar work elsewhere. Some of the factors considered for determining such compensation are the ability of the employer to pay, cost of living, labour productivity, demand and supply of labour, and job evaluation, among others (Yadav et al., 2019).

2.2.2 Working Conditions

The working conditions in any workplace determine the job satisfaction of employees, which in turn affects not only their productivity but also their overall performance. Issues such as opportunities to use and develop human capacities, continued growth, job security, merit-based promotions, involvement in decision-making, and open communication, among others, need to be considered in the workplace (Vetrimani & Maheswari, 2014). The job should contain a sufficient variety of tasks to not only provide a challenge but also to ensure the utilization of talents. In the modern day, work has become repetitive and mechanical, such that the worker has little control over it (Vishwakarma et al., 2022). The work should therefore provide opportunities for the career development of new abilities and the growth of existing skills continuously. Seniority should be considered during the promotion of employees, and merit should be used for the advancement of managerial personnel (Yadav et al., 2019). This means that the promotion policy should be fair and just. Further, communication should be two-way. This means that as employers give orders, employees should also be allowed to present their grievances and suggestions. This participatory approach helps organizations to grow at a fast pace (Zhu et al., 2024). Participation has been widely recognized as a means of improving the quality of work life and increasing the workers' productivity (Bamfo-Agyei et al., 2022b). In theory, participation releases creative energy and provides workers with a sense of accomplishment (Camarini et al., 2020).

2.2.3 Health and Safety

Construction activities tend to be labour intensive. Due to the critical negative impacts, such as safety accidents, injuries, and fatalities, safety in construction sites is crucial to the sustainable development of the construction industry (Zhu et al., 2024). Most construction workers are at risk, with a considerable number of fatalities reportedly caused by falls (Workplace Health and Safety Queensland, 2023). The high incident and accident rates in the construction industry have brought detrimental effects not only on construction companies but also on the entire industry, including losses in productivity and financial consequences (Hasan et al., 2018).

The quality of work life cannot be considered adequate unless the work environment is free from all hazards that may be detrimental to the health and safety of workers. Some of the main elements of a good physical environment for work include reasonable hours of work, a pollution-free atmosphere, cleanliness, and risk-free work, among others (Sinval et al., 2020). Working conditions that are unsafe cause problems for both the organization and employees (Liu et al., 2025). There may be little advantage to the employer in the short term, but in the medium and long-terms, it adversely affects the productivity within the organization (Swathi, 2017). Therefore, adequate investment should be made to ensure the working conditions are both safe and healthy for employees.

2.2.4 Welfare and Social Integration

It is crucial for workers to feel a sense of identity with the organization and develop a feeling of self-esteem, trust, openness, the scope for upward mobility, a sense of community feeling, and equitable treatment (Camarini et al., 2020). The concept of constitutionalism in the workplace is very important. It is related to organizational norms that influence the freedom of employees. Efforts should be made to ensure the right norms are implemented at the workplace. Such should be able to accommodate the privacy of individual workers, equity, freedom of speech, and dissent on some aspects (Easton & Van Laar, 2018). QWL provides constitutional protection to the employees, such that management can be challenged in times when it attempts to exploit the workers. Further, there should be a proper balance between work life and workers' personal lives. The demands of work, such as frequent travel, late hours, and quick transfers, are not only psychologically but also socially very costly and detrimental to the quality of work life of employees (Faatih Suwandi & Tentama, 2020).

Work should not only be a source of material and psychological satisfaction but also a means of social welfare. An organisation that has greater concern for social causes like pollution, national integration, consumer protection, and employment, among other issues, can improve the quality of work life (Hsu, 2016). When organizations allow their employees to raise work grievances and represent their problems, employees feel more confident and secure, as they are cared for by management as part of a family (Jerome, 2013). According to Swathi (2017), relationships between and among the workers are an important indicator of a healthy work organization. Therefore, opportunities should be provided to enhance both formal and informal interactions. It is critical that all kind of religions, classes, crafts, races, and designations be treated equally.

2.3 Performance of Construction Workers

Labor is essential in any construction firm and is estimated to represent one-third of the total direct capital expenditure of construction projects. It integrates the requisite resources from other projects essential for the production process of completed construction projects, hence its efficacy significantly influences the success or failure of these projects. The construction industry, being labour-intensive, might be asserted that the workforce is the principal productive resource (Ghate et al., 2016). Labour is the most crucial asset for a construction company since it directly influences construction productivity and the quality of the project fundamentally depends on the calibre of work performed by the labour force (Jagtap & Tidke, 2019). According to Bamfo-Agyei et al. (2022a), given that most construction projects require a substantial amount of labour, the issue of labour productivity assumes major importance as higher productivity levels typically result in increased profitability and competitiveness. The performance of workers should be considered from both quantitative and qualitative angles. The former has been discussed in this research as labour efficiency while the latter has been discussed under labour effectiveness.

2.3.1 Labour Productivity and Efficiency

Many terms are used in various contexts to describe productivity in the construction industry: production rate, performance factor, unit person-hour (p-h) rate, among others. Productivity is the ratio of the quantity of output to the quantity of input. It is an important aspect of the construction industry that can be used as an index for measuring production efficiency (Bamfo-Agyei et al., 2019). Productivity in construction is assessed at various levels of detail to serve different objectives. Productivity measurements at either the company or project level serve as benchmarks for comparing against established norms within the company or the construction project (Nguyen et al., 2021). Productivity is assessed at the level of individual activities to provide a thorough estimation and project schedule. Construction is typically characterized by a high demand for labour, hence productivity at the activity level is sometimes referred to as labour productivity. This measures the input in terms of hours worked and the output in terms of the monetary worth of the job accomplished (Nurhendi et al., 2022). As shown in Figure 2.1, construction labour productivity is considered a reliable measure of construction industry activities (Bamfo-Agyei et al., 2019). It is a crucial element of the construction sector that may be utilized as a metric for evaluating production efficiency. As a result, it can also be used to gauge the level of economic growth and production from industrial and business viewpoints.

According to (Adebowale & Agumba, 2023), the construction industry has experienced a persistent loss in labour productivity compared to other industries worldwide over the course of several decades.

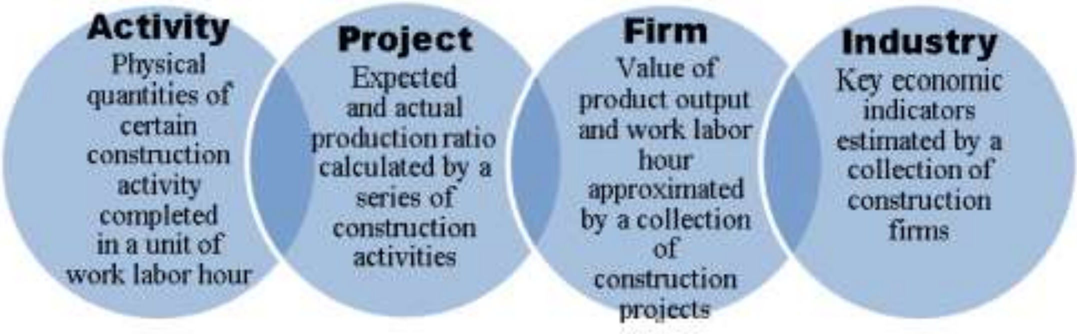

Figure 2.1: Measurements of Construction Labour Productivity

Source: (Bamfo-Agyei et al., 2019)

There is no universally agreed method of measuring labour productivity. The following variations have been suggested by different authors (Bartoschek & Kirchev, 2021; Chia et al., 2018; Thomas & Sudhakumar, 2013).

$$Labour\ Productivity = \frac{Output}{Labor\ cost} = \frac{Output}{Workhours} = \frac{Labor\ costs}{Output} = \frac{Workhours}{Output} = \frac{Output}{Available\ time}$$

Equation 2.1: Measuring Labour Productivity

Source: (Shehata & El-Gohary, 2011)

Work measurement is essential for organizing and controlling the activities of an enterprise that involve the element of time. Measurement is essential before engaging in any managerial activity. It is important to acknowledge that an inaccurate assessment of labour efficiency can result in misguided and skewed decisions made by the management team. Hence, the significance of accurately assessing the appropriate level of production at the appropriate moment in order to accurately represent the actual state of a company cannot be overstated. The measurements should provide the management with a chance to make effective and precise judgments

(Bamfo-Agyei et al., 2022b). It is necessary to investigate the many methods of providing information in order to determine the most appropriate measurement methodology for the current circumstances. Some of these methodologies include work sampling, time studies, subjective evaluations, and personal recording of activities (Grund & Przemeck, 2012). Utilizing technological advancements facilitates the effective acquisition of precise results. Bamfo-Agyei et al. (2022) point out that there are two methods of measuring labour productivity namely, task-measuring technique and activity-measuring technique.

a) Task-measuring technique

According to Autor and Handel (2013), tasks can be defined as distinct output-generating units. In the task framework, human labour is more important than machine input in manufacturing. Human labour has traditionally been preferred above machine input due to its flexibility and adaptability (Autor & Handel, 2013). The task framework adds site elements to the delay and activity frameworks (Agrawal & Baruah, 2018). Site factors recognize that during building, some acts are vital, some are supplemental yet essential, and some are useless. Time use, productivity, and leisure time were combined to create site variables. Fernández-Macías and Bisello (2022) suggest that using continuous variables with different and perhaps overlapping scores allows for a more detailed analysis of workload distribution across occupations. This method also helps identify task bundles that combine and cluster tasks. Quantifying many site factors allows this approach to evaluate performance discrepancies on a building site. Despite various studies and recommendations, tiredness recovery and other goals are mostly subjective and based on individual assessment. When subjectivity is likely to greatly impact study results, choose less subjective methods.

b) Activity-measuring technique

These frameworks use activity sampling to measure work (Yi & Chan, 2014). They measure the length of many specified tasks for most building project activities. The main objective is to calculate site non-productive time (Agrawal & Baruah, 2018). The assumption is that reducing superfluous time should free up time for direct work.

Construction companies must consider labour hours. The construction industry is focusing more on labour time utilization and waste removal due to lean thinking (Thomas & Sakarcan, 1994). Work sampling (WS) is a frequent construction work-study method that randomly observes workers' work time. Work sampling underpins the activity framework, which can be used for labour-intensive tasks. A good activity framework is needed to anticipate direct work durations and outputs (Tsehayae & Fayek, 2016). Further, the authors argue that it has been shown that job category and task classification can significantly affect construction labour productivity (CLP) proportions and correlations. Table 2.2 presents the distinction between the two techniques for measuring labour productivity.

Table 2.2: Techniques for Measuring Labour Productivity

Measuring technique	Main objective	Suitability	Ease of application in this research
Task	Identification of site factors (site production efficiency factors)	This is essentially a benchmarking model; it requires specific training for effective utilization	Specific knowledge and experience required for effective study
Activity	Identification and reduction of unproductive time	Suitable and detailed enough but does not focus directly on productivity	Can be applied effectively

Source: (Bamfo-Agyei et al., 2022b)

2.3.2 Distinction between Efficiency and Effectiveness of Labour

According to Dozzi and AbouRizk (2014), the two most important measures of labour productivity are the relative efficiency of labour, and the effectiveness with which labour is used in the construction process. There is no universally agreed upon position on these terms; nonetheless, effectiveness is typically defined as the ability to ‘do the right things’, while efficiency refers to the ability to ‘do things right’. Dozzi and AbouRizk (2014) define efficiency as “doing what it is required to do at a given time and place” The consensus among scholars is that efficiency is closely tied to the utilization of resources and primarily affects the input of the productivity ratio. Efficiency in manufacturing refers to the least number of resources needed to operate a system's desired functions, in comparison to the actual resources utilized. Effectiveness, conversely, is a more widespread concept and often challenging to quantify (Jang et al., 2016). It is frequently associated with generating value for the client and has an impact on the productivity ratio's output. Ultimately, solely prioritizing efficiency does not appear to be a productive approach to enhancing production. Nevertheless, it is the amalgamation of elevated levels of both efficiency and effectiveness in the process of transformation that results in superior production. It is conceivable for a system to be effective yet inefficient, as well as for a system to be efficient but ineffective.

2.4 Concept of Construction Mechanization

Technology is changing and developing around the world at a rate and pace never experienced before. The construction industry is one of the largest industries in both developing and developed countries in terms of investment, mechanization, employment, and contribution to GDP. Its impact on the environment is considerable across a broad spectrum of its activities. For this matter, construction organizations have aggressively embraced new technology to remain competitive in the current market (Alshawi et al., 2010).

Mechanization has long been defined as the process of shifting from working largely or exclusively manually to working with hand tools or powered equipment (Willis, 1875). In an overall sense, mechanization as used in this study comprises mechanization itself, automation, and robotization.

2.4.1 Mechanization in Construction

Mechanization can be described as the process of applying the use of mechanical plants in carrying out a task. It can also be defined as the act of implementing the control of equipment with advanced technology, usually involving electronic hardware. According to Kamaruddin et al. (2016), it is the method of employing mechanical equipment in the performance of a job. The level of mechanization is defined as the number of plants and equipment employed or the number of activities carried out by mechanical plants in an operation (Hwang et al., 2020).

Machines have been employed in many phases of construction including, excavation, earthworks and piling works, structural steel works, filing, demolition and site clearance, concrete works, formwork, building component assembly, flooring and pavement works, plumbing and drainage works, and masonry works, painting and finishing works, roof works. Most of these activities were for a long time fully carried out by manual labour but with time they gradually got mechanized.

2.4.2 Automation in Construction

According to Muro et al. (2019), automation can be defined as the substitution of human labour with machines, or the automatic operation of a machine or equipment, either autonomously or via remote control. Automation is described as a self-regulating process executed by programmable machines to conduct a sequence of tasks without requiring human presence. Automation surpasses mechanization by not just utilizing machines but also enabling these machines to operate according to a programmed system that governs their behaviour, so granting them the capacity for "cognition and reasoning." (Mahbub, 2008). A report by Muro, et al., (2019) described that automation is recognized as the technology related to the implementation of intricate mechanical, electronic, or computer-based systems for the operation and regulation of production or manufacturing.

It should be understood that the concept of automation has emerged from mechanization. The construction processes presently exhibit a minimal level of automation due to several factors. The primary cause is the conventional nature of the construction work, which hinders and obstructs the progress and implementation of automated systems for executing these tasks. The distinctive nature of the structures and the absence of standardization in their components is another significant concern. For a uniform ultimate result, such as a skyscraper constructed in various locations, the duties and their execution may differ markedly between two distinct construction sites. This sense of rootedness in a specific location introduces ambiguity and differentiation. The execution of identical activities across numerous construction sites is contingent upon multiple aspects that affect its potential for automation (Muro, et al., 2019). These factors are:

a) **A wide range of materials employed**. The difference of the materials employed in the execution of an identical process implies that the automation program of one site cannot be used entirely in another site. The automation system of the sites must understand the different algorithms applied for the different materials.
b) **Different Processes:-** The processes that constitute a constructive activity are contingent upon the nature of the material and the tools employed. The process flow may differ for the same task if any of these two elements changes, necessitating corresponding adjustments in automation.
c) **The complexity and singularity of the processes depend on the productive *system***:- The environment of a building site significantly impacts the work system and the methodologies employed. The environment is markedly unstructured. The intricacy of automation installations arises from the minimal standardization and inadequate supply chain planning.
d) **Costing*:***- The cost-benefit of automation of small batch production and high diversity is not clear. The automation machinery cost is very high.

One distinction must be made between the automation of construction and the automation of the different activities within a construction site. Automation of construction considers the building as a complete product and each floor is the element to be repeated.

2.4.3 Robotization in Construction

The domain of construction robotization is incorporated into the automation of construction. This concept pertains to the integration of robots into an automated system or the establishment of a fully automated system, as observed in Japan (Muro, et al., 2019). The primary impediment to the integration of robotics in the construction industry is the inconsistency of operations and the fluctuating conditions of the construction environment. Considering this, the application of robots in construction is increasingly shifting from rigid programming and fixed task sequences to a more adaptive type of utilization, enabling them to effectively do changeable tasks. The integration of robots into the building site serves as an optimal environment for testing and validating advancements in robotics.

Another issue is the limited payload of the existing robot technology. The manufacturing sector handles light to medium-weight components, whereas the construction sector deals with large loads and equipment. The correlation between payload and positional accuracy is another significant element. An increase in payload results in diminished positional precision at the robot's tip. The utilization of robots, as part of the automation domain, encompasses both the benefits and drawbacks previously outlined. The most significant differences with respect to classical electro-mechanical automation are:

a) **Increase in flexibility;** This aspect is enhanced by an increase in mobility, whether in the handling of materials or in the robot itself. Automatic systems exhibit enhanced flexibility by enabling the execution of various jobs through the integration of interchangeable tool systems in robots. Ultimately, the potential for reprogramming robotic actions enhances this versatility.
b) **Increase in complexity;** A robotic system is more advanced than a traditional automated system. The dynamic nature of robots complicates the hardware components required for their supervision and control. Moreover, the programming of robotic systems necessitates a higher level of specificity. There is a necessity for more specialized operators.

Robots can do more intricate manipulation and processing activities than traditional systems. One advantage of a robotic system is its ability to do manipulation tasks that would often need multiple machines, thereby consolidating the function into a single device.

2.4.4 Justification for Construction Mechanization

All three aspects of mechanization discussed above have been proven to drastically improve construction processes. According to Vishwakarma et al. (2022), moving towards industrialization through mechanization in the construction sector is crucial for addressing challenges related to productivity, performance, health and safety, and the environment as well as frequent cost overruns and delays. Contractors could expect to complete projects sooner when employing mechanization since it is faster compared to manual operations. Mechanization is relatively more widespread in developed countries with many manual procedures getting replaced due to the expansive and scarcity of skilled labour (Vidushi et al., 2022). Due to the critical importance of the construction sector to the GDP of developing countries like Kenya, it is momentous for these countries to keep up with the fast-growing mechanization trends to remain competitive in the global market (Vishwakarma et al., 2022).

According to Babatunde et al. (2019), the primary motivations for mechanization encompass enhanced productivity, the fulfilment of increasingly intricate specifications, the escalating complexity of contemporary designs, the ability to employ a multitude of new construction materials available in the market, adherence to client-imposed timelines and locations, the implementation of control measures, and the assurance of efficient and effective resource utilization in construction projects. The primary advantages of mechanization and automation in the construction sector encompass time and cost efficiency, greater working conditions, increased safety, superior performance in tasks exceeding human capability, and uniform quality standards (Kamaruddin et al., 2018). According to Iheama et al. (2017), some of the reasons for mechanization in the construction industry include; performing work more rapidly, completing of projects on time, ability to manage large quantities of materials, ability to maintain high-quality standards, ideal use of resources such as human and capital, and a shortage of relevantly skilled manpower. Calvetti et al. (2021) argue that construction mechanization offers the following advantages; enhanced safety, improved speed, cost-effectiveness, higher quality workmanship, waste reduction, improved standards of construction, and increased efficiency.

Vishwakarma et al. (2022) highlighted the following as the benefits of construction mechanization; increased safety on site, less dependency on labour, faster construction speed, higher accuracy, reduced material wastage, fewer reworks, reduced overall cost, improved client satisfaction, increased productivity, improved quality of work done, increased site cleanliness, an advantage during global pandemics, flexibility to designers, and improved image of the industry. Mechanization can significantly increase the efficiency and productivity of the production activities, as it allows workers to have the ability of handling an overwhelming workload in a short period of time (Lamsal, 2024).

2.4.5 Perceived Negative Effects of Construction Mechanization

Despite the justification provided for mechanization, it has several perceived negative effects. For instance, it poses a big threat to employment because in the process of mechanization, the need for human labour is reduced drastically. Depending on the industry and process, one machine or automated machine or robot can cut down the need of human labour by more than 90% (Wetangula & Mazurewicz, 2017). This implies that mechanization leads to unemployment. Additionally, mechanization can be very expensive in the short run and depending on the country, the money used to purchase the machines do not add significant value to the country's economy in cases where the machines are to be imported except through custom duties (Kamaruddin et al., 2016).

The construction sector is grappling with challenges concerning performance, productivity, environmental impact, and health and safety, as well as managing the influx of both domestic and international labour at construction sites.. Azman et al. (2012) noted that in the context of the Malaysian construction industry, a lot of transformation has been witnessed with regard to mechanization and the labour market. Furthermore, as observed by Vishwakarma et al. (2022), the construction industry is concerned with addressing the evaluation of inequality which is likely to grow with every mechanized process in the construction projects in relation to enhancing sustainability of job creation, environmental protection and waste generation. According to Babatunde et al. (2019), the biggest budget goes to the producers or owners of the machines and thus in the long run, mechanization encourages capitalism which in the long run does not translate to equitable social development.

In Muro, et al., (2019), it is recognized that in many cases, mechanization and artificial intelligence cause the displacement of human labour because fewer people are needed to work with the machines to deliver even better output. Notably, the displacements of people do not mean that a lot of capital is saved but rather it is paid to the producers or owners of the machines and AI which takes over some jobs from human labour. Consequently, inequality increases. Although in the long run, it would appear, that mechanization and adoption of AI are contributing to economic development, the question of inequality becomes even more complex, and as such economic development may only be considered so if limited to GDP of per capita income but not individual incomes. Muro, et al., (2019), go ahead to note that besides incomes, mechanization and AI force human labour either to overspecialize in terms of skill or to go back to training. This is particularly true where special skill is needed to safely interact and operate the machines. Notably, in many cases, some of the special skills require people to train in foreign developed countries if the application is to be done in developing and underdeveloped countries.

Barbosa et al. (2017) analyzed the effects of mechanization in the labour market in the United States over a period of four decades, starting in the 1980s, and noted that automation does seem to have coincided with a significant hollowing out of the employment distribution in the last nearly four decades. In this regard, work led by David Autor and his collaborators documents a striking polarization of the U.S. labour market, whereby the demand for work at both the high and low ends of the wage distribution has grown, even as it has slumped in the middle—contributing to a reduction of middle-skill employment (HM Government, 2014).

2.4.6 Construction Mechanization versus Manual Labour

The advantages and disadvantages of mechanization versus manual labour in construction projects have been presented in Table 2.3.

Table 2.3: Construction Mechanization versus Manual Labour

Mechanization	Manual labour
1. It can handle tough work which cannot be performed manually. 2. It is cheaper when quantum of work is large and material needs to be transported for long distances. 3. Better quality of work. 4. It is possible to adhere to schedules. 5. It is easy to predict the behaviour of a machine as compared to that of man, therefore planning is easy. 6. Due to the fewer number of persons, (operators only), it is easier to supervise and control. 7. It helps in the development of technical know-how, skills, and industrial development of the country. 8. Availability of manpower and seasonal fluctuations will not affect the project's progress. 9. The effect of climate and topographic conditions is less. 10. Minimal need for housing and transportation of persons and also for the arrangement for supply of food, water, light and medicines etc.	1. Initial heavy investments not required. 2. Valuable foreign exchange is saved. 3. Small and short duration projects can be economical with manual labour. 4. Direct advantage to considerably large number of people by way of employment which help in social and economic betterment. 5. No problem due to delay in procurement of spares for the repair of machines. The delay (lead time) is substantially high in the case of imported equipment. 6. The project can be started immediately, which is not possible in case machines are used. Since importation, shipment, transportation installation, and commissioning of equipment require a substantial time. 7. Disposal of equipment and its balance of spare parts poses a problem after the project is completed.

(Adapted from various sources)

2.4.7 Planning Construction Mechanization

Some of the most commonly used construction machinery include; earth-moving equipment, hauling machinery, hoisting machinery, conveying machinery, aggregate and concrete production machinery, pile driving machinery, tunneling, and rock drilling machinery, and pumping and de-watering machinery. The extent to which mechanization is employed in a project should be planned depends upon the following main factors:

(a) Manpower; The type of manpower required for the project execution is first decided, and whether this type of manual labour is cheaply and sufficiently available around the year. In case where manual labour is costly, or only available for a limited duration, or the required type of labour is not available locally, then the only solution is mechanization. In order to decide whether the labour is costly or cheap, the project manager must consider the labour output and overhead expenditure for the labour, such as accommodation, transportation, among others. on one hand and equipment output and expenditure on the other hand (Chia et al., 2018).

(b) Completion period; Every project is expected to be completed within a particular duration. Delay in project completion means an increase in construction cost due to inflation, increased overhead costs for the extended period, and imposition of delay penalties, among others. The overhead expenses include items such as equipment depreciation, accommodation expenses, supervisory expenses, water, light, power, and insurance expenses, etc. The completion period, therefore, plays a deciding role in the extent of construction mechanization (De Stefano, 2019). By employing a higher number of construction equipment, a project can be completed in a shorter duration.

(c) Nature of work; Where the nature of work is such that it is beyond the capacity of human labour to perform, the use of construction equipment is unavoidable (Fernández-Macías & Bisello, 2022). The nature of work includes matters such as adverse weather and climatic conditions, toughness, topography, and handling of large quantities of construction material for long distances.

(d) Availability of capital: Since the cost of equipment is often too high and needs to be spent initially, it needs heavy investment in the beginning; therefore, availability of finance is a main factor in deciding the extent of mechanization (Iheama et al., 2017).

(e) Availability of Indigenous Equipment: The import of costly equipment and its spare parts can prove to be a drain on foreign exchange resources (Kamaruddin et al., 2016). After-sales service and repair facilities are also factors to be considered in cases where equipment is to be imported. Because the time required for the importation, shipment, installation, and commissioning of the equipment, and thereafter lead time for the purchase of repair spares will adversely hamper the progress of the project.

(f) Social objects of the project: Sometimes projects are sanctioned with the object of providing employment opportunities, to improve the economic condition of the populace, in addition to the development of the area (Sharmila et al., 2018). In such cases, human labour is preferred over mechanization unless any particular activity is beyond the capacity of human labour.

(g) Labour Relations: In certain areas, past experience indicates labour unrest, strikes, uncertainty, absenteeism, labour unavailability, or seasonal fluctuations (Srisompun et al., 2019). In such circumstances, mechanization is preferred due to its reliability in completing the project in time.

2.4.8 Evaluating the Level of Mechanization in Construction Projects

Assessing the level of mechanization in construction projects is critical. It not only reports how well the assessed project is in terms of mechanization but also reveals the directions for improvement (Pan et al. 2018). As previously mentioned, the utilization of mechanical tools and equipment in building projects yields concrete advantages, including enhanced productivity, the ability to satisfy increasingly intricate technical demands, and the capacity to adhere to stringent timelines and objectives set by clients and owners (Love et al., 2018). Consequently, mechanized building techniques have predominantly replaced human methods during the previous decades, establishing themselves as a fundamental production approach in construction projects (Lamsal, 2024). In addition to the technical role, mechanization also plays a role in the management of construction projects. For instance, in the realization of the importance of equipment and tools in conducting construction projects, clients now consider the level of mechanization of contractors as a major criterion during tender evaluation (Afshar et al., 2017).

Evaluating mechanization is crucial as it provides insights into the degree of mechanization of various construction activities and identify areas in which further improvement can be made. Most of the studies in the past on mechanization assessment have been in the agricultural and mining sectors. For instance, Sharabiani and Ranjbar (2008) evaluated the level of the agricultural mechanization in the Sarab Region, by estimating the tractor power used per cultivated area. Jalalzadeh et al. (2016) also used a similar method to assess the extent of mechanization of Iran’s crop production. The most notable research dedicated to assessing construction mechanization is (Hwang et al., 2020). The authors developed and validated a framework for achieving this through a three-step process. First, based on a comprehensive literature review, the authors developed a Mechanization Index for Building Construction Projects (MIBCP), a comprehensive six-layer assessment framework that can assess the level of mechanization in building construction projects. Second, based on the proposed MIBCP, they developed a Mechanization Index Assessment Tool (MIAT), a Microsoft Excel-based tool for assessing the level of mechanization in building construction projects. Finally, the developed MIAT was validated by pilot interviews with experienced experts from the construction industry of Singapore. The developed MIAT was also sent to 14 construction companies in Singapore for application. The results showed that the mechanization level of the construction projects was 48.54 percent, which was described as moderate. The six-layered MIBCP assessment framework is presented in Figure 2.2.

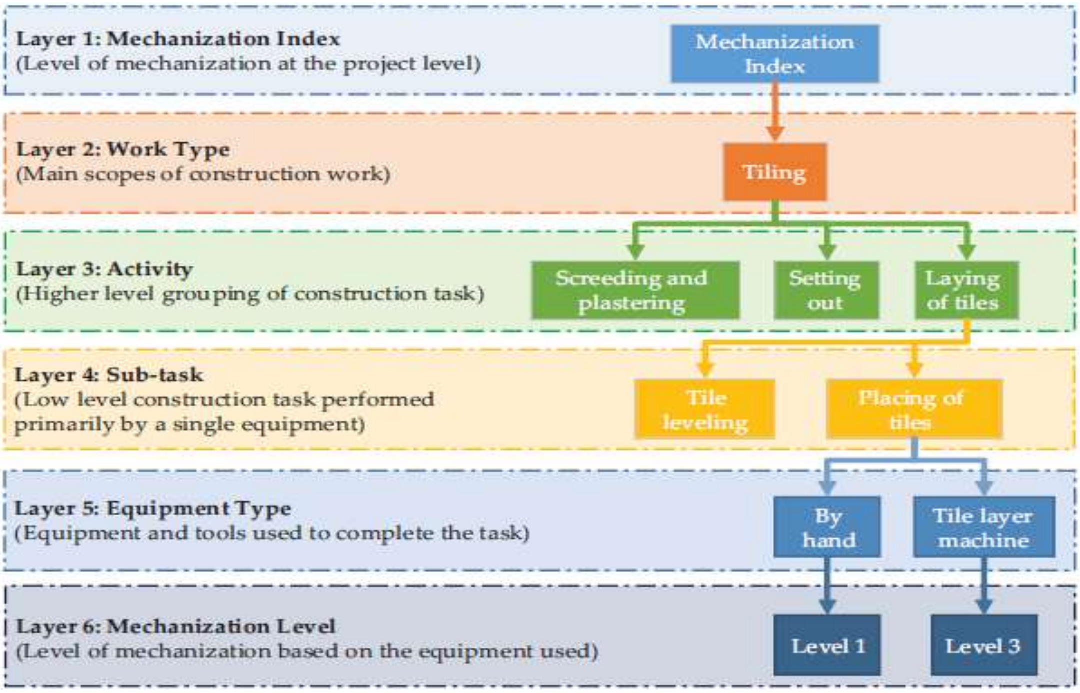

Figure 2.2: Structure of MIBCP

Source: (Hwang et al., 2020)

According to Hwang et al. (2020), Layer 1 (Mechanization Index) refers to the mechanization level of some given building construction project. Layer 2 (Work Type) refers to the several main scopes of construction work performed at construction sites, such as walling, tiling, and painting. Layer 3 (Activity) refers to a high-level grouping of some tasks performed under work types. Layer 4 (Sub-task) mainly refers to specific and low-level construction tasks that are performed under activities, with the aid of tools and equipment. Layer 5 (Equipment) refers to the specific equipment or tools used for the given sub-task. Layer 6 (Mechanization Level of Equipment) refers to the mechanization level of the equipment or tools used for the given sub-task. Notably, MIBCP uses a bottom-up strategy to assess the mechanization levels in building construction projects. This means, the mechanization level of the equipment or tools determines the mechanization level of subtasks, and then, in a step-wise manner, the mechanization level of subtasks will determine the mechanization level of activities, work types, and eventually the mechanization level of the given project (Hwang et al., 2020).

Based on an extensive review of construction handbooks, (Chudley & Greeno, 2016; Merritt & Ricketts, 2001; Watts, 2016), Hwang et al. (2020) came up with eight (8) work types for the MIBCP framework. These included (i) site preparation, (ii) scaffolding, (iii) formwork, (iv) internal partition-brick wall, (v) internal partition-dry wall, (vi) underground piping, (vii) tiling, and (viii) painting, together with their affiliated activities, sus-tasks, and the relevant equipment. The eight work types were chosen based on two considerations. First, all of them are common and essential work types for any type of building construction project. Second, the equipment used for these work types have a wide variety in terms of mechanization levels, which would be helpful to generate different results.

Modified from a seven-point rating scale earlier proposed by Frohm et al. (2008) for assessing the level of automation in the manufacturing industry, Hwang et al. (2020) developed a five-point rating scale to gauge the mechanization levels in building projects using the MIBCP. They justified this scale by arguing that a large number of studies have mentioned that the scale is readily comprehensible to respondents and can reduce respondents' frustration while making assessments, generating assessment results with higher reliability (Babakus & Mangold, 1992; Jenkins & Taber, 1977;

Saleh & Ryan, 1991; Wu et al., 2017). The five-point rating scale, together with their definitions and examples of tools and equipment is presented in Table 2.4.

Table 2.4: Levels of Mechanization Adopted by Mibcp

Mechanization Level	Definition	Example
1-Completely manual	Workers are on-site and use non-machineries or simple tools without mechanisms to work	Shovel, saw, and hammer, etc.
2-Hand tool	Workers are on site and use equipment with mechanisms (but not machines)	Hand winch, claw hammer, and spirit level, etc.
3-Automated hand tool	Workers are on site and use machinery to work on the construction project	Electric laser leveler, electric drill, electric bolt wrench, etc.
4-Machine/ Workstation	Workers operate a machine/workstation to complete the construction task	Crane, excavator, and pump, etc.
5-Completely automated/Robotized	Workers are not required to operate or monitor the machine and the machine will complete the work activities by itself.	Robotic tiling machine, bricklaying robot, etc.

Source: (Hwang et al., 2020)

The current study adopted and modified the MIBCP in its attempt to assess the level of mechanization in building construction projects in Kenya. While it retained the 5-point rating scale due to the justification provided by Hwang et al. (2020), it modified the number of work types from eight (8) to seven (7) namely; Site Preparation and Earthworks (SPE), Scaffolding and Formwork (SF), Concreting (C), Walling (W), Plastering and Flooring (PF), Tiling and Painting (TP), and Building Services (BS). Scaffolding and formwork were merged into a singly work type. This is due to the near similarity in the function of both.

2.5 Related Theories

This section dwells on some of the explanations which have been advanced around the questions of mechanization, labour and capitalism. Theories not only explain known facts; but also allow scientists to forecast what should be observed if a theory is true. In this study, four theories were used to explain the main concepts of the study. These theories are, the human capital theory, the theory of capitalism, the theory of induced innovation, and the sociotechnical systems (STS) theory.

2.5.1 Human Capital Theory

The term human capital can trace its roots to the early 1960s when Schultz (1961) suggested that it comprised ‘knowledge, skills, and abilities of the people employed in an organization’. Bontis et al. (1999) provided a more comprehensive definition by stating, ‘the human factor in the organization; the combined intelligence, skills, and expertise that gives the organization its distinctive character. The human elements of the organization are those that are capable of learning, changing, innovating, and providing the creative thrust which if properly motivated can ensure the long-term survival of the organization’.

The origin of the human capital theory could be attributed to the works of various authors (Becker, 1962; Mincer, 1958; Schultz, 1961) in the mid-20th century. The authors suggested a simplified explanation for personal income; when workers acquire skills (i.e., human capital), they become more productive which consequently leads to increased income. However, this was not a new idea. The concept that income results from productivity has been a fundamental principle of political economy for over a century (Blair, 2018). The concept was formalized by neoclassical theorists, (Clark, 1899; Wicksteed, 1894), who theorized that the distribution of income obeyed a ‘natural law’. They posited that in every market economy, each single factor of production would earn its marginal product. Marginal product was the increment in output caused by the increment in the input of capital/labour. This meant that if a capitalist earned more compared to a worker, it was because an additional unit of ‘capital’ added more to output than an additional unit of labour (Matache, 2023).

In a more simplified form of the human capital theory, Reder (1967) asserted that just like machines, humans are “human agents of production” with an increased productive capacity. The theory posits that individuals and society derive economic benefits by investing in people (Fleischhauer, 2011; McCracken et al., 2017; Merwe, 2010; Rajabhat, 2017; Sweetland, 1996; Zamora, 2007).

2.5.2 The Theory of Capitalism

Capitalism is a system of largely private ownership that is open to new ideas, new firms and new owners—in short, to new capital. Capitalism's rationale to proponents and critics alike has long been recognized to be its dynamism, in terms of innovations and selectiveness in the innovations it tries out (Braun, 2017). At the same time, capitalism is also known for its tendency to generate instability, often associated with the existence of financial crises, job insecurity and failures to include the disadvantaged (Makoto, 1988). This is the fear about which heavy mechanization in the construction industry particularly by foreign contractors provokes interest of study. There are fundamental concerns about capitalism that have hardly begun to be answered. Among the concerns include whether economic and social institutions engender innovation in the more capitalist of today's advanced economies, whether the benefits attributed to the system of capitalism can be quantified interim of productivity and rewards to the participants in the economy such as manual labour, whether capitalism encourages economic stability or not (Clarke, 1989). More recently, it has come to be argued that the corporatist economies of east Asia, which broke records of economic achievement when there was a yawning gap with the West, ran into trouble in the 1990s because state intervention in the corporate sector through permissions to capitalists, subsidies and guarantees led ultimately to mass overinvestment and insolvency (Phelps, 1999). Private ownership of capital such as heavy machinery is not sufficient for dynamism either: capitalism, in which capital is free to go in new directions without a green light from the state, becomes necessary at some point in economic development if dynamism is to continue (Braun, 2017). This raises the question of the need for a model which balances capital flows to owner of capital as well as owners of labour in an equitable manner.

Capitalism's proponents hold that the right both to hire and to fire freely helps to encourage capitalists to take the risks of job creation and thereby raises the average level of wages and perhaps employment too (Koslowski, 2013). However, capitalism appears to exhibit long swings in economic activity, as measured by employment and unemployment rates, of far wider amplitude than those detectable in the more corporatist economies (Zheleznyak, 2014). Here too a reply is conceivable. It may be that when contractionary schools of thought collide, the swift restructuring that firms in the relatively capitalist economy are generally allowed to do in the real sense diminishes the size of the slump that follows, while the rigid position held by firms in the relatively corporatist economies, with their position against dismissals, entails a much deeper and longer slump (Orkun, 2021). Another of the fluctuation issues is the justice of regarding long booms as no better than long slumps. A more radical position raises questions about the justification for blocking or moderating long slumps, provided they are purely or mainly structural rather than the result of monetary malfunctioning (Zoega & Phelps, 2004). The subject of long swings is only now beginning to enjoy a revival of attention in the economic landscape, and there is much to be done in this area.

The last of the great questions about capitalism is whether it is best only for the elite of more able and advantaged participants, who can find rich rewards from its stimulation and challenges, or whether ways can be found to integrate the less able and less advantaged into capitalism's sphere (Hans-Hermann, 2010). This is the question of economic inclusion. Quite possibly, there is little cost from a failure of highly corporatized or highly socialized economies to include the less advantaged; in those economies, a low rate of inclusion is often deemed acceptable and, in some of them, only a minority of the population are in the labour force (Zheleznyak, 2014). Far more may be at stake in the inclusion of the less advantaged where the business sector is predominantly capitalist. If these capitalist business sectors offer relatively good job satisfaction and personal growth on the whole or offer relatively high wages in comparison with the pay in underground and domestic activities, then an appreciable deficiency in inclusion arising from a wide gap between low-end wage rates and the median wage, with the consequent demoralization and decline of employability, may be deemed unacceptable and may impose high social costs on virtually everyone (Phelps, 2009).

2.5.3 The Theory of Induced Innovation

According to the theory of induced innovation, changes in the relative scarcity of the factors of production lead to the development of technologies that "facilitate the substitution of relatively abundant and hence cheap factors for relatively scarce and hence expensive factors of production" (Ruttan, 1977). Theory of Induced innovation is a microeconomic theory first proposed by John Hicks in 1932 (Ruttan & Hayami, 1984). He argued that the cost of a factor of production can readily induce invention of a more cost saving a factor of production. He went further to argue that such invention is normally meant to economize the use of a factor of production which has become relatively expensive. According to Daum and Birner (2020), a purely manual labour production process is relatively costly in terms of time, efficiency, quality, downtime and cost as compared to mechanized production. From this background, therefore, a purely manual labour-based construction production is relatively expensive and thus informs the innovation drives which have seen the emergence and introduction of plants and equipment which besides making construction relatively cheaper have also promoted efficiency, quality and timeliness (Funk, 2002).

The theory posits that mechanization, as a labour-saving technology, may be prompted by a rising scarcity or cost of labour, analogous to how land-saving technologies, like high-yielding crops, have emerged in response to diminishing land availability in agricultural production (Ruttan, 1997). Historical data supports the theory, as indicated by accounts of extensive mechanization in densely populated nations, such as Japan. The opposite is seen in countries with low population density, such as the USA, Canada, and Australia (Sahota, 2024). The argument justifies the contentions that mechanization saves the cost of production and is thus one of the reasons why mechanization is hailed by the proponents. On the basis of this reasoning, a high level of mechanization should be necessitated by the high cost of other factors of production including labour. In other words, mechanization should be/is adopted on a large scale primarily to save on the cost of production (Koppel & Oasa, 1987). The dimension of cost saving however should be those associated with factors of production namely labour and land (Ruttan & Hayami, 2011). In the context of this study, cost of labour is therefore the focal point with regard to the cost of production which could induce the adoption of mechanization.

In Kenya, just like in many African countries, the supply of labour is far higher than the demand. Consequently, the reverse of the theory of induced innovation should be the case. In other, words, the supply of labour and the cost associated is not something which can induce mechanization as proposed by the theory. In fact, going by the arguments of the theory, less mechanization should be witnessed because labour as a factor of production is neither scarce nor expensive.

As many African countries are relatively land-abundant, the question arises as to why mechanization levels have remained relatively low (see section 2.2). According to the theory of farming systems evolution by Boserup (1965), mechanization occurs solely after population density attains a threshold that prompts a shift from fallow cropping to permanent agricultural systems. This change results in heightened weed pressure and necessitates soil tillage, hence prompting the utilization of the plough.

2.5.4 Socio-Technical Systems Theory

Sociotechnical Systems (STS) Theory, also known as Sociotechnical Theory, is one of the most comprehensive bodies of conceptual and empirical work underlying employee involvement and work design applications practices today (Appelbaum, 1997). It explores the interrelatedness of ‘social’ and ‘technical’ and is based on two fundamental principles. The first principle is that the interaction between the social and technical factors determines whether the systems perform well or poorly (Walker et al., 2008). These interactions consist of both linear (cause and effect) and non-linear (complex and unpredictable) relationships. In the former, the relationships are usually “designed” and therefore predictable (Davis, 1977). One of the consequences of combining ‘socio’ and ‘technical’ is that both have distinct behaviour with the former mostly exhibiting non-linear unpredictability and the latter portraying linear predictability (Driskell & Mullen, 2005). When a sociotechnical system is implemented, inevitably, both types of interaction are manifested. The second principle is that optimization of either the socio or technical tends to escalate not only the amount of nonlinear unpredictable relationships, but also those relationships that are harmful to the system's performance. Sociotechnical Systems Theory, therefore, is all about '*joint optimization*' (Walker et al., 2008). The STS theory utilizes the principles of general systems theory, particularly the concept of 'open systems' to describe, analyze, and design systems based on joint optimization, especially those with either inherent non-linearity, or their environment exhibits unpredictability (Bertalanffy, 1950). The theory reflects certain specific methods of joint optimization to design organizations that reflect open systems properties and can therefore cope better in complex, dynamic, innovative and competitive environments (Beekun, 1989; Ciborra et al., 1984; Clegg, 2000).

According to Abbas and Michael (2023), the STS is an organizational theory that conceptualizes a given work or other systems by considering its constituent social and technical subsystems, to achieve system success through joint optimization. The theory was first proposed by Trist and Bamforth (1951) and its parent theories are the General Systems Theory (GST) and Open Systems Theory (OST). With the development of the STS theory, there was a shift from the assumption that human labour was dispensable to a new perspective whereby humans were treated as a "resource to be developed" (Hirschhorn et al., 2001). The new theory emphasized; joint optimization, labour as complementary machines and as a resource to be developed, optimum task grouping and multiple broad skills, internal controls consisting of self-regulating subsystems, participative style, and collaboration among others (Abbas & Michael, 2023; Kelly, 1978). STS theory focuses on the mutual benefits derived from the intersection of social and technical elements. According to various proponents of the theory, (Baxter & Sommerville, 2011; Bednar & Welch, 2020; Chai & Kim, 2012; Kelly, 1978), this intersection emphasizes mutual reciprocity between machines and humans, whereby simultaneous shaping of both the social and technical systems occurs.

The emergence of the STS theory could be attributed to the then-dominant technocratic models that were technologically centred, ignoring human factors (Kelly, 1978). These models were viewed as restrictive due to their disregard for the social aspects of a system, especially concerning how the social subsystem interacts with the technical subsystem (Chai & Kim, 2012). Therefore, a socio-technical approach was brought forth to acknowledge the significance of society and the social aspects in the design and interventions affecting a system, whereby the goal of each subsystem would be to "meet its own objectives, by using its own means, but is also in an interdependent relation with other subsystems" (Abbas & Michael, 2023; Fischer & Herrmann, 2011).

2.6 Theoretical Framework

From the literature reviewed on construction mechanization and the general theories related to it, there are positive and negative effects of mechanization. The positive effects include efficiency, effectiveness, and quality output. In other words, mechanization helps with saving cost and time, which would otherwise be wasted if manual labour were fully relied on for the delivery of the project. Additionally, mechanization enables the actualization of construction phases that would otherwise be impossible without machines. However, it is also notable that mechanization brings a new way of management of construction projects in terms of workforce planning, and cost planning for both machines as well as skills acquisition. Furthermore, mechanization implies that there are more risks and health safety measures that have to be taken into consideration. In some instances, mechanization induces environmental pollution through the generation of noise, dust, and other emissions.

Based on both the empirical and theoretical review, interactions amongst the variables can be explained as follows: The nature of construction projects to be accomplished demands the use of machines, to make the work possible and easy to accomplish. Consequently, the need induces innovation, whose success attracts more adopters. This explains the continued and increasing mechanization in the construction industry. That notwithstanding affordability of the innovation provokes the question of whether the adoption encourages equitable sharing of the national incomes among those who possess factors of production such as those with machines, and the labourers.

The human capital theory emphasizes the need to invest in the knowledge, skills, and capabilities of workers since they are essential for organizational and project productivity and competitiveness. This theory was used to explore the role of construction mechanization in either enhancing or hindering the development of worker skills and human capital. Some of the key concepts emanating from this theory include; (i) human capital (this includes an individual's educational background, knowledge, expertise, and competencies, which hold significant value in the economic realm, (ii) investment in human capital (such investment comes in the form of providing training, education, and opportunities for skill development to enhance productivity and innovation). This theory was key in the conceptualization of the performance of construction workers variable. Issues surrounding quality of work, training, skillset, career growth, and development were based on this theory.

The capitalism theory advocates for an economic system where private actors own and control property according to their interests, and demand and supply freely set prices in markets to serve the best interests of society. The key concepts emanating from the capitalism theory include; (i) private property (this allows individuals to own assets, such as land, houses, stocks, and bonds), (ii) self-interest (individuals act in pursuit of their interests, which can lead to economic prosperity), (iii) market mechanism (this means that prices are determined through interactions between market players, allocating resources to their highest reward). Capitalism theory dictates that contractors are free to choose whichever means of effectively executing their projects they prefer. The market cannot dictate the use of human labour when there is no need for such.

The theory of induced innovation suggests that changes in relative prices usually induce technical innovations through both external and internal channels, leading to the development of new technologies and processes. The key concepts considered in this study emanating from this theory include; (i) induced innovation (ii) interaction between sectors: The theory emphasizes the interaction between the manufacturing sector, where the new technologies are initially developed, and the construction sector, where they are applied. This theory is fundamental in understanding the current study in the context of construction in Kenya in a number of ways: (i) the scarcity of land in urban areas of Kenya and the rise of confined sites may induce the adoption of space-saving construction methods such as prefabricated modular systems, lightweight materials, and high-density building designs all of which heavily rely on mechanization, (ii) increases in the prices of conventional building materials such as cement and steel could drive the adoption of alternative, more cost-effective construction technologies like recycled materials and innovative lightweight composites, and (iii) as labour costs continue to rise, construction firms may be incentivized to adopt more mechanized and automated technologies that can substitute for expensive labour.

The STS theory emphasizes the interrelation and interdependence between the social (i.e., people, organization) and technical (i.e., tools, technology) subsystems within a work environment. The theory suggests that the optimal design of a work system requires consideration of both the social and technical aspects to achieve success. Some of the key concepts emanating from this theory include; (i) the social subsystem (this refers to the human factors that are present in a system, including individuals, their relationships, values, structure, work-related elements, and associations, (ii) the technical subsystem (this refers to the physical and material flows within a system, including tasks, control, and maintenance functions, (iii) the environmental subsystem (this refers to the context, surroundings, and conditions within which the system operates, including both internal and external environments). In this study, the STS theory informs the socio-economic effect of mechanization on human labour and local contractors. Although most of the previous studies have focused on agricultural mechanization and the findings of the effects of mechanization are mostly limited to agriculture, the same should sustain an argument that mechanization could have the same or related effects on a construction project.

The study's theoretical framework can be diagrammatically presented as shown in Figure 2.3. The underlying principle is that there exists a cyclic relationship between people (humans) and technology (machines). Each affects the other and the key is to jointly optimize the use of the two subsystems to ensure the success of the system i.e., the construction project. These interactions happen in a capitalist market whereby the contractors and developers are free to select either humans or machines to run their projects.

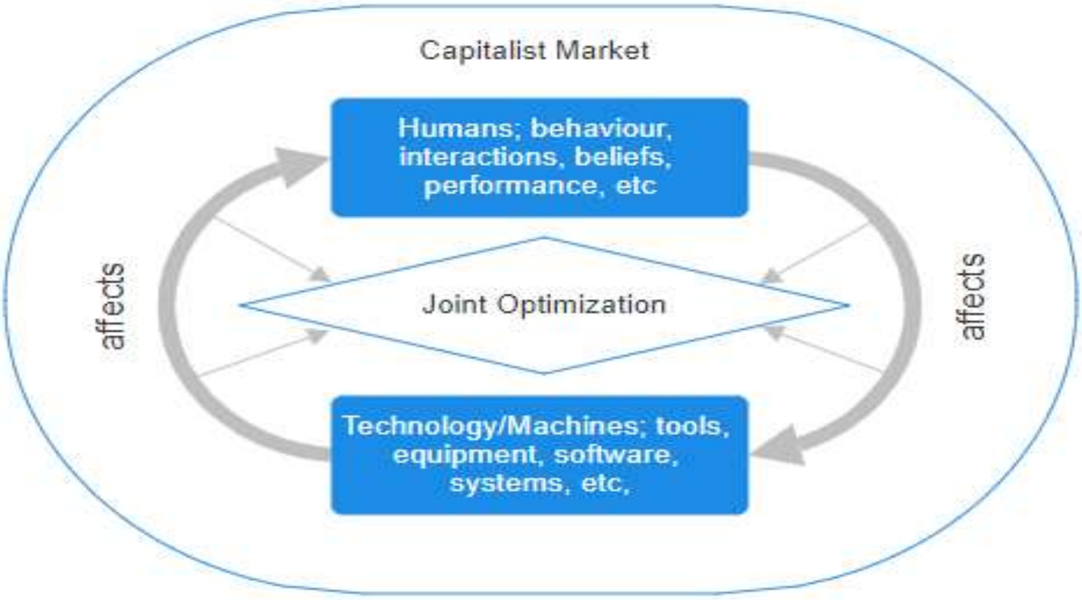

Figure 2.3: Theoretical Framework

Source: (Own formulation)

The adopted theoretical framework provides a comprehensive and well-grounded approach to investigating the influence of construction mechanization on the quality of work life and performance of construction workers in Kenya. By integrating various theories and concepts from the fields of organizational behaviour, human capital development, and economic systems, this framework will guide the research strategy and design, data collection, and analysis to generate meaningful insights and recommendations for the construction industry in Kenya.

2.7 Research Gap

This study is pegged on the following; (i) the extent of construction mechanization in Kenya is currently unknown, (ii) the quality of work life of construction workers in Kenya is undocumented, (iii) the effect of mechanization on the performance of construction workers here in Kenya is unknown, (iv) the effect of mechanization on the quality of work life of construction workers here in Kenya is unknown, and (v) a framework for optimizing the construction mechanization such that performance and quality of life of construction workers is enhanced has not been developed.

From the literature reviewed, significant research has focused on the macroeconomics of the construction industry at the industry level. In many instances, research have focused on how mechanization is changing the construction industry (Bamfo-Agyei et al., 2022a, 2022b; Barbosa et al., 2017; Bartoschek & Kirchev, 2021; Bommet et al., 2020). This study did not find any specific research works conducted to establish the influence of mechanization on construction workers' quality of work life and performance and how the integration of manual labourers and construction mechanization can be optimized for the long-run benefit of the manual labourers amidst growing demand of mechanization in the construction industry. The gap is the inspiration of this study which proposes to establish an optimal framework to balance mechanization and manual labourers' quality of work life and performance.

While a significant number of studies have been done on mechanization, a lot of the studies have been in other fields (especially agriculture) other than construction (Sahota, 2024; Srisompun et al., 2019). Only a handful of studies have focused on the economic impacts of mechanization in the construction industry. Such studies have often focused on the effects of mechanization on cost saving, time saving and overall quality of productivity (Grover & Solanki, 2023). Most of the studies reviewed dwelt on how mechanization has changed the construction industry as well as barriers which have hindered mechanization (Hwang et al., 2020; Iheama et al., 2017). Some studies (Jalalzadeh et al., 2016) focused on cost of mechanization and the inequality it causes relative to the varying sizes of the major competitors while others (Kamaruddin et al., 2018) focused on how mechanization of the construction industry influences the productivity, without factoring in the integration of mechanization and manual labour. No particular study was found to focus on the implication of mechanization on worker-related issues as the main focal point. Furthermore, a few of the studies which highlighted the issues of employment, and labour productivity were not those conducted in the Kenyan construction industry context. Most of the studies (Muro et al., 2019) considered the benefits of mechanization as a contributor to economic growth but with regard to the overall GDP growth. There has never been a focus on the influence of construction mechanization on the quality of work life and performance of construction workers in Kenya.

By addressing these underlying issues that constitute the research gap, this study could make a significant contribution to the body of literature and provide valuable insights for policymakers, industry stakeholders (including contractors and clients among others), and workers in the Kenyan construction sector.

2.8 Conceptual Framework

Based on both the theoretical framework and the empirical review of literature, the conceptual framework for the study is shown in Figure 2.4. On the left of the conceptual framework are the independent variables, that is, the extent of construction mechanization in the various work elements in a building project. On the right side are the two dependent variables namely, performance and the quality of work life of construction workers. The performance of construction workers has been measured using two surrogates, namely, labour efficiency and construction worker effectiveness. On the other hand, the quality of work life of construction workers has been evaluated based on four surrogates namely, compensation and reward systems, working conditions, health and safety, and welfare and social integration. It is worth noting that these surrogates have further been operationalized into measurable indicators

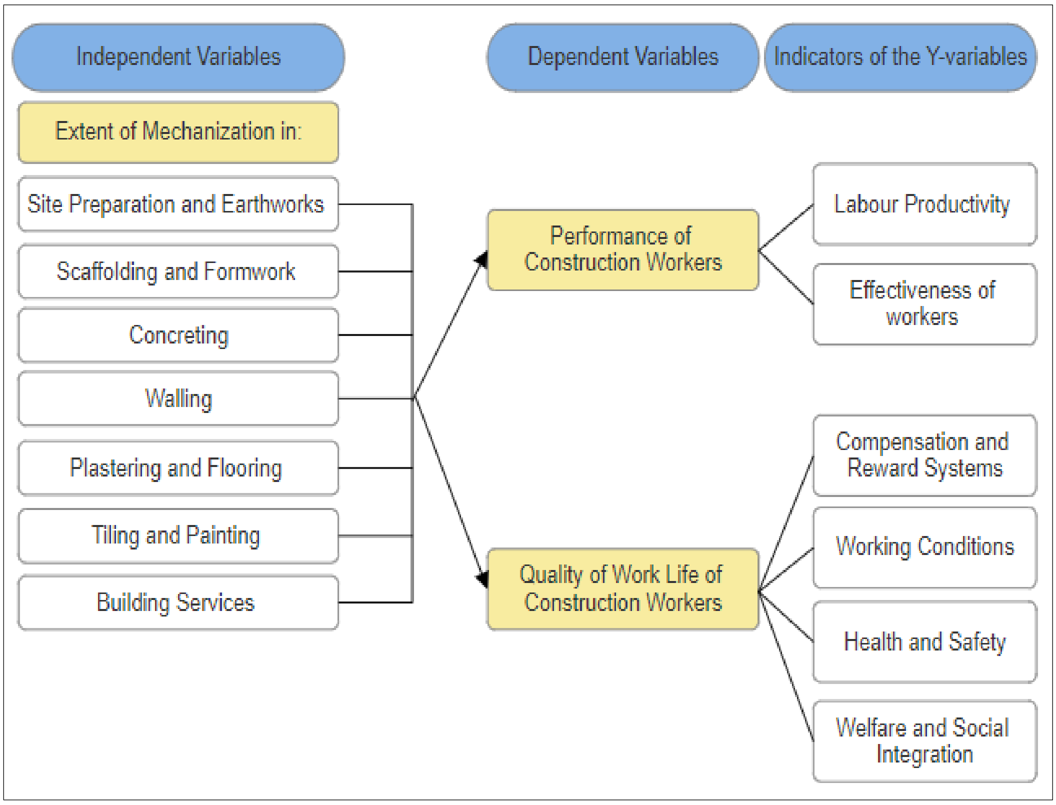

Figure 2.4: Conceptual Framework

Source: (Own formulation)

2.9 Conclusion

This chapter presented a discussion on the concepts of quality of work life, performance of construction workers, and construction mechanization. An empirical review of the underlying issues, such as compensation and reward systems, working conditions, health and safety, welfare and social integration, labour efficiency and effectiveness, was presented. The concept of construction mechanization was also broken down into issues such as the distinction between mechanization, automation and robotization, justification for mechanization and its perceived negative effects, and a method for evaluating the extent of construction mechanization. The underlying theories, including STS theory, human capital theory, theory of induced behaviour, and capitalism theory, were discussed. The theoretical and conceptual frameworks illustrating the relationships among the study's constructs were also presented. The next chapter presents the research methodology for testing these proposed relationships.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter explains the research method used in delivering the objectives of the study and thus answering the research questions. It therefore describes the research philosophy that was adopted, the research strategy and design, the target population of the study, the sample size and sampling techniques that were adopted, data collection and instruments thereof, pilot testing, validity, and finally, how the data collected was processed, analyzed, interpreted, and presented

3.2 Research Philosophy

A research philosophy is a belief and assumption about how data about a phenomenon should be collected, processed, analyzed, and used to generate new knowledge. Research philosophy helps with strengthening the choice of methodology, research strategy, data collection, and data analysis techniques and procedures (Crossan, 2003). Several philosophies have been fronted by various scholars, including positivism, pragmatism, realism, or interpretivism. Positivism holds to the view that only “factual” knowledge gained through observation, including measurement, is trustworthy when considered objectively (Bryman, 2012). Pragmatism, on the other hand, holds that there are various ways of interpreting the world and undertaking research, that no single point of view can ever give the entire picture, and that there may be multiple realities depending on how the interpretation is done (Goldkhul, 2012). Realism relies on the idea of the independence of reality from the human mind (Greener, 2008). Finally, interpretivism upholds the assumption that access to reality (given or socially constructed) is only through social constructions such as language, consciousness, shared meanings, and instruments (Saunders et al., 2019).

This research was conducted as guided by the philosophy of positivism. The choice of philosophy of positivism is informed by the fact that the researcher's purpose is to be as objective as possible throughout the study and to present the findings as they are, with the corresponding conclusion and recommendation, without any subjective bias. Positivism entails working with an observable social reality to produce law-like generalizations. Positivists strictly focus on the scientific empiricist method, formulated to generate pure data and facts without the biased influence of human interpretation. In other words, the researcher was independent from the study, and there were no provisions for human interests within the study. Positivism argues that a researcher should see an organization or social entities and their systems as real as tangible objects and other natural phenomena. Epistemologically, positivist research focuses on discovering observable and measurable parameters and thus the reliability and significance of data produced. According to Ryan (2018), a researcher can quest for spontaneous relationships from the data collected so as to establish law-like generalizations which can then be used to guess behaviour and events within an organization, a system, an industry, or within a social setup. Axiologically, positivism holds that research should be value-free and that the researcher is detached or remains impartial and independent of the research problem. In other words, the researcher operates purely on standards of objectivity. A positivist research philosophy is therefore typically deductive, highly structured, involves measurement of large samples, and depends on quantitative methods of analysis, but a range of data can be analyzed.

3.3 Research Strategy

According to Bryman (2012), research strategy is the general orientation of social research. Based on this description, the research strategy can either be qualitative or quantitative. A quantitative research strategy can be understood as research that focuses on quantification in the type of data collected and the corresponding analysis employed to interpret the data. Quantitative research strategy, therefore, involves a deductive approach to the association between research and theory, incorporation of practices and norms of the natural scientific model and positivism, and embodying a view of social reality as an external objective reality (Cohen et al., 2007). Qualitative research strategy, on the other hand, is understood as a research approach that focuses on words or statements in the collection and analysis of data. In this light, therefore, qualitative research design emphasizes an inductive approach to the association between research and theory in which primary interest in the generation of theories gives preference to how people interpret their social world and embodies a view of social reality and a dynamic emergent property of people's creations (Cooper & Schindler, 2006). Based on the above distinction, this study adopted a quantitative research strategy approach, which advocates for the collection of a large data sample to test hypothesized relationships. This is because a research hypothesis and a conceptual framework had already been presented in the preceding chapters.

3.4 Research Design

A research design is a blueprint, a roadmap, or a framework that a researcher uses to realize the objectives of his or her study (Neuman, 2020). It's a framework that incorporates the different components of research logically and coherently. The function of a research design is to ensure that the evidence obtained at the end of the study enables the researcher to effectively address the research problem as unambiguously as possible. Based on the study's research philosophy, this study adopted a survey research design. The method involves collecting data from a sample drawn from a target population to identify the extent and nature of relationships between variables. This research is normally conducted to assess the effects of certain phenomena on other phenomena, norms, or processes (Sekaran, 2003). A survey design employs the use of a questionnaire, focus group discussion, or key informants to collect data. From the data collected, this research design enables the researcher to accurately and factually generalize findings about the subject matter of the study. This method made it possible for data to be collected effectively without any manipulation of the research context.

3.5 Target Population and Sampling

The unit of analysis for this study was construction site workers. The respondents for the survey, however, comprised accredited construction site supervisors who were required to answer questions regarding the construction site workers and the construction project. There were two reasons behind this decision. First, there was a need to eliminate bias resulting from self-reporting by the construction workers, and secondly, most of the construction workers were perceived not to be academically competent to answer the questionnaire effectively. The target population, on the other hand, was based on the number of registered construction projects. This was the only possible way of reaching the respondents. Further, it enabled the researcher to visit construction sites to confirm the extent of mechanization in the construction projects.

3.5.1 Sample Size

The study's sample was established using Cochran's formula. This involves two phases in the sample size determination. In the first phase, the sample size is estimated from the infinite universe based on a desired level of precision, confidence level, and estimated proportion of the attribute of interest in the target population (Cochran, 1977).

$$n_o = \frac{t^2 \times s^2}{d^2} = \frac{1.96^2 \times 1.25^2}{0.15^2} = 266$$

Where;

- t = value for a selected alpha level of .025 in each tail = 1.96 (the alpha level of .05 indicates the level of risk the researcher is willing to take that the true margin of error may exceed the acceptable margin of error.)
- s = estimate of standard deviation in the population = 1.25. (estimate of variance deviation for 5-point scale calculated by using 5 [inclusive range of scale] divided by 4 [number of standard deviations that include almost all of the possible values in the range]).
- Where d = acceptable margin of error for mean being estimated = .15. (number of points on primary scale * acceptable margin of error; points on primary scale = 5; acceptable margin of error = .03 [error researcher is willing to except]).

In the second phase, the sample size is adjusted using the correction formula below. The adjustment applies because the estimated sample size exceeds 5% of the population (i.e., 235×5% = 12) (Bartlett et al., 2001).

$$n = \frac{n_0}{1 + {}^{n_0}/_{Population}} = \frac{266}{1 + {}^{266}/_{235}} = 125$$

Where;

- n_o = 266 (Obtained from the Cochran's formula)
- Population size = 235. (Number of building projects worth more than KShs. 100 million registered by the National Construction Authority in Nairobi County)

Hence, n = **125** construction projects

3.5.2 Sampling Technique

Sampling techniques refer to the methods used to select respondents targeted in a study out of the study population (Otzen & Manterola, 2017). Since simple random sampling ensures that all the target participants get an equal opportunity to participate in the study, it was used to select the construction projects from the target population. The study chose the site agent or clerk of works (whoever was first available) as the accredited construction site supervisor to respond to the questionnaire. The accredited construction site supervisors helped answer the question on the centrality, dispersion, and degree of mechanization, as well as the construction workers' work life and performance.

3.6 Operational Definitions of Variables

The operational definition of the study variables has been presented in Tables 3.1, 3.2, and 3.3. The study comprises two dependent variables, namely, the Performance of Construction Workers (PCW) and Quality of Work Life (QWL). The Performance of Construction Workers has been broken down into two constructs (quantitative and qualitative aspects), namely labour efficiency (LE) and effectiveness of construction workers (EF). The labour efficiency has been further broken down into the various work elements found in a typical building construction project, as shown in Table 3.1. The effectiveness of construction workers, on the other hand, has been broken down into the quality of work (QWo) and the Extent of Training, Skillset, and Development (TSD). The second dependent variable, Quality of Work Life (QWL), was broken down into four constructs, namely, Fairness of Compensation and Reward Systems

(CRS), Quality of Working Conditions (WC), Quality of Health and Safety (HS), and Quality of Welfare and Social Integration (WSI). The independent variable, the Extent of Construction Mechanization (M), was evaluated across the various work elements found in a typical building construction project.

Table 3.1: Operational Definitions of Construction Worker Performance

Variable	Operational Definition
Y_1: Performance of Construction Workers (PCW);	The extent to which construction workers achieved their assigned tasks and met the required standards of quantity (labour efficiency) and quality (effectiveness of construction workers).
$Y_{1.1}$: Labour Efficiency (LP)	The rate at which construction workers produce work, measured quantitatively based on their estimated efficiency in task delivery.
$Y_{1.1a}$: Site Preparation and Earthworks (LP_{SPE})	The efficiency with which construction workers delivered tasks associated with Site Preparation and Earthworks, measured as a percentage
$Y_{1.1b}$: Scaffolding and Formwork (LP_{SF})	The efficiency with which construction workers delivered tasks associated with Scaffolding and Formwork, measured as a percentage
$Y_{1.1c}$: Concreting (LP_C)	The efficiency with which construction workers delivered tasks associated with Concreting, measured as a percentage
$Y_{1.1d}$: Walling (LP_W)	The efficiency with which construction workers delivered tasks associated with Walling, measured as a percentage
$Y_{1.1e}$: Plastering and Flooring (LP_{PF})	The efficiency with which construction workers delivered tasks associated with Plastering and Flooring, measured as a percentage
$Y_{1.1f}$: Tiling and Painting (LP_{TP})	The efficiency with which construction workers delivered tasks associated with Tiling and Painting, measured as a percentage
$Y_{1.1g}$: Building Services (LP_{BS})	The efficiency with which construction workers delivered tasks associated with Building Services, measured as a percentage
$Y_{1.2}$: Effectiveness of Construction Workers (EF)	The ability of construction workers to achieve the goals and objectives associated with the tasks they were performing.
$Y_{1.2a}$: Quality of Work (QWo)	The degree to which construction workers produced outputs that met or exceeded the specified standards, requirements, and expectations. This was evaluated based on five (5) indicators and a 5-point Likert scale

Variable		Operational Definition
	$Y_{1.2b}$: Extent of Training, Skillset, and Development (TSD)	The extent of a combination of technical, cognitive, and interpersonal skills possessed by construction workers. This was evaluated based on five (5) indicators and a 5-point Likert scale

(Own Formulation)

Table 3.2: Operational Definitions of Quality of Work Life

Variable		Operational Definition
Y_2: Quality of Work Life (QWL)		The overall satisfaction and well-being of construction workers while at work. This was measured based on the following;
	$Y_{2.1}$: Fairness of Compensation and Reward Systems (CRS),	The degree to which construction workers perceived their pay, benefits, and recognition to be equitable, competitive, and aligned with their skills, experience, and contributions to the construction project. This was measured based on six (6) indicators and a 5-point Likert scale
	$Y_{2.2}$: Quality of Working Conditions (WC),	The physical, social, and psychological environment in which construction workers operated. This was measured based on nine (9) indicators and a 5-point Likert scale
	$Y_{2.3}$: Quality of Health and Safety (HS),	The degree to which construction workers were protected from physical, mental, and emotional harm while performing their duties on site. This was measured based on eight (8) indicators and a 5-point Likert scale
	$Y_{2.4}$: Quality of Welfare and Social Integration (WSI).	The extent to which construction workers' basic needs, such as food, water, shelter, and sanitation, were met, and the degree to which they felt socially connected, supported, and included within the organization. This was measured based on eight (8) indicators and a 5-point Likert scale

Source: (Own formulation)

Table 3.3: Operational Definitions of Construction Mechanization

Variable	Operational Definition
X: Extent of Construction Mechanization (M)	The degree to which construction processes and activities were mechanized, automated, or robotized, replacing traditional manual labour with machines and technology.
X_1: Site Preparation and Earthworks (M_{SPE})	The extent to which construction processes and activities associated with Site Preparation and Earthworks were mechanized, automated, or robotized.
X_2: Scaffolding and Formwork (M_{SF})	The extent to which construction processes and activities associated with Scaffolding and Formwork were mechanized, automated, or robotized.
X_3: Concreting (M_C)	The extent to which construction processes and activities associated with Concreting were mechanized, automated, or robotized.
X_4: Walling (M_W)	The extent to which construction processes and activities associated with Walling were mechanized, automated, or robotized.
X_5: Plastering and Flooring (M_{PF})	The extent to which construction processes and activities associated with Plastering and Flooring were mechanized, automated, or robotized.
X_6: Tiling and Painting (M_{TP})	The extent to which construction processes and activities associated with Tiling and Painting were mechanized, automated, or robotized.
X_7: Building Services (M_{BS})	The extent to which construction processes and activities associated with Building Services were mechanized, automated, or robotized.

Source: (Own formulation)

3.7 Validity of the Study

Validity looks at how accurately the data obtained in the study represent the variables of the study (Mugenda & Mugenda, 2003). Boudah (2011) more explicitly states that validity is the extent to which the conclusions extracted by a study from the analysis results are free from flawed processes. Validity explains how well-collected data covers the actual area of interest of a study (Ghauri & Grønhaug, 2005). It means the research instruments measure what they are intended to measure (Field, 2005). There are various forms of validity, including face validity, criterion validity, and construct validity.

3.7.1 Face Validity

Face validity is about the opinion of a reviewer on whether a construct seems to measure the parameter it is supposed to measure. Face validity is consequently validity based on the opinion of an independent person from the research on whether a construct is relevant and appropriate for measuring the parameter of interest. Measurement of face validity is one of the simplest and easiest steps of measuring the general validity of a research construct or technique (Raykov & Marcoulides, 2012). The credibility of the outcome of face validity is, however, dependent on whether the person whose opinion is sought is an expert or well-informed about the subject matter of the research. Satisfactory face validity implies that the research construct measures the parameter it is meant to measure. However, to get a satisfactory face validity node, the researcher must pick well-informed participants in the pilot and must ensure that the construct is relevant, appropriate, and adequate (Sharon et al., 2019). This study relied on experts and researchers in the same field to review the research constructs and gauge their suitability on a scale of 1-10. The experts comprised two practitioners with more than 20 years of experience, a Quantity Surveyor and an Architect, and two senior members of teaching staff, one from the University of Nairobi and another from the Technical University of Kenya. These experts were asked whether the questions regarding the constructs were relevant to the parameters being measured, whether the measurement method was suitable, and whether the measure applied to the variable. Their feedback was used to adjust the questionnaire where necessary.

3.7.2 Criterion Validity

Criterion validity is a measure of how well a test correlates with the established thresholds of comparison. Criterion validity is therefore more a validity based on comparison with the gold standards, which therefore relies on the same constructs, conceptually relevant constructs, or conceptually relevant performance or behaviour. The credibility of validity tested based on gold standards may not be ascertained if the gold standard yardstick is biased (Ghauri & Grønhaug, 2005). Notably, in most research, there are no predetermined gold standards against which a research construct can be juxtaposed. It is therefore imperative to complement criterion validity with others. That notwithstanding, criterion validity can be established through statistical testing of a new measurement technique or by statistically testing against a future performance to determine predictive validity (Raykov, 2012). This study used statistical testing of the variable measurements. The correlations between the scores on the variable tests and the criterion variables were calculated in SPSS using Pearson's correlation coefficient.

3.7.3 Construct Validity

Construct validity refers to the precision with which a test measures more complex concepts that cannot be directly measured by observation or a standard scale. Baik et al. (2019) define it as the degree to which a questionnaire measures the theoretical construct it is intended to measure. Construct validity is concerned with the degree to which a research test accurately measures what it is supposed to measure. While the other validities are just about valid or not valid, construct validity goes the extra mile to tell how accurate the validity is. This explains why it is critical to differentiate constructs of research from other related constructs and to ensure that every item in the construct and the aspects of the measurement method are solely focused on the specific construct.

To ensure construct validity, this study made sure that all questions in the questionnaire were stated concisely and in simple language, which eliminated any possible ambiguity and made sure the respondents fully understood the questions before responding. All suggestions from the pilot study, which raised issues of lack of clarity, were dealt with. For example, a table describing the various levels of mechanization coupled with given examples was provided to ensure there was no confusion on how to rate the level of mechanization. This study uses statistical analyses to test for the validity of the constructs through correlation analysis. Additionally, the study conducted regression analyses in SPSS.

3.8 Reliability of the Study

Reliability refers to the consistency of the data of a survey, observation, test, or measuring device. It is a measure of the repeatability of the processes using the same instruments and yielding the same results. Indeed, according to Boudah (2011), reliability is the extent to which an analytic instrument and processes produce steady and unfailing results. There are two types of reliability: internal and external. Internal reliability is the extent to which data collection, analysis, and interpretations are consistent given the same conditions. External reliability is the extent to which an independent researcher could replicate the study in another setting. An instrument is said to have high internal consistency reliability if the items of a scale “hang together” and measure the same construct (Huck, 2012). Cronbach's Alpha coefficient is the most commonly used measurement for internal consistency. It is viewed as the most appropriate measure of reliability where an instrument uses Likert scales (Johannesson & Perjons, 2014). No absolute rules exist for internal consistencies; however, most authors (Kombo & Tromp, 2006; Kothari, 2012; Leedy & Ormrod, 2010) agree on a minimum internal consistency coefficient of 0.70. This study applied Cronbach’s alpha, which is a statistical formula used to determine reliability based on at least two parts of the test for internal reliability.

3.9 Data Collection

The study collected data using questionnaires containing a set of questions logically related to the problem under study. The questionnaires were designed such that they induced the desired responses from the respondents, in which content, response structure, the wording of questions, question sequence, etc., were uniform for all respondents. The questionnaires contained both closed-ended and open-ended questions. The close-ended questions were measured using a 5-point Likert scale. The questionnaires were only administered physically to enable the researcher to confirm the extent of mechanization on the construction sites. Most of the questionnaires were filled in the presence of the researcher. However, in cases where it was impossible to do so, the physical questionnaires were administered through the drop-and-pick method, but after a detailed induction of the respondents. The use of a questionnaire is a fast, efficient, and relatively affordable technique for collecting large amounts of data from a sizable sample size.

The questionnaire was broken down into five parts. Part I sought to collect background data regarding the respondent and the construction project. Included in this section were the professional experience of the respondent, the project value, and the project duration. Part II measured the first dependent variable, the performance of construction workers. This was evaluated both quantitatively (labour efficiency) and qualitatively (effectiveness of construction workers). The level of effectiveness was further broken down into two aspects: quality of work and the extent of training, skill, and development. Part III evaluated the second dependent variable, the quality of work life of construction workers. This was measured across five aspects, namely, compensation and reward systems, working conditions, health and safety, and welfare and social integration. Each of these aspects was further broken down into measurable indicators. Part IV evaluated the extent of mechanization in the construction projects. The level of construction mechanization was broken down into the various work elements of a typical construction project. Construction mechanization was measured in five levels, namely, completely manual (Level 1), the use of hand tools (Level 2), the use of automated hand tools (Level 3), the use of machines and/or workstations (Level 4), and complete automation and/or robotization (Level 5). Part V of the questionnaire consisted of open-ended questions seeking to understand the subject matter in the words of the respondents. Included in this section were questions regarding the effect of construction mechanization (positive and negative) on the performance and welfare of construction workers, and ways in which mechanization can be incorporated in a construction project such that it promotes the performance and welfare of construction workers.

3.10 Data Analysis

The data collected was entered into the Statistical Package for Social Sciences (SPSS) v. 25 and followed by processing. The processing involved cleaning the raw data by checking for redundant, incorrect, or incomplete data. Additionally, the processing involved coding the raw data into a quantitative form. Coding helps with transforming the data into a quantitative format so that quantitative analysis can be done. The initial analysis focused on general findings through descriptive measures such as means and standard deviations. Secondly, a normality test was done on the data collected to determine whether the data collected was normally distributed. The Shapiro-Wilk test was used as an indicator of normality. This test identifies deviation of data from normality due to skewness or kurtosis. A limit of *p*-value of 0.05 was used to measure the normality of the data. *P*-values above 0.05 are indicative of approximately normally distributed data. Inferential statistical analysis was also done using SPSS v. 25. To establish the strength and significance of the relationship between construction mechanization, performance, and the quality of work life of construction workers, correlation analysis was undertaken. Further, two regression models were developed for each of the two dependent variables, that is, the performance and the quality of work life of construction workers.

3.10.1 Hypothesis Testing

The study hypothesized a statistically significant relationship between the two dependent variables (i.e., quality of work life and performance of construction workers) and the level of mechanization on construction projects in Kenya. The study adopted the following two multiple regression models to assess the extent to which the independent variable affects each of the dependent variables.

$$QWL = \beta_0 + \beta_1.M_{SPE} + \beta_2.M_{SF} + \beta_3.M_C + \beta_4.M_W + \beta_5.M_{PF} + \beta_6.M_{TP} + \beta_7.M_{BS} + \varepsilon$$

$$PCW = \beta_0 + \beta_1.M_{SPE} + \beta_2.M_{SF} + \beta_3.M_C + \beta_4.M_W + \beta_5.M_{PF} + \beta_6.M_{TP} + \beta_7.M_{BS} + \varepsilon$$

Where:

- QWL = Quality of Work Life, measured using four proxies namely: Fairness of Compensation and Reward Systems (CRS), Quality of Working Conditions (WC), Quality of Health and Safety (HS), Quality of Welfare and Social Integration (WSI). These proxies were also further broken down into individual indicators during data collection and analysis.
- PCW= Performance of Construction Workers; this has been measured using two proxies, namely Labour Efficiency (LP) and Effectiveness

(EF). These proxies were further broken down into individual indicators during data collection and analysis.

- B_0 = Constant.
- $B_{1,2\ldots6,7}$ = Regression coefficients for each of the X-variables
- M = Extent of Mechanization of various construction elements as follows;
    - X_1 = Site Preparation and Earthworks (M_{SPE})
    - X_2 = Scaffolding and Formwork (M_{SF})
    - X_3 = Concreting (M_C)
    - X_4 = Walling (M_W)
    - X_5 = Plastering and Flooring (M_{PF})
    - X_6 = Tiling and Painting (M_{TP})
    - X_7 = Building Services (M_{BS})

Therefore,

Null Hypothesis (H_0): $\beta_i = 0$ for all relationship coefficients of X_i. This means that mechanization does not affect the quality of work life and the performance of construction workers in Kenya.

Alternate Hypothesis (H_1): $\beta_i \neq 0$ for at least one of the relationship coefficients of X_i. This implies that at least one of the explanatory variables affects the quality of work life and the performance of construction workers in Kenya.

3.10.2 Statistical Assumptions and Diagnostic Tests

The study supposes that the respondents from whom the data were collected are normally distributed; therefore, before the analysis was done, diagnostic tests were carried out. Normality is the postulation that the error is evenly dispersed with a mean of zero and a uniform variance (Neuman, 2020). Data is considered normally spread when the Skewness and Kurtosis Z-values are within ±1.96. Alternatively, data is considered normally or approximately normally distributed if the p-values (Sig.) from Shapiro-Wilk tests are above 0.05 (Razali & Wah, 2011). Normality was tested using the Shapiro-Wilk test, which identifies deviation of data from normality due to skewness or kurtosis. A limit of the *p*-value of 0.05 was used to measure the normality of the data. *P*-values above 0.05 were indicative of approximately normally distributed data. The second assumption was that of a linear relationship. The core premise of multiple linear regression analysis is the existence of a linear relationship between the dependent and the independent variables. This linearity was visually inspected using scatterplots, which revealed a straight-line relationship. The third assumption was homoscedasticity, that is, the variance of error terms (residuals) should be consistent across all levels of the independent variables. A scatterplot of the residuals versus predicted values should not display any noticeable pattern, such as cone-shaped distributions, which would indicate heteroscedasticity.

The multicollinearity test was done using the Pearson Correlation Coefficient test to investigate the linear relationship between the study's independent variables. The test identifies the direction of the relationship between more than two variables and how strong the relationship is. When there is a seamless linear relationship between the predictors, the estimates for a regression model cannot be exclusively worked out. The multicollinearity test is used when more than two variables are involved in the linearity test. The main fear is that when the level of multicollinearity rises, the regression model's measurements of the coefficients tend to be unpredictable, and the standard errors for the coefficients can be outrageously exaggerated. The "tolerance" is a measurement of the percentage of divergence in the predictor that cannot be explained through other predictors. Inconsequential values show that a variable is surplus, and values that are below 0.1 imply that multicollinearity among the predictors is not a problem (Raykov & Marcoulides, 2012). The Variance Inflation Factor (VIF), is (1/tolerance) and as conventionally accepted, a variable whose VIF value is above 10 may point need for additional analysis. A positive value shows a direct relationship between the variables while a negative value indicates that the parameters measured are inversely related (Dancey & Reidy, 2004).

3.11 Ethical Considerations

This study followed all due diligence in having all approvals from relevant authorities before carrying out data collection. To adhere to ethical standards, the respondents were informed that their participation was voluntary. They were guaranteed the power to withdraw their participation from the study if they wished to. They were only to take part in the study by consenting to the prior information and assurances about taking part in the research, and that all the information would be held with absolute privacy. Names of respondents would not be required to ensure the anonymity of the individuals responding to the study. To uphold integrity, the researcher used gender-sensitive and acceptable language in the formulation of questionnaires and data presentation. The highest level of objectivity in discussions and analysis was maintained throughout the study, as well as maintaining all the ethical requirements of the University and the National Commission for Science, Technology and Innovation (NACOSTI).

CHAPTER FOUR

DATA ANALYSIS AND DISCUSSION

4.1 Introduction

This chapter presents the results obtained from the data collection exercise. The analysis of those results and their discussion have also been covered in this chapter. However, the chapter first presents the response rate analysis and the reliability and validity test results. The chapter then presents an analysis of the background information before delving into the results pertaining to the research objectives.

4.2 Response Rate, Reliability, and Validity Tests

A total of 125 questionnaires were administered physically to the randomly selected construction sites. A total of 116 questionnaires were received back. However, three of the questionnaires were discarded due to incompleteness. Two of these questionnaires had the entire Part IV of the questionnaire left blank, while the other had not responded to large sections of Part II. Therefore, the number of usable questionnaires was 113 which was equivalent to a response rate of 90.4%. In these questionnaires, the number of missing values was negligible. Notably, Part 1 (Background Information) of the questionnaire was completely filled out. The highest recorded number of missing values in a single questionnaire was three (3). In all cases, the missing values were replaced with the mean of the available responses.

Table 4.1: Response Rate

Distributed	Total returned	Non-usable	Usable	Response rate	Remark
125	116	3	113	90.4%	Acceptable

Source: (Fieldwork, 2025)

The reliability of the collected data was established using Cronbach Alpha values obtained using SPSS version 25. The aim of this was to determine the internal consistency of the data. The results have been presented in Table 4.2. 71% of the variables recorded values exceeding 0.9. The remaining 29% which recorded values lower than 0.9 were X-variables (Level of Mechanization). This could be attributed to the expected varying levels of mechanization across different tasks and subtasks within a construction project, resulting in lower internal consistency. Nevertheless, all the variables recorded acceptable Cronbach's Alpha values.

Table 4.2: Reliability Test Results

	Variables	N of Items	Cronbach Value	Remarks
Y_1	Performance of Construction Workers	30	0.958	Excellent
	Y_{1a}) Labour Efficiency	20	0.990	Excellent
	Y_{1b}) Effectiveness	10	0.963	Excellent
	i). Quality of Work	5	0.960	Excellent
	ii). Training, Skillset and Development	5	0.979	Excellent
Y_2	Quality of Work Life of Construction Workers	31	0.957	Excellent
	Y_{2a}) Compensation and Reward Systems	6	0.984	Excellent
	Y_{2b}) Working Conditions	9	0.969	Excellent
	Y_{2c}) Health and Safety	8	0.969	Excellent
	Y_{2d}) Welfare and Social Integration	8	0.991	Excellent
X	Level of Mechanization	88	0.958	Excellent
	X_1) Site Preparation and Earthworks	11	0.857	Good
	X_2) Scaffolding and Formwork	18	0.951	Excellent
	X_3) Concreting	15	0.934	Excellent
	X_4) Walling	7	0.859	Excellent
	X_5) Plastering and Flooring	11	0.667	Acceptable
	X_6) Tiling and Painting	13	0.929	Excellent
	X_7) Building Services	13	0.654	Acceptable

NB: The highlighted cells are a summation/average of factors below

Source: (Fieldwork, 2025)

The construct validity of the collected data was checked using Pearson's Product-Moment Correlation as advocated by Karras (1997). The validity test was conducted by correlating each variable with a newly computed variable (Total) which was the sum of all the variables under consideration. Significant relationships are an indication of the presence of validity (Ahrens et al., 2020). As presented in Table 4.3, all the variables were found to have construct validity.

Table 4.3: Construct and Criterion Validity Test Results

Variable		**Total (Sum of the Variables)**
Labour Efficiency (LP)	Pearson Correlation	0.246**
	Sig. (2-tailed)	0.009
Effectiveness of Construction Workers (EFF)	Pearson Correlation	.365**
	Sig. (2-tailed)	0.000
Fairness of Compensation and Reward Systems (CRS)	Pearson Correlation	0.627**
	Sig. (2-tailed)	0.000
Quality of Working Conditions (WCs)	Pearson Correlation	0.830**
	Sig. (2-tailed)	0.000
Quality of Health and Safety (HS)	Pearson Correlation	0.540**
	Sig. (2-tailed)	0.000
Quality of Welfare and Social Integration (WSI)	Pearson Correlation	0.537**
	Sig. (2-tailed)	0.000
Level of Mechanization (M)	Pearson Correlation	0.042*
	Sig. (2-tailed)	0.046
	Sig. (2-tailed)	

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Source: (Fieldwork, 2025)

4.3 Background Information

Three aspects were included in the background information section. These included professional experience, project value, and project duration. Their results have been analyzed and discussed in the following sections.

4.3.1 Professional Experience

The professional experience was grouped into five categories namely: 1-5, 6-10, 11-15, 16-20, and above 20 years. The results are presented in Figure 4.1. The highest frequency was recorded between 6-10 years (n=48, 42.5%) while the lowest was reported for the group above 20 years (n=9, 8%). Those with minimal professional experience of between 1-5 years were not considerably high, as they only had a frequency of 13 (11.5%). Since an overwhelming majority (n=100, 88.5%), it is evidently clear that the respondents had adequate experience and exposure in the construction industry to provide results rich in “validity”.

Figure 4.1: Professional Experience

Source: (Fieldwork, 2025)

4.3.2 Project Value

In this section, the researcher enquired about the current project value. The aim of this was to better understand the context and provide an explanation for the reported levels of mechanization, since high-value projects are expected to embrace machines and technology more than smaller projects. In this regard, the study only considered projects that were worth more than KShs 100 million. This is to avoid skewed results since very small projects would record negligible levels of mechanization and thus need a study on their own. The majority of the projects (n=103, 91.2%) had their contract sums between KShs 100 and 900 million with only 10 (8.8%) being worth over KShs 100 million. As shown in Figure 4.2, the highest frequency (n=43, 38.1%) was reported in “KShs 301-500 million”, followed by “KShs 101-300 million” (n=28, 24.8%)

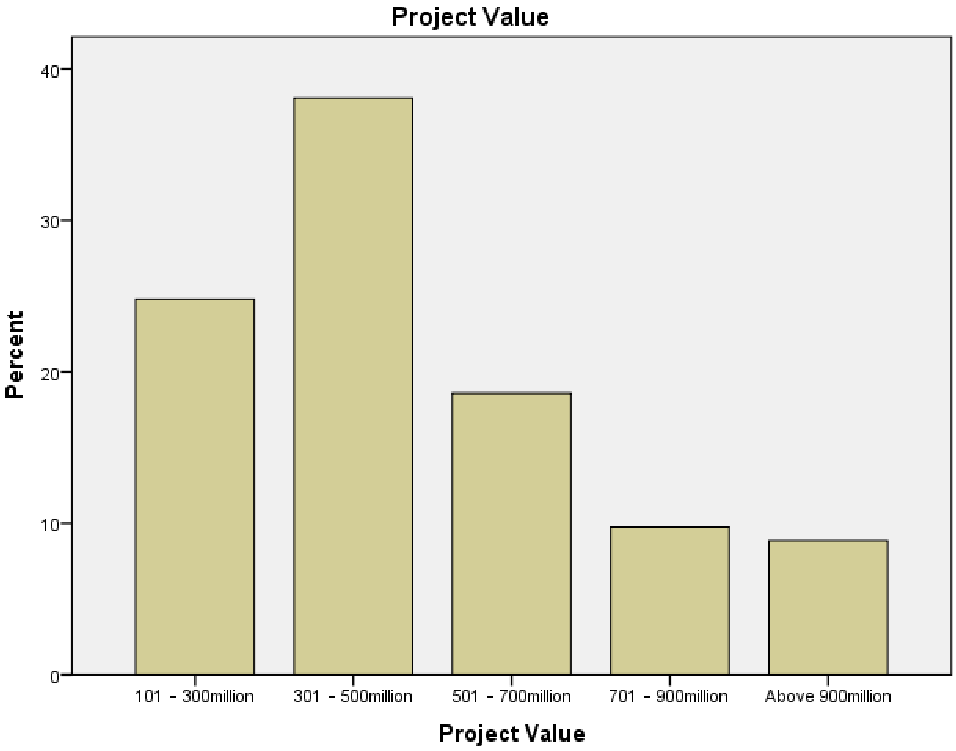

Figure 4.2: Project Value

Source: (Fieldwork, 2025)

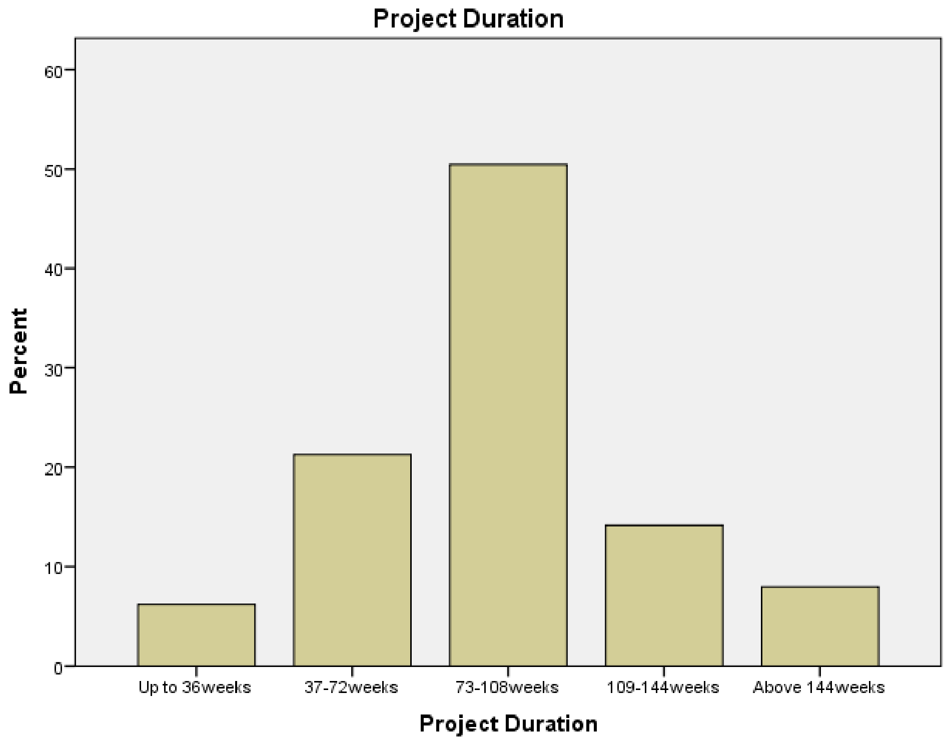

Figure 4.3: Project Duration

Source: (Fieldwork, 2025)

4.3.3 Project Duration

The project duration was measured in weeks based on intervals of 36 weeks. As seen in Figure 4.3, the results were fairly distributed demonstrating a bell curve with the majority of the projects (n=97, 85.8%) lying between 37 and 144 weeks. Projects with durations below 36 weeks and above 144 weeks recorded frequencies of 7 (6.2%) and 9 (8.0%), respectively. The highest frequency was reported between 73-108 weeks (n=57, 50.4%).

4.4 Performance of Construction Workers

Performance of Construction Workers (PCW) was one of the two dependent variables in this study. As demonstrated in the theoretical framework, performance can either be viewed quantitatively or qualitatively. It is not just about work being done (quantitative), but being done correctly (qualitative). The former was evaluated based on the labour efficiency in various tasks while the latter was assessed based on the quality of work and the extent of training, skillset, and development of construction workers.

4.4.1 Labour Efficiency

Labour efficiency was evaluated based on how long the workers took to accomplish various tasks per unit of time. It was a measure of how quickly tasks were executed. The labour efficiency was broken down into the various work elements found in a typical building construction project. It was measured as a percentage ranging from 0% to 100% and broken down in an ordinal scale which was interpreted as demonstrated in Table 4.4.

Table 4.4: Interpretation Scale for Labour Efficiency Values

Score	1=0-20%	2=21-40%	3=41-60%	4=61-80%	5=81-100%
Remark	Very Low	Low	Moderate	High	Very High

Source: (Author formulation)

The results of the labour efficiency together with normality tests have been presented in Table 4.5. The labour efficiency in the studied construction projects ranged between 64.8% (plumbing works) and 69.6% (concrete mixing), representing a very small range of only 4.8%. This was an indication that tasks in various work elements are carried out at a fairly equal rate. This includes even works which are usually subcontracted, such as plumbing and electrical works. However, aggregated labour efficiency values presented in Table 4.6 show that these works have the lowest performance. The overall labour efficiency in the studied construction projects was 66.8%. Based on the developed interpretation scale, all the tasks reported “high” labour efficiency results.

The standard deviation results (ranging between 0.579 and 0.700) indicated that the data were not heavily spread out across all measured indicators of the labour efficiency variable. The normality tests revealed that the data were normally distributed as seen in the skewness and kurtosis values lying between -1.0 and +1.0. The reported standard error for the skewness and kurtosis results was 0.227 and 0.451 respectively.

Table 4.5: Labour Efficiency in Construction Projects

Work Category	Task	Mean	SD	Skewness	Kurtosis	%
Site Preparation and Earthworks	a) Site clearance (m^2/hr)	3.28	.688	-.603	-.038	65.6%
	b) Setting out (m^2/hr)	3.36	.682	-.605	-.710	67.2%
	c) Earthworks (m^3/hr)	3.28	.661	-.382	-.739	65.6%
Scaffolding and Formwork	a) Erecting lifts (m^2/hr)	3.35	.579	-.211	-.667	67.0%
	b) Installing deck (m^2/hr)	3.24	.616	-.196	-.545	64.8%
	c) Dismantling scaffold (m^2/hr)	3.32	.587	-.202	-.608	66.4%
	d) Formwork (fixing/removing) (m^2/hr)	3.35	.611	-.376	-.643	67.0%
Concreting	a) Rebar preparation (kgs/hr)	3.46	.627	-.731	-.437	69.2%
	b) Material batching (m^3/hr)	3.36	.642	-.502	-.649	67.2%
	c) Mixing (m^3/hr)	3.48	.584	-.597	-.588	69.6%
	d) Concrete pouring (m^3/hr)	3.36	.613	-.404	-.642	67.2%
	e) Vibrating (m^3/hr)	3.34	.621	-.375	-.644	66.8%
Walling	a) Preparation (m^3/hr)	3.39	.647	-.585	-.613	67.8%
	b) Stone laying (m^2/hr)	3.35	.667	-.549	-.696	67.0%
Plastering and Flooring	a) Plastering and Screeding (m^3/hr)	3.40	.662	-.651	-.603	68.0%
	b) Terrazzo flooring (m^3/hr)	3.33	.700	-.553	-.817	66.6%
Tiling and Painting	a) Tiling (m^3/hr)	3.27	.682	-.389	-.820	65.4%
	b) Painting (m^3/hr)	3.28	.688	-.435	-.830	65.6%
Building Services	a) Plumbing works (piping)(m/hr)	3.24	.698	-.365	-.899	64.8%
	b) Electrical works (conduits)(m^3/hr)	3.30	.680	-.457	-.790	66.0%

Source: (Fieldwork, 2025)

The labour efficiency among the work categories was summarized in Table 4.6. As can be seen, the aggregated values ranged from 65.40% to 68.00% in building services and concreting respectively. The range was also narrow (2.6%), just like in the detailed labour efficiency results presented in Table 4.5. The second and third-best performers were walling (67.40%) and plastering and flooring (67.30%), while tiling and painting were the second-least performed with a labour efficiency of 65.50%.

Table 4.6: Summary of Labour Efficiency

	Labour Efficiency		
Work Category	**Mean**	**Percentage**	**Rank**
a) Site Preparation and Earthworks	3.31	66.13%	5
b) Scaffolding and Formwork	3.32	66.30%	4
c) Concreting	3.40	68.00%	1
d) Walling	3.37	67.40%	2
e) Plastering and Flooring	3.37	67.30%	3
f) Tiling and Painting	3.28	65.50%	6
g) Building Services	3.27	65.40%	7
Overall	**3.33**	**66.80%**	

Source: (Fieldwork, 2025)

The construction industry is generally labour-intensive and heavily relies on the skills of its workforce. Bamfo-Agyei et al. (2019) noted that the workforce is the industry's most valuable asset and accounts for at least a quarter of the total project cost. Construction labour efficiency and productivity are regarded as effective indicators of the efficiency of the industry's activities (Jang et al., 2016). A decrease in labour efficiency is an increase in labour cost (Amae, 2020). It is a critical aspect of the construction industry that is mostly used as an index for evaluating the efficiency of production. Its importance can be highlighted by its ability to predict the status of economic growth and related production from both industrial and corporate perspectives (Jarkas & Bitar, 2012).

Based on the results in Table 4.6, Concreting emerged as the work category with the highest labour efficiency. For a long time now, the construction industry operations in Kenya, especially on project sites, have remained constant. This is because a previous study by Wachira (1999) corroborates these findings by suggesting that the highest efficiency is recorded in Concreting operations due to the belief that it is the most expensive trade and hence a need to keep a keen eye on it. The labour efficiency values reported in Table 4.6 range from 65.4% and 68.0%. Though based on the adopted scale in Table 4.4, this could be described as High, it still falls short of the expected 100% rating. These values are comparatively lower than the average working rate of 80 reported by Wachira (1999). The lower-than-standard efficiency rating reflects the inadequacy of the workers' supervision and shows that with increased supervision, labour productivity and efficiency can increase even without altering other site conditions.

4.4.2 Effectiveness of Construction Workers

The effectiveness of construction workers was the qualitative way of assessing their performance. It was measured based on two aspects, namely; quality of work (QWo) and the Extent of Training, Skillset, and Development (TSD). The results have been presented in the following sections.

a) Quality of Work (QWo)

The quality of work produced by the construction workers was evaluated based on 5-point criteria namely: accuracy, workmanship, timeliness, minimal rework, and minimal supervision. This was measured using a 5-point Likert scale. The results have been presented in Table 4.7. The means ranged between 2.98 (accuracy, 59.6%) and 3.14 (minimal rework, 62.8%). This was found to be very interesting since these two aspects ought to be highly related and dependent on one another. It is expected that where accuracy is the lowest, there would be the highest rework. However, since the range between these two was found to be minimal (0.16), there was no need to seek further explanation for the phenomenon. The levels of accuracy and workmanship were found to be almost equal which was very understandable given that these two aspects go hand in hand. The overall level of quality of work was found to be 3.03 (60.6%).

The standard deviation results (ranging between 0.463 and 0.597) indicated that the data were not heavily spread out across all measured indicators of the quality of work variable. The normality tests for the quality of work variable revealed that the data were normally distributed as seen in the skewness and kurtosis values lying between -1.0 and +1.0. The reported standard error for the skewness and kurtosis results was 0.227 and 0.451 respectively.

Table 4.7: Quality of Work

QWo Factors	Mean	%	SD	Skewness	Kurtosis	Rank
Accuracy	2.98	59.6%	.463	-.067	1.836	5
Workmanship	2.99	59.8%	.543	-.007	0.498	4
Timeliness	3.04	60.8%	.550	.022	0.390	2
Minimal rework	3.14	62.8%	.532	.133	0.308	1
Minimal supervision	3.02	60.4%	.597	-.005	-0.128	3

Source: (Fieldwork, 2025)

Accuracy and workmanship were the two worst-performing aspects of the effectiveness of workers. Studies in Kenya dating as far back as the 1990s cited worrying levels of workmanship. For example, Munderu (1990) attributed poor workmanship in rural construction projects to inadequacies in the specified materials and a poor level of competence. Ndoka (2007) attributed it to lack of close supervision, lack of work experience, lack of training for workers, lack of clarity in specifications, lack of care, subcontracting, lack of proper tools and equipment, poor communication, and lack of motivation by workers. Clearly, based on the results presented in Table 4.7, these problems continue to plague the construction industry in Kenya.

This problem is not only unique to Kenya. In Nigeria, Yahya et al. (2019) observes that poor workmanship in construction projects is as a result of Inadequate involvement of the client during construction, aggressive competition during tendering, which results in low bids, lack of conformance to specifications, and poor monitoring. According to Ntuli and Allopi (2014), workmanship is one of the most frequent non-conformances on construction sites and is mostly caused by poor project management, Unsuitable construction equipment, poor communication and language barrier, incompetence by workers, subcontracting, limited cost, limited time, and poor weather conditions. Findings by Abdu (2019) show that the quality rating for workmanship for floor, wall, and ceiling was 55%, 86%, and 58%, respectively, and were rated moderate quality. These results were not very different from those presented in Table 4.7 whereby the level of workmanship was 59.8%. These findings demonstrate that the quality of workmanship in construction projects in developing countries is still very low compared to developed countries.

b) Extent of Training, Skillset, and Development (TSD)

The research also sought to establish the extent of training, skillset, and development among the construction workers. This is because such would be a measure of how effective the construction workers were in the delivery of assigned tasks. The measurement was achieved using a 5-point Likert scale. The results presented in Table 4.8 showed the leading indicator to be learning new methods (mean=3.43, 68.6%) while the lowest ranking was the possibility of career growth (mean=3.27, 65.4%). The range between these two was almost negligible (0.16). The overall level of the extent of training, skillset, and development among the construction workers was found to be 3.36 (67.2%).

The standard deviation results (ranging between 0.650 and 0.783) indicated that the data were not heavily spread out across all measured indicators of the extent of training, skillset, and development variable. The normality tests revealed that the data were normally distributed as seen in the skewness and kurtosis values lying between -1.0 and +1.0. The reported standard error for the skewness and kurtosis results was 0.227 and 0.451 respectively.

Table 4.8: Extent of Training, Skillset, and Development

TSD Factors	Mean	%	SD	Skewness	Kurtosis	Rank
Worker development	3.41	68.2%	.715	.259	-.094	2
Career growth	3.27	65.4%	.658	-.359	-.731	5
Personal growth	3.29	65.8%	.650	-.374	-.704	4
New methods	3.43	68.6%	.653	.642	.080	1
Training	3.38	67.6%	.783	.008	-.414	3

Source: (Fieldwork, 2025)

The extent of training, skillset, and development among the construction workers was relatively greater than the quality of work by these workers discussed in the previous section. This could be attributed to combined efforts by various government agencies, such as the National Construction Authority (NCA) and the National Industrial Training Authority (NITA), who have initiated various onsite training programmes aimed at enhancing skill development among construction workers in Kenya. For example, the NCA created an apprenticeship programme in 2016 to attract new construction workers who had experience of less than two years and no technical certifications (National Construction Authority, 2021). The NCA set up another training and certification programme in 2017, themed '*Jenga smart'*, targeting artisans and site supervisors. The training was provided at no cost and aimed at sharpening the skills of the artisans, training them on the importance of using Personal Protective Equipment (PPE), and sensitizing them on industrial rights (Wandia & Ralwala, 2024). The training sessions were on-site. The NCA also partnered with Technical and Vocational Education and Training (TVET) institutions and successfully trained 15,000 skilled workers (Mwitari, 2018). According to Mwitari (2018), other governmental and non-governmental stakeholders in the construction industry have partnered with the NCA and NITA to adopt this form of training to bridge the skill gap and empower the trainees. Further, according Ndaiga (2016), several construction firms in Kenya have also engaged in training and certifying semi-skilled workers to enhance their competence and improve their employability. Some of these firms are registered with NCA and/or NITA as trainers and also work in partnership with other non-profit organizations.

4.4.3 Overall Performance of Construction Workers

The aggregated results for the performance of construction workers have been presented in Table 4.8. In order to enable comparison, the effectiveness of construction workers was also converted into a percentage. The results indicate that the qualitative aspect (effectiveness) of construction worker performance was lower than the quantitative aspect (labour efficiency) by 4 percentage points. It is an indication that there is a higher emphasis on the quantity of output compared to the quality of the resulting work. Construction workers and perhaps their supervisors care more about the delivery of the job. This is despite the fact that the labour efficiency performance was also not as impressive as it would be expected (62.4%).

The standard deviation results (0.405 and 0.463) indicated that the data were not heavily spread out across all measured indicators of the performance of the construction workers variable. The normality tests revealed that the data were normally distributed as seen in the skewness and kurtosis values lying between -1.0 and +1.0. The reported standard error for the skewness and kurtosis results was 0.227 and 0.451 respectively.

Table 4.8: Overall Performance of Construction Workers

Aspect	N	Mean	SD	Skewness	Kurtosis	%
Labour efficiency	14	3.33	.463	-.181	-.241	62.4%
Effectiveness	14	3.20	.405	.311	-.100	58.4%

Source: (Fieldwork, 2025)

Evidently, the performance of construction workers is below par. There is a huge potential for improvement in the performance of construction workers in Kenya's construction industry, which needs to be exploited in the push for improved delivery of construction projects. Advances in technology and the consequent increase in construction mechanization globally can be harnessed to improve construction workers' performance.

4.5 Quality of Work Life of Construction Workers

Quality of Work Life (QWL) was the second dependent variable in this study. It was broken down into four aspects in its evaluation. These were, Fairness of Compensation and Reward Systems (CRS), Quality of Working Conditions (WC), Quality of Health and Safety (HS), and Quality of Welfare and Social Integration (WSI). Their results have been presented and discussed in the following sections.

4.5.1 Fairness of Compensation and Reward Systems (CRS)

This section sought to determine the fairness of compensation and reward systems for construction workers. This was measured using a 5-point Likert scale and the results are presented in Table 4.9. The leading factor was established to be "timely payments" (mean=3.44, 68.8%), followed by "reward for exemplary work" with a mean of 3.36 (67.2%). Coincidentally, the equity of remuneration within and outside the construction project reported the same mean of 3.19. The least ranked factor was "adequacy of wages" (mean=3.04, 60.8%). Construction workers felt that they were not adequately compensated for their services. Notably, "the regular increase of wages" also performed dismally, coming second-last with a mean of 3.11 (62.2%). The overall extent of "fairness of compensation and reward systems" to the construction workers was established to be 3.22 (64.4%).

The standard deviation results (ranging between 0.783 and 0.844) indicated that the data were not heavily spread out across all measured indicators of the "fairness of compensation and reward systems" variable. The normality tests revealed that the data were normally distributed as seen in the skewness and kurtosis values lying between -1.0 and +1.0. The reported standard error for the skewness and kurtosis results was 0.227 and 0.451 respectively.

Table 4.9: Fairness of Compensation and Reward Systems

CRS factors	Mean	SD	Skewness	Kurtosis	Rank
Fair wages	3.04	.828	-.083	-1.538	6
Wage increment	3.11	.783	-.190	-1.341	5
Timely payments	3.44	.812	-.982	-.759	1
Reward for exemplary work	3.36	.814	-.761	-1.062	2
Equity of remuneration (within)	3.19	.851	-.368	-1.526	3
Equity of remuneration (without)	3.19	.844	-.384	-1.493	3

Source: (Fieldwork, 2025)

The construction industry in Kenya is multi-layered, with most construction workers operating under contractors, sub-contractors, and clients, who tend to be informal and not registered with government authorities. This poses challenges in monitoring and enforcing regulations, labour laws, and standards in the sector (Riisgaard et al., 2021). Most construction workers are hired on a short-term basis, ranging from daily, a few days, weekly, and monthly, with very few having steady employment with one employer for more than six months. This makes them ineligible for any worker benefits due to their classification as casual workers. Only in a few cases do employers cater for some aspects of their social protection, but without full commitment, leaving workers straddling between formal and informal social protection models (Mitullah, 2021). According to a recent survey, unskilled construction labourers typically earn between Ksh10,957 and Ksh25,751 net per month, while skilled workers earn up to Ksh68,338 (Wage Indicator Foundation, 2024).

4.5.2 Quality of Working Conditions (WC)

The quality of working conditions is an important aspect of QWL. Nine (9) factors were used to assess the quality of working conditions experienced by construction workers on sites. These were measured based on a 5-point Likert scale and the results are presented in Table 4.10. The extent of quality of working conditions ranged between 3.42 (68.4%) and 3.72 (72.4%). As noted, the range was also low. There seems to be comparatively less involvement of construction workers in decision-making as seen in the low ranking. Also, the work environment is not highly encouraging. The overall extent of quality of working conditions was established to be 3.63 (72.6%).

The standard deviation results (ranging between 0.624 and 0.881) indicated that the data were not heavily spread out across all measured indicators of the quality of working conditions variable. The normality tests revealed that the data were normally distributed as seen in the skewness and kurtosis values lying between -1.0 and +1.0. The reported standard error for the skewness and kurtosis results was 0.227 and 0.451 respectively.

Table 4.10: Quality of Working Conditions

WC Factors	Mean	SD	Skewness	Kurtosis	Rank
Favourable work environment	3.72	.796	-1.175	.753	1
Encouraging work environment	3.64	.802	-.934	.167	6
Adequate facilities	3.65	.812	-.893	.131	4
Easier to receive materials	3.64	.802	-.934	.167	6
Adequate job security	3.65	.812	-.893	.131	4
Workers self-motivation	3.71	.873	-.702	-.123	3
Resolution of grievances	3.72	.881	-.685	-.158	1
Workers involvement in decision-making	3.50	.733	-.016	-.248	8
Relationships between supervisors and workers	3.42	.624	-.607	-.554	9

Source: (Fieldwork, 2025)

Construction workers who tend to be informal operate under precarious and difficult working conditions, often without social protection, contracts, and labour rights (Mitullah et al., 2021). Of particular concern is the absence of contracts among construction workers who work in an identifiable employment relationship, which undermines their chances of accessing labour rights as provided in Kenya's policies and regulations.

A number of studies have been done on stress levels among workers in the construction industry globally. In Nigeria, a study established that there were high stress factors among construction workers resulting from insufficient thermal comfort, insufficient feedback, high workload, fragmentation of construction work into specialized fields, and inadequate security and safety measures on site (Ibem et al., 2011). In the United Kingdom, it was established that construction professionals were progressively viewing their jobs as being stressful (Campbell, 2006). In Hong Kong, high levels of job burnout have been reported among construction professionals, which has not only endangered their well-being but also diminished their efficiency and long-term competitiveness (Yip et al., 2005). Here in Kenya, the main causes of work stress among construction workers were found to be work overload, complexity of roles, role conflict, and feedback (Kioko, 2020).

4.5.3 Quality of Health and Safety (HS)

The quality of health and safety experienced by the construction workers was evaluated based on 8-point criteria. This was measured using a 5-point Likert scale. The results have been presented in Table 4.11. The means ranged between 3.29 (65.8%) and 3.81 (76.2%). Other than training in health and safety, other poorly ranked factors included safety and health of the physical environment (mean=3.32, 66.4%), and reasonable working times (mean=3.61, 72.2%). The overall level of the quality of health and safety experienced by the construction workers was found to be 3.63 (72.6%).

The standard deviation results (ranging between 0.439 and 0.554) indicated that the data were not heavily spread out across all measured indicators of the quality of health and safety variable. The normality tests revealed that the data were normally distributed as seen in the skewness and kurtosis values lying between -1.0 and +1.0. The reported standard error for the skewness and kurtosis results was 0.227 and 0.451 respectively.

Table 4.11: Quality of Health and Safety

HS Factors	Mean	SD	Skewness	Kurtosis	Rank
Emphasis on worker health and safety	3.68	.468	-.789	-1.402	5
Reasonable working times	3.61	.490	-.460	-1.821	6
Safety and health of physical environment	3.32	.468	.789	-1.402	7
PPEs	3.81	.549	-.081	-.065	1
Barricading and safety signage	3.81	.544	-.103	.009	1
Health and safety inspections	3.74	.439	-1.129	-.738	4
Training in health and safety	3.29	.494	1.371	.848	8
Reasonable noise levels	3.80	.554	-.058	-.134	3

Source: (Fieldwork, 2025)

The construction industry has, for a long time, earned the reputation of being a dangerous and highly hazardous industry due to the disproportionately high incidence of accidents and fatalities occurring on construction sites globally (Haupt et al., 2020). The results presented in Table 4.11, showing the quality of health and safety to range between 65.8% and 76.2%, demonstrate that the construction industry of Kenya is still performing dismally since the expected compliance levels based on both the Occupation Health and Safety Act (2007) and NCA safety guidelines is 100%. According to Ndinyo et al. (2023), the high incidence of unhealthy and unsafe construction projects has caused significant anguish to stakeholders in the construction industry in Kenya.

In the study conducted in Nairobi (Kemei et al., 2016), it was established that most injuries in construction sites are as a result of falling objects (17%), falling from heights (15%), operating motor vehicles or light machines (13%), and lifting heavy objects (11%). The study further found out that the main factors causing these accidents are: lack of training (12%), reluctance to provide resources for safety (12%), poor safety consciousness among workers (11%), failure to enforce rules and regulations (12%), and lack of strict operational procedures (11%) in construction sites.

4.5.4 Quality of Welfare and Social Integration (WSI)

The research also sought to establish the extent of quality of welfare and social integration. The measurement was achieved using a 5-point Likert scale. The results presented in Table 4.12 showed the leading indicator to be fairness in workload distribution (mean=3.71, 74.2%) while the lowest ranking was Sense of one community (mean=3.44, 68.8%). The range between these two was low (0.3). The overall extent of quality of welfare and social integration was found to be 3.55 (71.0%).

The standard deviation results (ranging between 0.593 and 0.628) indicated that the data were not heavily spread out across all measured indicators of the quality of welfare and social integration variable. The normality tests revealed that the data were normally distributed as seen in the skewness and kurtosis values lying between -1.0 and +1.0. The reported standard error for the skewness and kurtosis results was 0.227 and 0.451 respectively.

Table 4.12: Quality of Welfare and Social Integration

WSI Factors	Mean	SD	Skewness	Kurtosis	Rank
Workers' rights	3.63	.615	.432	-.638	3
Worker transport to work	3.48	.628	.965	-.102	5
Sense of one community	3.44	.597	.996	.011	8
Sense of equality	3.45	.597	.958	-.061	7
Sense of teamwork	3.48	.599	.847	-.250	5
Sharing of feelings and ideas	3.58	.608	.519	-.608	4
Workers mutually helpfulness	3.65	.609	.348	-.640	2
Fairness in workload distribution	3.71	.593	.188	-.561	1

Source: (Fieldwork, 2025)

The construction sector in Kenya is not strong in associational life, based on a random sample showing 33% compared to the trade and transport sectors, which had 47% and 57%, respectively (Mitullah, 2021). The report shows that construction workers who are members of an association revealed that 53%, 40%, and 7% belong to work-related associations, SACCOs, and other associations, respectively. Construction associations offer mainly two services to workers, informal social protection as well as employment opportunities. According to the same report, only a third (33%) are enrolled in formal social insurance, which could be either the National Social Security Fund (NSSF) or the National Hospital Insurance Fund (NHIF) or both, with the majority (18 percent) preferring the latter. Indimuli et al. (2023) established the following reasons for low enrolment in NHIF: institutional constraints such as complex registration procedures, premium costs, and poor-quality services, irregular earnings leading to apprehension of paying penalty charges for the late premium payments, and inadequate knowledge about health insurance schemes.

Since most of the employers tend to be informal and not registered with government authorities, and the resulting challenge in monitoring and enforcing regulations, labour laws, and standards in the sector, construction workers lack both an employer who can contribute to the financial responsibilities linked to social protection measures, and the necessary rights mandated by government policies, rules, and standards (Riisgaard et al., 2021).

Table 4.12 showed that workers' rights are guaranteed only to a tune of 72.6%, compared to an expected 100%. Labour rights, such as work safety, are sometimes handled in a complex, multi-layered manner and are not exclusively the responsibility of the employer. According to a survey by Mitullah (2021), in cases of work injury, both employers and workers are responsible for paying medical bills, with each party contributing 38%. Other cases are handled by the site manager and/or the owner of the construction, work colleagues, and relatives. This implies that workers are primarily relying on the financial assistance of others to cover their medical costs through their associations.

4.5.5 Overall Quality of Work Life (QWL) of Construction Workers

A summary of the results in Tables 4.9, 4.10, 4.11, and 4.12 indicates that the extent of QWL among various aspects to be: fairness of compensation and reward systems (CRS=64.4%), quality of working conditions (WC=72.6%), quality of health and safety (HS=72.6%), and quality of welfare and social integration (WSI=71.0%). These have been presented in Figure 4.4.

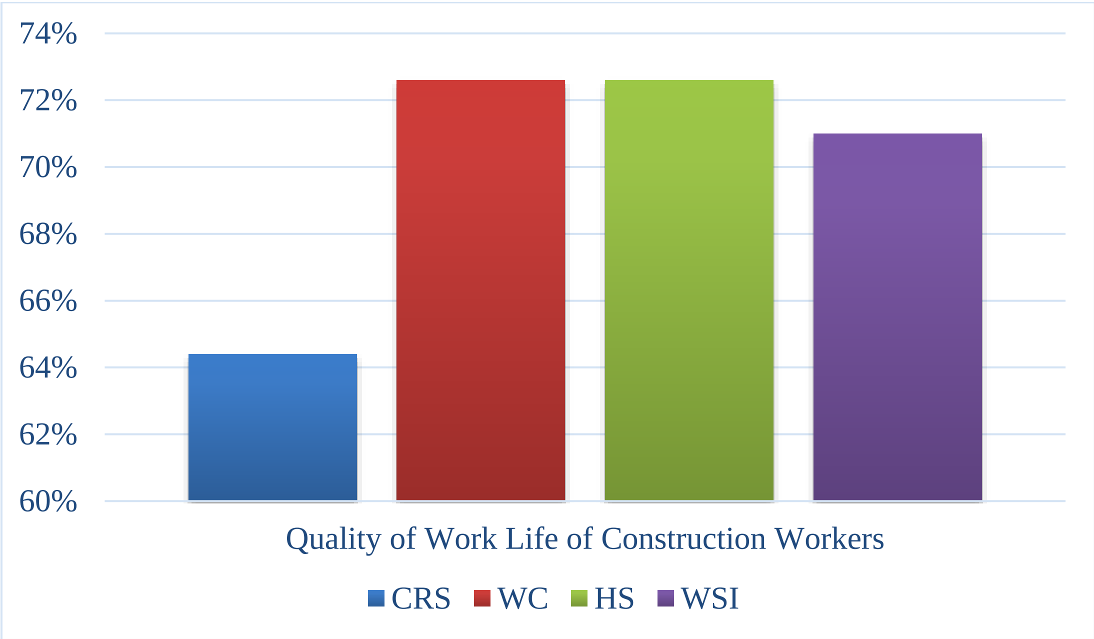

Figure 4.4: Overall Quality of Work Life of Construction Workers

Though the various aspects of QWL did not exhibit a wide range, fairness of compensation and reward systems (CRS) ranked last, with a considerable margin from the rest. Though it may be true, to some extent, that the other aspects may be performing better than worker compensation, it may also be a perception issue. Based on Douglas McGregor's Theory X, employees are primarily motivated by monetary rewards, and whatever they are paid, they will always want more due to the perception that whatever they are being paid is not enough. However, low satisfaction with current compensation and reward systems could also be attributed to other external factors, such as the performance of the country’s economy at large. For example, rising inflation (5.3%), especially on food products (Shaban, 2024) reduces the spending power of earned salaries and wages, therefore making them comparatively less adequate. This calls for a review of salaries and wages earned by construction workers to match the rising inflation rates.

4.6 Level of Mechanization

The independent variable, the Extent of Construction Mechanization (M), was evaluated across the various work elements found in a typical building construction project. This evaluation was based on a tool developed by Hwang et al. (2020). This tool has been presented in Table 4.13, which shows the definition for each level of mechanization and examples. This table was also shared with the respondents so that they could fully understand the meaning and description of every mechanization level. This helped ensure the collected data had validity.

Table 4.13: Level of Mechanization Scale

Mechanization Level	**Definition**	**Example**
Completely manual	Workers are on-site and use non-machineries or *simple tools* without mechanisms to work	Shovel, saw, and hammer, etc.
Hand tool	Workers are on site and use equipment with mechanisms (but not machines)	Hand winch, claw hammer, and spirit level, etc.
Automated hand tool	Workers are on site and use machinery to work on the construction project	Electric laser leveler, electric drill, electric bolt wrench, etc.
Machine/Workstation	Workers operate a machine/workstation to complete the construction task	Crane, excavator, and pump, etc.
Completely automated/Robotized	Workers are not required to operate or monitor the machine and the machine will complete the work activities by itself.	Robotic tiling machine, bricklaying robot, etc.

Source: Adapted from: (Hwang et al., 2020)

4.6.1 Site Preparation and Earthworks (SPE)

The results for the extent of construction mechanization of Site Preparation and Earthworks (SPE) have been presented in Tables 4.14a and 4.14b. The former presents the frequencies, while the latter presents the means for each task and subtask under SPE. Three (3) tasks were considered under SPE: (i) Site clearance, (ii) Setting out, and (iii) Earthworks. These were further broken down into various subtasks as shown in Tables 4.15a and 4.14b.

As seen in Table 4.14a, none of the tasks were Completely manual or Completely automated (robotized). The majority of the subtasks under Site clearance and Setting out were carried out using Hand tools (76%), while the remaining (24%) were done using Automated hand tools. Under Earthworks, Trench and Column excavation were mostly done using Automated hand tools (55% and 62% respectively) while the remaining was excavated using Hand tools and Machines (workstations). As for Basement excavation, most of the work was done using Machines (workstations) to the tune of 70%. This was followed by Automated hand tools (29%) and Hand tools

(1%) respectively. Transportation of soil/rock was not any different from the basement excavation. The use of Machines (workstations) was the most common (55%) followed by Automated hand tools (43%) and Hand tools (2%), respectively.

The overall aggregation showed that the use of Hand tools and Automated hand tools was almost similar at 43% and 41%, respectively. Machines (workstations) were less commonly used at 16%, while Completely manual and Completely automated (robotized) methods of carrying out SPE works were completely absent.

Table 4.14a: Mechanization of Site Preparation and Earthworks (Frequencies)

Task	Subtask	Completely Manual	Hand Tool	Automated Hand Tool	Machine/ Workstation	Robotized
Site clearance	a) Barricading out worksite	_	83(73%)	30(27%)	_	_
	b) Cutting the vegetation	_	83(73%)	30(27%)	_	_
	c) Removing tree stump	_	95(84%)	18(16%)	_	_
	d) Light demolition works	_	90(80%)	23(20%)	_	_
Setting out	a) Site clearance	_	74(65%)	39(35%)	_	_
	b) Excavations	_	33(29%)	80(71%)	_	_
	c) Foundations	_	35(31%)	78(69%)	_	_
Earthworks	a) Trench excavation	_	25(22%)	62(55%)	26(23%)	_
	b) Column base excavation	_	16(14%)	70(62%)	27(24%)	_
	c) Basement excavation	_	1(1%)	33(29%)	79(70%)	_
	d) Transporting soil/rock	_	2(2%)	49(43%)	62(55%)	_
	Overall Mean Percentage	**0%**	**43%**	**41%**	**16%**	**0%**

Source: (Fieldwork, 2025)

As seen in Table 4.14b, the three subtasks with the highest level of mechanization were Basement excavation, (mean=3.69, 74%), Transporting soil/rock (mean=3.53, 71%), and Column base excavation (mean=3.10, 62%). The least mechanized tasks were;

Barricading out the worksite and Cutting the vegetation (mean=2.27, 45%), Removing tree stumps (mean=2.16, 43%), and Light demolition works (mean=2.16, 43%). Interestingly. The first four ranking subtasks fell under Earthworks followed by the three subtasks of Setting out and lastly the four subtasks under Site clearance. As expected therefore, Earthworks (mean=3.33, 66%) was the most mechanized task under SPE followed by Setting out (mean=2.57, 51%) and Site clearance (mean=2.23, 45%) respectively. The overall level of mechanization for SPE works was a mean of 2.72 (54%).

The standard deviation results (ranging between 0.368 and 0.640) indicated that the data was not heavily spread out across all measured indicators of the mechanization of site preparation and earthworks variable. The normality tests revealed that the data was normally distributed as seen in the skewness and kurtosis values lying between -1.0 and +1.0. The reported standard error for the skewness and kurtosis results were 0.227 and 0.451 respectively.

Table 4.14b: Mechanization of Site Preparation and Earthworks (Descriptives)

Task	Subtask	Mean	SD	Skewness	Kurtosis	Rank
Site clearance	a) Barricading out worksite	2.27	.444	1.076	-0.857	8
	b) Cutting the vegetation	2.27	.444	1.076	-0.857	8
	c) Removing tree stump	2.16	.368	1.887	1.589	11
	d) Light demolition works	2.20	.404	1.493	0.231	10
Setting out	a) Site clearance	2.35	.478	0.660	-1.593	7
	b) Excavations	2.67	.471	-0.745	-1.471	6
	c) Foundations	2.69	.464	-0.834	-1.328	5
	a) Trench excavation	3.01	.423	-1.300	-0.316	4
	b) Column base excavation	3.10	.368	-1.887	1.589	3
	c) Basement excavation	3.69	.640	-.475	-.656	1
	d) Transporting soil/rock	3.53	.601	-.195	-.547	2

Source: (Fieldwork, 2025)

Pulling down heavy trees, demolition works, and mass excavation are some of the activities involved in Site Preparation and Earthworks. These activities cannot practically be achieved using manual methods. According to the Food and Agriculture Organization (2024), use of equipment such as the 240hp Crawler tractor achieves efforts of up to 2,000 times compared to manual methods. This therefore explains why Earthwork activities are among the most mechanized in a construction project, as seen in Tables 4.14a and 4.14b. According to Brosnan (2023), correct use of heavy equipment ensures site preparation work can both be carried out efficiently and effectively (to a high standard), and that workers remain safe throughout.

Basement excavation was the most mechanized activity, not just within this work category, but also in the entire construction project, because hydraulic excavators are mostly used to achieve both efficiency and effectiveness. Due to the mass excavation, it is also practically impossible to achieve efficiency using manual methods. Transportation of excavated soil and rock was also established to be among the most mechanized activities, even when compared to activities in other work categories. This is primarily due to the use of tippers and other haulage equipment to economically and practically dispose of excavated material from construction sites.

Trench excavation posted a comparatively high level of mechanization (mean=3.01, 60%) and ranked fourth out of the eleven (11) subtasks considered. Previous research also indicates a considerable use of machines for this task. For example, Idoro (2011) reports that in Nigeria, mechanical excavation of trenches is employed to the tune of 67% compared to 33% use of manual methods. However, the same study contradicts the findings of this study by reporting a relatively low use of equipment (33%) to remove excavated material compared to the high usage reported in Table 4.14b (mean=3.53, 71%)

4.6.2 Scaffolding and Formwork (SF)

The results for the extent of construction mechanization of Scaffolding and Formwork (SF) have been presented in Tables 4.15a and 4.15b. The former presents the frequencies while the latter presents the means for each task and subtask under SF. Four (4) tasks were considered under SF: (i) Erecting base lift and subsequent lifts, (ii)

Installing deck, (iii) Dismantling scaffold, and (iv) Formwork (fixing and removing). These were further broken down into various subtasks as shown in Tables 4.15a and 4.15b.

As seen in Table 4.15a, none of the tasks were Completely automated (robotized), while there was a negligible (1%) use of Machines (workstations). The only use of Machines (workstations) was recorded in ‘Soil compaction’ (3%) under the task of ‘Erecting base lift and subsequent lifts’ whereby the majority of the other subtasks under this task were carried out using Automated hand tools (49%) and Hand tools (35%) with the use of Completely manual methods being less common (13%). The task of ‘Installing deck’ was mostly carried out using Hand tools (50%), followed by Automated hand tools (45%) and Completely manual (5%) respectively. Dismantling scaffold was also mostly carried out using Hand tools (65%) followed by Automated hand tools (28%) and Completely manual (7%) respectively. Notably, ‘Hoisting of materials down to the ground’ was only carried out using Hand tools and Automated hand tools. ‘Formwork fixing and removal’ was majorly carried out using Hand tools (64%) and Automated hand tools (36%) with negligible use of Completely manual methods (less than 1%).

The overall aggregation showed that the use of Hand tools was the most common (50%) method of working under the Scaffolding and Formwork work category. This was closely followed by Automated hand tools at 41%. Completely manual methods came a distant third (8%) while Machines (workstations) reported almost negligible use at 1%. Again, Completely automated (robotized) methods of carrying out SF works were totally absent.

Table 4.15a: Mechanization of Scaffolding and Formwork (Frequencies)

Task	Subtask	Completely Manual	Hand Tool	Automated Hand Tool	Machine/ Workstation	Robotized
Erecting base lift and subsequent lifts	a) Soil compaction	_	38(34%)	53(47%)	22(19%)	_
	b) Laying sole plates	17(15%)	43(38%)	53(47%)	_	_
	c) Placing standards into jacks	24(21%)	38(34%)	51(45%)	_	_
	d) Fitting transoms to standards	14(12%)	46(41%)	53(47%)	_	_
	e) Inserting and connecting ledgers to the base of the scaffold	17(15%)	35(31%)	61(54%)	_	_
	f) Installation of diagonal bracing	18(16%)	33(29%)	62(55%)	_	_
	g) Tying scaffold to building	16(14%)	44(39%)	53(47%)	_	_
Installing deck	a) Securing deck to standards, transoms, and ledgers	12(11%)	50(44%)	51(45%)	_	_
	b) Installing toe boards	6(5%)	57(50%)	50(44%)	_	_
	c) Installing guardrails	_	62(55%)	51(45%)	_	_
Dismantling scaffold	a) Clearing loose materials on platform	10(9%)	76(67%)	27(24%)	_	_
	b) Removal of hessian net	17(15%)	67(59%)	29(26%)	_	_
	c) Dismantling of deck, transom, ledgers, and standards	5(4%)	79(70%)	29(26%)	_	_
	d) Hoisting of materials down to the ground	_	71(63%)	42(37%)	_	_

Task	Subtask	Completely Manual	Hand Tool	Automated Hand Tool	Machine/ Workstation	Robotized
Formwork (fixing and removing)	a) Foundations formwork	_	70(62%)	43(38%)	_	_
	b) Columns formwork	1(1%)	69(61%)	43(38%)	_	_
	c) Lift shafts formwork	2(2%)	70(62%)	41(36%)	_	_
	d) Beams & Slab formwork	_	79(70%)	34(30%)	_	_
Overall Mean Percentage		**8%**	**50%**	**41%**	**1%**	**0%**

Source: (Fieldwork, 2025)

As seen in Table 4.15b, the two subtasks with the highest level of mechanization were; Soil compaction, (mean=2.86, 57%), and Installing guardrails (mean=2.45, 49%). The least mechanized tasks were; ‘Dismantling of deck, transom, ledgers, and standards’ (mean=2.21, 44%), ‘Clearing loose materials on platform’ (mean=2.15, 43%), and ‘Removal of hessian net’ (mean=2.11, 42%). ‘Erecting base lift and subsequent lifts’ (mean=2.41, 48%) was the most mechanized task under SF closely followed by ‘Installing deck’ (mean=2.40, 48%), ‘Formwork fixing and removing’ (mean=2.35, 47%), and Dismantling scaffold (mean=2.21, 44%) respectively. Notably however, all the tasks recorded low levels of mechanization with closely spaced means (having a range of only 0.2). It was therefore not surprising that the overall level of mechanization for SF works was a mean of 2.35 (47%).

The standard deviation results (ranging between 0.461 and 0.782) indicated that the data were not heavily spread out across all measured indicators of the mechanization of scaffolding and formwork variable. The normality tests revealed that the data were normally distributed as seen in the skewness and kurtosis values lying between -1.0 and +1.0. The reported standard error for the skewness and kurtosis results was 0.227 and 0.451 respectively.

Table 4.15b: Mechanization of Scaffolding and Formwork (Descriptives)

Task	Subtask	M	SD	Skewness	Kurtosis	Rank
Erecting base lift and subsequent lifts	a) Soil compaction	2.86	.718	.217	-1.025	1
	b) Laying sole plates	2.32	.723	-.568	-.900	13
	c) Placing standards into jacks	2.24	.782	-.449	-1.227	15
	d) Fitting transoms to standards	2.35	.691	-.580	-.764	9
	e) Inserting and connecting ledgers to the base of the scaffold	2.39	.737	-.766	-.765	3
	f) Installation of diagonal bracing	2.39	.749	-.780	-.796	3
	g) Tying scaffold to building	2.33	.713	-.574	-.853	12
Installing deck	a) Securing deck to standards, transoms, and ledgers	2.35	.665	-.523	-.705	9
	b) Installing toe boards	2.39	.589	-.359	-.687	3
	c) Installing guardrails	2.45	.500	.198	-1.996	2
Dismantling scaffold	a) Clearing loose materials on platform	2.15	.555	.057	.068	17
	b) Removal of hessian net	2.11	.632	-.086	-.485	18
	c) Dismantling of deck, transom, ledgers, and standards	2.21	.508	.312	.047	16
	d) Hoisting of materials down to the ground	2.37	.485	.538	-1.741	7
Formwork (fixing and removing)	a) Foundations formwork	2.38	.488	.499	-1.783	6
	b) Columns formwork	2.37	.503	.324	-1.387	7
	c) Lift shafts formwork	2.35	.514	.253	-1.040	9
	d) Beams & Slab formwork	2.30	.461	.880	-1.248	14

Source: (Fieldwork, 2025)

Findings reported by Vadukkumchery and Myneni (2023) showed that both Scaffolding and Formwork had mechanization levels of 1.08, which if converted to match the scale used in the current study, translated to 1.80. The results in the current study therefore, post relatively higher levels of mechanization in these two work categories (2.35). Sharmila et al. (2018) observed that system formwork matched the average utilization in most construction projects. This is not different from the current study, whereby the mechanization level of both Scaffolding and Formwork matched the overall level of mechanization in high-rise building projects (2.35).

4.6.3 Concreting (C)

The results for the extent of construction mechanization of Concreting (C) have been presented in Tables 4.16a and 4.16b. The former presents the frequencies, while the latter presents the means for each task and subtask under Concreting. Five (5) tasks were considered under Concreting; (i) Rebar preparation, (ii) Material batching, (iii) Mixing, (iv) Concrete pouring, and (v) Vibrating. These were further broken down into various subtasks as shown in Tables 4.16a and 4.16b.

As seen in Table 4.16a, none of the tasks were Completely manual or Completely automated (robotized). The majority of the subtasks under Rebar preparation were carried out using Automated hand tools (66%), followed by Hand tools (20%) and Machines (workstations) (14%). Material batching was only carried out using by Automated hand tools (67%) and Machines (workstations) (33%). Similarly, 66% of Concrete mixing was done using Automated hand tools, while the rest was done using Machines (workstations) (34%). The same trend was observed in Concrete pouring (66% Automated Hand tools and 32% Machines/Workstation), though in this case Hand tools were also used, albeit to a very small extent (2%). 76% of Vibrating concrete was done using Automated hand tools, while the rest was done using Machines (workstations) (24%).

The overall aggregation showed that the use of Automated hand tools was the most dominant method of construction (67%), followed by Machines (workstations) (26%). The use of Hand tools was minimal at 7%, while Completely manual and Completely automated (robotized) methods of concreting were completely absent.

Table 4.16a: Mechanization of Concreting (Frequencies)

Task	Subtask	Completely Manual	Hand Tool	Automated Hand Tool	Machine/ Workstation	Robotized
Rebar preparation	a) Cutting	_	22(19%)	75(66%)	16(14%)	_
	b) Bending	_	23(20%)	74(65%)	16(14%)	_
	c) Tying	_	24(21%)	74(65%)	16(14%)	_
	d) Hoisting	_	23(20%)	75(66%)	15(13%)	_
	e) Placing	_	23(20%)	74(65%)	16(14%)	_
Material batching	a) Ballast	_	_	75(66%)	38(34%)	_
	b) Sand	_	_	75(66%)	38(34%)	_
	c) Cement	_	_	75(66%)	38(34%)	_
	d) Water	_	_	75(66%)	38(34%)	_
	e) Additives and admixtures	_	_	83(73%)	30(27%)	_
Mixing	a) Concrete mixing	_	_	75(66%)	38(34%)	_
Concrete pouring	a) Hoisting	_	1(1%)	75(66%)	37(33%)	_
	b) Transporting horizontally	_	2(2%)	75(66%)	36(32%)	_
	c) Placing concrete	_	2(2%)	74(65%)	37(33%)	_
Vibrating	a) Vibrating concrete	_	_	86(76%)	27(24%)	_
	Overall Mean Percentage	**0%**	**7%**	**67%**	**26%**	**0**

Source: (Fieldwork, 2025)

Compared to the two previous work categories, the level of mechanization in the various tasks and subtasks under Concreting was relatively higher. As presented in Table 4.16b, the three subtasks with the highest level of mechanization were: Hoisting and Placing concrete (both with a mean of 3.37, 67%), and Transporting concrete horizontally (mean=3.36, 67%). The least mechanized tasks of Concreting were; Bending rebars (mean=2.94, 59%), Placing rebars (mean=2.94, 59%), Hoisting rebars (mean=2.93, 59%), and Tying rebars (mean=2.92, 58%). There was a very narrow range of the mean (between 2.92 and 2.95) for the tasks under Rebar preparation, an indication that the methods used to prepare rebars were pretty much the same. A similar trend was also observed in Material batching whereby three out of the four subtasks had a similar mean. This was, however, expected since, in practice, the same technique used to batch cement is also used for sand and ballast, except for additives.

Out of the four (4) tasks considered under Concreting, the two most mechanized tasks were Concrete pouring and Vibrating, both with a mean of 3.34 (67%). Material batching ranked next with a very close mean of 3.33 (66%). Rebar preparation came last with a mean of 2.94 (59%). The overall level of mechanization of Concreting was established to be a mean of 3.18 (64%).

The standard deviation results (ranging between 0.439 and 0.587) indicated that the data were not heavily spread out across all measured indicators of the Mechanization of Concreting variable. The normality tests revealed that the data were normally distributed as seen in the skewness and kurtosis values lying between -1.0 and +1.0. The reported standard error for the skewness and kurtosis results was 0.227 and 0.451 respectively.

Table 4.16b: Mechanization of Concreting (Descriptives)

Task	Subtask	Mean	SD	Skewness	Kurtosis	Rank
Rebar preparation	a) Cutting	2.95	.580	.001	.028	11
	b) Bending	2.94	.587	.009	-.051	12
	c) Tying	2.92	.585	.009	-.050	15
	d) Hoisting	2.93	.578	.000	.027	14
	e) Placing	2.94	.587	.009	-.051	12
Material batching	a) Ballast	3.34	.475	.702	-1.534	4
	b) Sand	3.34	.475	.702	-1.534	4
	c) Cement	3.34	.475	.702	-1.534	4
	d) Water	3.34	.475	.702	-1.534	4
	e) Additives and admixtures	3.27	.444	1.076	-.857	9
Mixing	a) Concrete mixing	3.34	.475	.702	-1.534	4
Concrete pouring	a) Hoisting	3.37	.485	.538	-1.741	1
	b) Transporting horizontally	3.36	.483	.578	-1.696	3
	c) Placing concrete	3.37	.485	.538	-1.741	1
Vibrating	a) Vibrating concrete	3.26	.439	1.129	-.738	10

Source: (Fieldwork, 2025)

The findings in Table 4.16b agree with those by Sharmila et al. (2018) that placing concrete is not only the most mechanized activity within concreting but among the highest ranking among all construction activities in a building project. The situation is also the same for material (cement, ballast, sand, and water) batching and concrete mixing. A different study by Vadukkumchery and Myneni (2023) also reported batching, mixing, and placing of concrete to be the most mechanized activities in a building construction project in India. Idoro (2011) however, contradicts these findings by reporting that only 33% of concrete batching and mixing is mechanized in Nigeria's construction industry. Table 4.16b showed Hoisting concrete as the joint-first-ranked activity. This is expected since in a high-rise building, such activity would be impossible to accomplish manually. Cranes (ranging from portable gantry cranes to complex tower cranes) are usually used to lift concrete from the ground floor to upper floors. Hoisting of rebars is relatively lower since, in lower floors, workers improvise methods such as rope-pulling to lift rebars. Such improvisation is impossible with concrete. Further, just like in this study, Sharmila et al. (2018) also reported concrete transportation to be among the most mechanized activities in a construction project. This could also be explained by the utilization of cranes.

4.6.4 Walling (W)

The results for the extent of construction mechanization of Walling (W) have been presented in Tables 4.17a and 4.17b. The former presents the frequencies while the latter presents the means for each task and subtask under Walling. Two (2) tasks were considered under Walling: (i) Preparation, and (ii) Stone laying. These were further broken down into various subtasks as shown in Tables 4.17a and 4.17b.

As seen in Table 4.17a, none of the tasks were Completely automated (robotized). The majority of the subtasks under Preparation were carried out using Hand tools (58%) followed by Automated hand tools (27%). The remaining were done using Completely manual (14%) and Machines (workstations) (1%). Similarly, most of the activities under Stone laying were carried out using Hand tools (49%), followed by Automated hand tools (40%). Some of the remaining activities were done using Completely manual methods (7%) while the rest were done using Machines (workstations) (4%).

The overall aggregation showed that the use of Hand tools was the most dominant (54%), followed by Automated hand tools (33%). Completely manual methods and Machines (workstations) were less commonly used, with reported usages of 11% and

2%, respectively. Completely automated (robotized) methods of walling were completely absent.

Table 4.17a: Mechanization of Walling (Frequencies)

Task	Subtask	Completely Manual	Hand Tool	Automated Hand Tool	Machine/ Workstation	Robotized
Preparation	a) Setting out	46(40%)	61(54%)	6(5%)	_	_
	b) Mortar preparation	10(9%)	69(61%)	33(29%)	1(1%)	_
	c) Mortar transportation	1(1%)	72(64%)	39(35%)	1(1%)	_
	d) Placing and removing excess mortar	5(4%)	61(54%)	45(40%)	2(2%)	_
Stone laying	a) Hoisting and transporting	_	52(46%)	55(49%)	6(5%)	_
	b) Aligning	24(21%)	50(44%)	38(34%)	1(1%)	_
	c) Cutting	_	65(58%)	42(37%)	6(5%)	_
Overall Mean Percentage		**11%**	**54%**	**33%**	**2%**	**0%**

Source: (Fieldwork, 2025)

Compared to concreting, the level of mechanization in the various tasks and subtasks under Walling was significantly reduced. As presented in Table 4.17b, the three subtasks with the highest level of mechanization were: Setting out (2.65, 53%), Hoisting and transporting (mean=2.59, 52%), and Cutting stones (mean=2.48, 50%). The least mechanized tasks of Walling were: Mortar transportation (mean=2.35, 47%), Mortar preparation (mean=2.22, 44%), and Aligning stones (mean=2.14, 43%). Coincidentally, the two (2) tasks of Walling, that is, Preparation and Stone laying, had an exact same level of mechanization with a mean of 2.40 (48%). Due to this, the overall level of mechanization of Walling was also 2.40 (48%).

The standard deviation results (ranging between 0.516 and 0.754) indicated that the data were not heavily spread out across all measured indicators of the mechanization of walling variable. The normality tests revealed that the data were normally distributed as seen in the skewness and kurtosis values lying between -1.0 and +1.0. The reported standard error for the skewness and kurtosis results was 0.227 and 0.451 respectively.

Table 4.17b: Mechanization of Walling (Descriptives)

Task	Subtask	Mean	SD	Skewness	Kurtosis	Rank
Preparation	a) Setting out	2.65	.581	.241	-.678	1
	b) Mortar preparation	2.22	.608	.091	-.020	6
	c) Mortar transportation	2.35	.516	.615	-.611	5
	d) Placing and removing excess mortar	2.39	.604	.066	-.270	4
Stone laying	a) Hoisting and transporting	2.59	.592	.420	-.672	2
	b) Aligning	2.14	.754	-.114	-.949	7
	c) Cutting	2.48	.599	.847	-.250	3

Source: (Fieldwork, 2025)

The extent of mechanization in walling was not great. This was because in nearly all the projects visited, the walling material was quarry stones. Only a handful of the projects were using precast walling panels. It is in only these projects that the use of Machines/Workstations was reported. Walling using quarry stones is usually achieved using simple hand tools, while precast concrete panels can only be undertaken using cranes and other lifting equipment.

4.6.5 Plastering and Flooring (PF)

The results for the extent of construction mechanization of Plastering and Flooring (PF) have been presented in Tables 4.18a and 4.18b. The former presents the frequencies while the latter presents the means for each task and subtask under PF. Two (2) tasks were considered under PF: (i) Plastering and Screeding, and (ii) Terrazzo flooring. These were further broken down into various subtasks as shown in Tables 4.18a and 4.18b.

As seen in Table 4.18a, none of the tasks were Completely automated (robotized), while there was a negligible (1%) use of Machines (workstations). Hand tools were dominantly (72%) used in Plastering and Screeding activities, while the adoption of Automated hand tools (17%) and Completely manual methods (10%) was not as popular. The use of Machines (workstations) in this task was very minimal (2%). Terrazzo flooring activities were also majorly carried out using Hand tools (79%), while Automated hand tools (13%) and Completely manual methods (8%) were used to a lesser extent. Machines (workstations) and Completely automated (robotized) methods of carrying out Terazzo flooring works were not used.

The overall aggregation showed that the use of Hand tools was the most dominant (70%) method of working under Plastering and Flooring work category. This was distantly followed by Automated hand tools at 14%. Completely manual methods followed at 8%, while Machines (workstations) reported almost negligible use at 1%. Again, Completely automated (robotized) methods of carrying out PF works were totally absent.

Table 4.18a: Mechanization of Plastering and Flooring (Frequencies)

Task	Subtask	Completely Manual	Hand Tool	Automated Hand Tool	Machine/ Workstation	Robotized
Plastering and Screeding	a) Mortar batching and mixing	_	83(73%)	28(25%)	2(2%)	_
	b) Mortar transportation	3(3%)	82(73%)	24(21%)	4(4%)	_
	c) Plastering and screeding surfaces	27(24%)	71(63%)	15(13%)	_	_
	d) Cleaning plastered surfaces	15(13%)	90(80%)	8(7%)	_	_
Terrazzo flooring	a) Shot blasting	_	79(70%)	34(30%)	_	_
	b) Floor preparation and leveling	18(16%)	89(79%)	6(5%)	_	_

Task	Subtask	Completely Manual	Hand Tool	Automated Hand Tool	Machine/ Workstation	Robotized
	c) Design layout	24(21%)	89(79%)	_	_	_
	d) Mixing terrazzo		91(81%)	22(19%)	_	_
	e) Pouring terrazzo	19(17%)	91(81%)	3(3%)	_	_
	f) Grinding the floor surface	_	91(81%)	22(19%)	_	_
	g) Polishing the terrazzo floor	_	94(83%)	19(17%)	_	_
Overall Mean Percentage		**9%**	**70%**	**14%**	**1%**	**0%**

Source: (Fieldwork, 2025)

As presented in Table 4.18b, the three subtasks with the highest level of mechanization were: Shot blasting (mean=2.30, 46%), Mortar batching and mixing (mean=2.28, 45%), and Mortar transportation (mean=2.26, 45%). The least mechanized tasks of Plastering and Flooring were: Plastering and screeding surfaces (mean=1.89, 39%), Floor preparation and leveling (mean=1.89, 39%), and Design layout (mean=1.79, 36%). The level of mechanization in Plastering and screeding ranged between 1.89 (Plastering and screeding surfaces, 39%) and 2.28 (Mortar batching and mixing, 45%). On the other hand, the level of mechanization in Terazzo flooring ranged between 1.79 (Design layout, 36%) and 2.30 (Shot blasting, 46%).

By comparison, the two tasks considered under PF, that is, Plastering and Screeding (2.09, 42%) and Terazzo flooring (2.06, 41%), almost had the same level of mechanization. The overall level of mechanization of Plastering and Flooring was established to be a mean of 2.07 (41%).

The standard deviation results (ranging between 0.376 and 0.603) indicated that the data were not heavily spread out across all measured indicators of the mechanization of plastering and flooring variable. The normality tests revealed that the data were normally distributed as seen in the skewness and kurtosis values lying between -1.0

and +1.0. The reported standard error for the skewness and kurtosis results was 0.227 and 0.451 respectively.

Table 4.18b: Mechanization of Plastering and Flooring (Descriptives)

Task	Subtask	Mean	SD	Skewness	Kurtosis	Rank
Plastering and Screeding	a) Mortar batching and mixing	2.28	.490	1.429	1.038	2
	b) Mortar transportation	2.26	.563	1.205	1.789	3
	c) Plastering and screeding surfaces	1.89	.603	.046	-.254	8
	d) Cleaning plastered surfaces	1.94	.449	-.279	1.974	7
Terrazzo flooring	a) Shot blasting	2.30	.461	.880	-1.248	1
	b) Floor preparation and leveling	1.89	.450	-.460	1.605	8
	c) Design layout	1.79	.411	-1.425	.032	10
	d) Mixing terrazzo	2.19	.398	1.563	.450	4
	e) Pouring terrazzo	1.86	.420	-.897	1.605	
	f) Grinding the floor surface	2.19	.398	1.563	.450	4
	g) Polishing the terrazzo floor	2.17	.376	1.799	1.257	6

Source: (Fieldwork, 2025)

Spray machines for plastering have become increasingly popular in Europe and other developed parts of the world (Jessica, 2021). Such popularity has been attributed to a number of benefits, such as increasing the speed of plastering, reducing manual labour, improved consistency of plaster, less room for human error, and greater uniformity across large-scale projects. Unfortunately, though the use of such machines has in the past been reported here in Kenya, none of the projects visited were using them. This explains the low mechanization level of plastering (mean=1.89, 39%)

4.6.6 Tiling and Painting (TP)

The results for the extent of construction mechanization of Tiling and Painting (TP) have been presented in Tables 4.19a and 4.19b. The former presents the frequencies, while the latter presents the means for each task and subtask under TP. Two (2) tasks were considered under TP: (i) Tiling, and (ii) Painting. These were further broken down into various subtasks as shown in Tables 4.19a and 4.19b.

As seen in Table 4.19a, none of the tasks under TP were completed using Machines (workstations) and Completely automated (robotized) methods. Again, just like in the tasks under the previous work category, Hand tools were dominantly (77%) used in Tiling activities, while the adoption of Completely manual methods (18%) and Automated hand tools (5%) was not as commonly used. Painting activities were also majorly carried out using Hand tools (77%) while Completely manual methods (18%) and Automated hand tools (5%) were used to a lesser extent.

The overall aggregation showed that the use of Hand tools was the most dominant (77%) method of working under the Tiling and Painting work category. This was distantly followed by Completely manual methods at 18%. Automated hand tools followed at 5% while Machines (workstations) and Completely automated (robotized) methods reported 0% adoption.

Table 4.19a: Mechanization of Tiling and Painting (Frequencies)

Task	**Subtask**	**Completely Manual**	**Hand Tool**	**Automated Hand Tool**	**Machine/ Workstation**	**Robotized**
Tiling	a) Setting out	18(16%)	90(80%)	5(4%)	_	_
	b) Hoisting and transporting materials	20(18%)	87(77%)	6(5%)	_	_
	c) Mortar preparation and placing	21(19%)	84(74%)	8(7%)	_	_
	d) Placing and leveling of tiles	17(15%)	88(78%)	8(7%)	_	_
	e) Grouting	21(19%)	87(77%)	5(4%)	_	_
	f) Cleaning tiled surfaces	23(20%)	84(74%)	6(5%)	_	_
Painting	a) Hoisting and transporting materials	22(19%)	86(76%)	5(4%)	_	_

Task	Subtask	Completely Manual	Hand Tool	Automated Hand Tool	Machine/ Workstation	Robotized
	b) Protecting surfaces not to be painted	21(19%)	87(77%)	5(4%)	_	_
	c) Smoothing and cleaning surface	22(19%)	86(76%)	5(4%)	_	_
	d) Mixing of paint	26(23%)	82(73%)	5(4%)	_	_
	e) Application of sealer coat	28(25%)	83(73%)	2(2%)	_	_
	f) Application of paint	18(16%)	90(80%)	5(4%)	_	_
	g) Elevating painters to higher grounds	2(2%)	92(81%)	19(17%)	_	_
Overall Mean Percentage		**18%**	**77%**	**5%**	**0%**	**0%**

Source: (Fieldwork, 2025)

Compared to all the previous work categories, the level of mechanization in the various tasks and subtasks under Tiling and Painting was relatively lower. As presented in Table 4.19b, the two subtasks with the highest level of mechanization were; Elevating painters to higher grounds (mean=2.15, 43%), and Placing and leveling of tiles (mean=1.92, 38%). The least mechanized tasks of TP were: Mixing of paint (mean=1.81, 36%), and Application of sealer coat (mean=1.77, 35%). There was a very narrow range of the mean (between 1.85 and 1.92) for the tasks under Tiling, an indication that the methods used to prepare rebars were pretty much the same. Though slightly wider, the situation was not so different in Painting, where the means ranged between 1.77 (35%) and 2.15 (43%). By comparison, the two tasks considered under TP, that is, Tiling (1.89, 39%) and Painting (1.88, 37%), almost had the same level of mechanization. The overall level of mechanization of Tiling and Painting was established to be a mean of 1.88 (37%).

The standard deviation results (ranging between 0.438 and 0.496) indicated that the data were not heavily spread out across all measured indicators of the mechanization of tiling and painting variable. The normality tests revealed that the data were normally distributed as seen in the skewness and kurtosis values lying between -1.0 and +1.0. The reported standard error for the skewness and kurtosis results was 0.227 and 0.451 respectively.

Table 4.19b: Mechanization of Tiling and Painting (Descriptives)

Task	Subtask	Mean	SD	Skewness	Kurtosis	Rank
Tiling	a) Setting out	1.88	.438	-.584	1.718	3
	b) Hoisting and transporting materials	1.88	.465	-.430	1.208	3
	c) Mortar preparation and placing	1.88	.496	-.249	.864	3
	d) Placing and leveling of tiles	1.92	.466	-.283	1.541	2
	e) Grouting	1.86	.460	-.522	1.098	7
	f) Cleaning tiled surfaces	1.85	.486	-.371	.726	9
Painting	a) Hoisting and transporting materials	1.85	.467	-.498	.926	9
	b) Protecting surfaces not to be painted	1.86	.460	-.522	1.098	7
	c) Smoothing and cleaning surface	1.85	.467	-.498	.926	9
	d) Mixing of paint	1.81	.492	-.395	.363	12
	e) Application of sealer coat	1.77	.463	-.736	-.081	13
	f) Application of paint	1.88	.438	-.584	1.718	3
	g) Elevating painters to higher grounds	2.15	.406	1.128	1.590	1

Source: (Fieldwork, 2025)

Most of the tasks under Tiling and Painting are usually executed using hand tools. They do not require complex machines to achieve. Simple tools like tile cutters are used by skilled workers involved in tiling. The most common tool used in painting is the spray gun, which is mainly used for gloss paints. The study by Hwang et al. (2020) reported only a slightly higher mechanization level of 43% compared to the 37% reported in this study.

4.6.7 Building Services (BS)

The results for the extent of construction mechanization of Building Services (BS) have been presented in Tables 4.20a and 4.20b. The former presents the frequencies, while the latter presents the means for each task and subtask under BS. Two (2) tasks were considered under BS: (i) Plumbing works, and (ii) Electrical works. These were further broken down into various subtasks as shown in Tables 4.20a and 4.20b.

As seen in Table 4.20a, none of the tasks were Completely automated (robotized) while there was a negligible (1%) use of Machines (workstations). Hand tools were dominantly (71%) used in Plumbing works, while the adoption of Completely manual methods (16%) and Automated hand tools (13%) was not as popular. The use of Machines (workstations) in this task was very minimal (1%) and was only reportedly used in the testing of the installations. Electrical works were also majorly carried out using Hand tools (66%), while Completely manual methods (19%) and Automated hand tools (13%) were used to a lesser extent. Just like under plumbing works, the use of Machines (workstations) in this task was very minimal (1%) and was also only reportedly used in the testing of the installations.

The overall aggregation showed that the use of Hand tools was the most dominant (68%) method of working under the Building services work category. This was distantly followed by Completely manual methods and Automated hand tools at 17% and 13% respectively while Machines (workstations) reported almost negligible use at 1%. Again, just like in all other work categories, there was no use of Completely automated (robotized) methods in carrying out BS works.

Table 4.20a: Mechanization of Building Services (Frequencies)

Task	Subtask	Completely Manual	Hand Tool	Automated Hand Tool	Machine/ Workstation	Robotized
Plumbing works	a) Setting out	42(37%)	67(59%)	4(4%)	_	_
	b) Hoisting and transporting materials	20(18%)	89(79%)	4(4%)	_	_
	c) Hacking for pipes	1(1%)	112(99%)	_	_	_
	d) Pipe cutting and installation	23(20%)	86(76%)	4(4%)	_	_
	e) Installing fixtures	19(17%)	87(77%)	7(6%)	_	_
	f) Testing	_	38(34%)	67(59%)	8(7%)	_
Electrical works	a) Setting out	38(34%)	75(66%)			_
	b) Hoisting and transporting materials	20(18%)	89(79%)	4(4%)	_	_
	c) Hacking for conduits and fittings	36(32%)	74(65%)	3(3%)	_	_
	d) Conduit cutting and installation	23(20%)	83(73%)	7(6%)	_	_
	e) Pulling cables through conduits	32(28%)	78(69%)	_	_	_
	f) Installing fittings	1(1%)	112(99%)	_	_	_
	g) Testing	_	16(14%)	86(76%)	11(10%)	_
Overall Mean Percentage		**17%**	**68%**	**13%**	**1%**	**0%**

Source: (Fieldwork, 2025)

As presented in Table 4.20b, the two subtasks with the highest level of mechanization were: Testing electrical works (2.96, 59%), and Testing plumbing works (mean=2.73, 54%). The three least mechanized tasks of Building services were: Hacking for conduits and fittings (mean=1.71, 34%), Setting out plumbing works (mean=1.66, 33%), and Setting out electrical works (mean=1.66, 33%). By comparison, the two tasks considered under BS, that is, Plumbing works (2.00, 40%) and Electrical works (1.96, 39%), almost had the same level of mechanization. The overall level of mechanization of Building services was established to be a mean of 1.97, 39%.

The standard deviation results (ranging between 0.000 and 0.583) indicated that the data were not heavily spread out across all measured indicators of the mechanization of building services variable. Notably, both Hacking of pipes and Installing fittings recorded a standard deviation of 0.000, meaning that nearly all (99%) of the respondents selected the same method of work in each case (Hand tools). The normality tests revealed that the data were normally distributed as seen in the skewness and kurtosis values lying between -1.0 and +1.0. The reported standard error for the skewness and kurtosis results was 0.227 and 0.451 respectively.

Table 4.20b: Mechanization of Building Services (Descriptives)

Task	Subtask	Mean	SD	Skewness	Kurtosis	Rank
Plumbing works	a) Setting out	1.66	.545	-.011	-.752	12
	b) Hoisting and transporting materials	1.86	.441	-.685	1.343	6
	c) Hacking for pipes	2.00	.000	.	.	3
	d) Pipe cutting and installation	1.83	.461	-.599	.782	8
	e) Installing fixtures	1.89	.470	-.349	1.290	5
	f) Testing	2.73	.583	.111	-.476	2
Electrical works	a) Setting out	1.66	.475	-.702	-1.534	12
	b) Hoisting and transporting materials	1.78	.495	-.415	.012	9
	c) Hacking for conduits and fittings	1.71	.512	-.302	-.623	11
	d) Conduit cutting and installation	1.86	.498	-.288	.668	6
	e) Pulling cables through conduits	1.74	.496	-.437	-.345	10
	f) Installing fittings	2.00	.000	.	.	3
	g) Testing	2.96	.489	-.112	1.273	1

Source: (Fieldwork, 2025)

Coincidentally, the extent of mechanization in plumbing works reported in this study (2.00, 40%) was almost similar to that reported by Vadukkumchery and Myneni (2023). In their study, they established the mechanization level of Plumbing, underground piping and drainage works to be 1.256 based on a 3-point scale. When converted to the 5-point scale used in the current study, this value comes to 2.09 (41%). In both Plumbing and Electrical works, testing was the most mechanized activity. This is expected since the utilization of equipment such as pumps and generators is common in testing of plumbing and electrical installations.

4.6.8 Overall Level of Mechanization

Assessing the level of mechanization in construction projects is not only important but also critical, since it both reports how well the assessed project is in terms of mechanization and reveals the directions for improvement (Pan et al., 2018). The results for the overall extent of Construction Mechanization (M) have been presented in Table 4.21a, Figure 4.5, and Table 4.21b. These results are a summary of all seven (7) work categories discussed in the preceding sections.

As demonstrated in Table 4.21a, more than half (53%) of the activities in the building construction sector are carried out using Hand tools. This is then followed by Automated hand tools with an approximate usage of 31%. Completely manual methods and Machines (workstations) are used almost similarly at 9% and 7% respectively. None of the activities in construction is Completely automated (robotized).

Table 4.21a: Overall Extent of Mechanization (Frequencies)

	Work Category	Completely Manual	Hand Tool	Automated Hand Tool	Machine/ Workstation	Robotized
1	Site Preparation and Earthworks (MSPE)	0%	43%	41%	16%	0%
2	Scaffolding and Formwork (MSF)	8%	50%	41%	1%	0%
3	Concreting (MC)	0%	7%	67%	26%	0%
4	Walling (MW)	11%	54%	33%	2%	0%
5	Plastering and Flooring (MPF)	9%	70%	14%	1%	0%
6	Tiling and Painting (MTP)	18%	77%	5%	0%	0%
7	Building Services (MBS)	17%	68%	13%	1%	0%
	Overall Mean	**9%**	**53%**	**31%**	**7%**	**0%**
	Rank	**3**	**1**	**2**	**4**	**0**

Source: (Fieldwork, 2025)

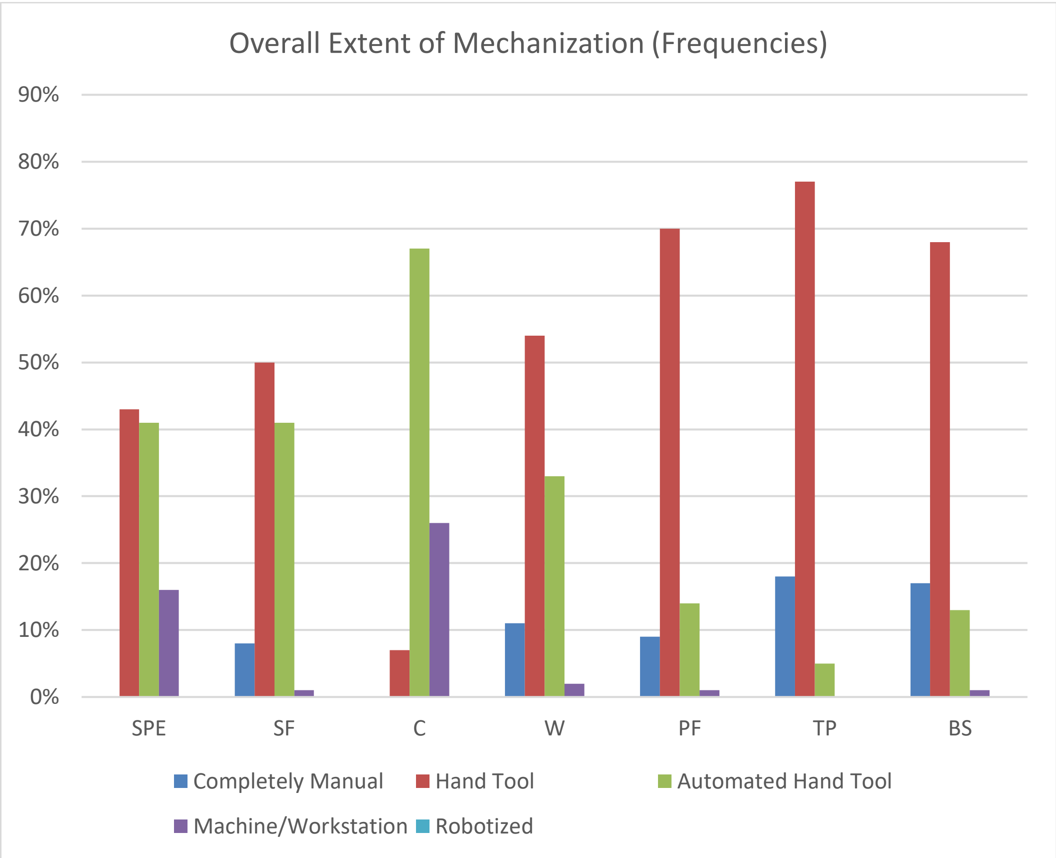

Figure 4.5: Overall Extent of Mechanization (Frequencies)

As seen in Table 4.21b, the three work categories with the highest level of mechanization were: Concreting (mean=3.18, 64%), Site Preparation and Earthworks (mean=2.62, 52%), and Walling (mean=2.40, 48%). The least mechanized work categories were: Plastering and Flooring (mean=2.07, 41%), Building Services (mean=1.97, 39%), and Tiling and Painting (mean=1.88, 38%). The levels of mechanization ranged between 1.88 (38%) and 3.18 (64%). The overall level of Construction Mechanization was established to be a mean of 2.35 (47%).

The standard deviation results (ranging between 0.134 and 0.407) indicated that the data were not heavily spread out across all measured indicators of the mechanization variable. The normality tests revealed that the data were normally distributed as seen in the skewness and kurtosis values lying between -1.0 and +1.0. The reported standard error for the skewness and kurtosis results was 0.227 and 0.451 respectively.

Table 4.21b: Overall Extent of Mechanization (Descriptives)

Work Category	Mean	%	SD	Skewness	Kurtosis	Rank
a) Site Preparation and Earthworks (MSPE)	2.62	52%	.223	-.518	.288	2
b) Scaffolding and Formwork (MSF)	2.35	47%	.407	.479	-1.068	4
c) Concreting (MC)	3.18	64%	.362	.817	.001	1
d) Walling (MW)	2.40	48%	.365	.227	-1.093	3
e) Plastering and Flooring (MPF)	2.07	41%	.156	.888	1.016	5
f) Tiling and Painting (MTP)	1.88	38%	.155	.854	1.692	7
g) Building Services (MBS)	1.97	39%	.134	-.324	-.506	6

Source: (Fieldwork, 2025)

According to a study based on India's construction industry (Vadukkumchery & Myneni, 2023), earthwork works (RII=2.33), batching and mixing (RII=2.31), and concreting (RII=2.26) are the most mechanized tasks in the construction of a high-rise building in India. The same study reported masonry to be the least mechanized activity, followed by formwork activities (RII=1.08), scaffolding works (RII=1.08), painting (RII=1.18), and tiling/laying activities (RII=1.18). Though the study in India used a 3-point scale (low, moderate, high), the results are not very different from the ones presented in Table 4.21b, whereby Concreting emerged as the most mechanized construction activity. Similarly, Painting was among the least mechanized activities.

Just like the study in India as well, Site Preparation and Earthworks also ranked highly in the comparison among various work categories. In both studies as well, the mechanization of Building services ranked lowly. Another study by Vishwakarma et al. (2022) also established that mechanization and automation is least adopted in painting and other finishing works, such as plastering, and most utilized in earthworks.

However, the results in Table 4.21b contradict the findings by Sharmila et al. (2018) which found masonry activities to be the least mechanized, though these two studies agree on Plastering as one of the least mechanized activities. Vishwakarma et al. (2022) also found masonry to be among the least mechanized activities. Notably, Sharmila et al. (2018) also agrees that excavation is among the most mechanized activities in commercial construction projects.

As indicated earlier, the tool adopted in this research was adapted from Hwang et al. (2020). After developing this tool, the authors validated it by implementing it using 14 Singapore-based construction companies. Though their survey had a small sample size, their results were not very different from the ones reported in Tables 4.21a and 4.21b, especially on the general overview of the ranking of the mechanization levels in different work categories. Concreting, which was the most mechanized activity in the current study, was not considered by Hwang et al. (2020). In both studies, Site Preparation and Earthworks were highly mechanized, while the least mechanized were Tiling and Painting, which were reported to have a mechanization level of 43% in Hwang et al. (2020). Their study also established the level of mechanization in Scaffolding and Formwork to be 46% and 45 respectively, while the current study combined the two activities and obtained a mechanization level of 47%. Hwang et al. (2020) reported an overall level of mechanization of 49%, which was higher by only two percentage points than the current study.

4.7 Effect of Mechanization on the Performance of Construction Workers

Studies on the effects of mechanization date as far back as the 1930s. Jerome (1934) wrote extensively on the effects of mechanization on labour requirements across several industries. The current study used correlations and multiple regression to establish the effect of mechanization on the Performance of Construction Workers (PCW). The findings have been presented and discussed in the following sections.

4.7.1 Correlations

Before the correlation analysis was done, a comparison was made between the labour efficiency of construction workers and the extent of mechanization in construction projects based on their descriptive statistics. Data presented in Table 4.22 showed a possibility of some relationship, especially based on the rankings. For example, both the labour efficiency and mechanization in Concreting, and Scaffolding and Formwork had similar rankings, while there was a difference of only one unit in the ranking of a majority of the remaining work categories, that is, Walling, Building Services, and Tiling and Painting. The only item that had a relatively large variation in the ranking was Site Preparation and Earthworks.

These results showed speculation of a possible linear relationship between labour efficiency and mechanization. High-ranked labour efficiency values were coupled with a high ranking of mechanization levels in the same work categories. The vice versa was also true, low-ranked labour efficiency values were coupled with high ranking of mechanization levels in the same work categories. This speculation was, however, disapproved in the correlation results presented in Table 4.23.

Table 4.22: Descriptive Comparison between Labour Efficiency and Mechanization

	Labour Efficiency		Mechanization	
Work Category	**Mean**	**Rank**	**Mean**	**Rank**
a) Site Preparation and Earthworks	3.31	5	2.62	2
b) Scaffolding and Formwork	3.32	4	2.34	4
c) Concreting	3.40	1	3.18	1
d) Walling	3.37	2	2.40	3
e) Plastering and Flooring	3.37	3	2.07	5
f) Tiling and Painting	3.28	6	1.88	7
g) Building Services	3.27	7	1.97	6
Overall	**3.33**		**2.35**	

Source: (Fieldwork, 2025)

Table 4.23 presents a Pearson's correlation matrix between Labour efficiency and Mechanization in the seven (7) work categories considered for this study. The results indicate that out of the seven work categories, only Concreting demonstrated a statistically significant relationship (-0.189, p=0.045). The relationship was very weak and negative.

Table 4.23: Labour Efficiency Vs Mechanization Correlation Matrix

		MSPE	MSF	MC	MW	MPF	MTP	MBS
LESPE	Coefficient	-.118	.103	-.206*	-.116	.014	.025	.100
	Sig. (2-tailed)	.213	.280	.029	.223	.883	.797	.292
LESF	Coefficient	-.057	.089	-.196*	-.163	-.001	-.081	.083
	Sig. (2-tailed)	.551	.348	.038	.085	.993	.395	.380
LEC	Coefficient	-.091	.300**	-.189*	-.157	-.108	-.031	.143
	Sig. (2-tailed)	.338	.001	.045	.096	.255	.747	.129
LEW	Coefficient	-.134	.252**	.065	.110	.067	.046	.178
	Sig. (2-tailed)	.156	.007	.494	.244	.479	.629	.059
LEPF	Coefficient	-.079	.254**	.126	.123	.058	.057	.113
	Sig. (2-tailed)	.405	.007	.185	.194	.540	.547	.233
LETP	Coefficient	-.231*	.122	-.064	-.035	-.142	-.041	.036
	Sig. (2-tailed)	.014	.197	.501	.714	.133	.669	.705
LEBS	Coefficient	-.261**	.071	-.080	-.011	-.095	-.022	.050
	Sig. (2-tailed)	.005	.457	.398	.906	.317	.817	.598

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

*. Correlation is significant at the 0.05 level (2-tailed).

Source: (Fieldwork, 2025)

Table 4.24 presents a summary of the correlation between Labour efficiency and Mechanization for the aggregated seven (7) work categories. The results generally indicate no statistically significant relationship between Mechanization and Labour efficiency. This means that mechanization does not improve the labour efficiency of construction workers in the construction industry of Kenya. Studies based on the agricultural industry found no significant improvements in output per acre due to mechanization (Caunedo & Kala, 2021; Reimer, 1984). Other studies have even established a decrease in rice production efficiency to be associated with increased mechanization due to increased associated costs (Srisompun et al., 2019).

However, previous studies based on the construction industry demonstrate conflicting findings. For example, the study by Vadukkumchery and Myneni (2023) demonstrates a 40 to 67% savings in cost and a 55 to 75% savings in time when mechanization is employed. The study also reported a reduction of 11.26% in its duration is by mechanizing masonry and wall finishes' activities in addition to the conventionally mechanized activities. Further, Llale et al. (2020) noted that automation and robotics in construction can potentially increase both efficiency and productivity on construction sites. The authors pointed out that, unlike human labour productivity, which can be negatively affected by factors such as tiredness, fatigue and absenteeism, automation and robotics are more productive than human labour where bricklaying robotics can be able to build a complete house in two days, in comparison to weeks and months achieved by human labour.

Table 4.24: Overall Correlation between Mechanization and Labour Efficiency

		M	LE
M	Pearson Correlation Coefficient	1	.009
	Sig. (2-tailed)		.921
	N	113	113
LE	Pearson Correlation	.009	1
	Sig. (2-tailed)	.921	
	N	113	113

Source: (Fieldwork, 2025)

Table 4.25 presents the correlation between Mechanization and the two aspects of Labour effectiveness, that is, Quality of Work (QWo) and Extent of Training, Skillset, and Development (TSD). A statistically significant relationship was noted between Mechanization and TSD. The relationship was moderately weak but positive (0.379, p=0.000), indicating that increased levels of mechanization were associated with increased levels of training, skillset, and development of construction workers.

Table 4.25: Overall Correlation between Mechanization and Labour Effectiveness

		M	QWo	TSD
M	Pearson Correlation	1	-.145	.370**
	Sig. (2-tailed)		.126	.000
	N	113	113	113
QWo	Pearson Correlation	-.145	1	.286**
	Sig. (2-tailed)	.126		.002
	N	113	113	113
TSD	Pearson Correlation	.370**	.286**	1
	Sig. (2-tailed)	.000	.002	
	N	113	113	113

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

Source: (Fieldwork, 2025)

Similarly to the results in Table 4.25, a previous study revealed that improved workforce skills, training, and morale were associated with increased mechanization (Mekgwe, 2016). These findings could be explained by the fact that the use of machines requires workers to obtain specific and the latest skills to operate such machines, hence the need for training and development of skillset. Indeed, Sharmila et al. (2018) asserts that increased training and skill requirements are a necessity created by mechanization.

4.7.2 Multiple Regression (PCW versus Mechanization)

In the multiple regression, both the labour efficiency and labour effectiveness measures were aggregated to create a single variable known as Performance of Construction Workers (PCW), which was regressed on the levels of mechanization in different work categories. The results have been presented in Tables 4.26, 4.27, and 4.28.

As noted in Table 4.26, the R, R-squared, and the Adjusted R-squared values for the regression model were 0.44, 0.194, and 0.140, respectively. This means that Mechanization accounts for 14% of the variation in PCW. Consequently, it means that 86% of the PCW is explained by factors other than Mechanization.

Table 4.26: Regression Analysis between PCW and Mechanization (Model Summary)

Model	R	R Square	Adjusted R-Square	Std. Error of the Estimate
1	.440[a]	.194	.140	.30945

a. Predictors: (Constant), MBS, MW, MSF, MSPE, MC, MPF, MTP

Source: (Fieldwork, 2025)

The ANOVA test presented in Table 4.27 shows that the achieved regression model was statistically significant (p=0.002) and the model was fit to explain the relationship between PCW and the various levels of Mechanization in different work categories.

Table 4.27: Regression Analysis between PCW and Mechanization (ANOVA[a])

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.420	7	.346	3.611	.002[b]
	Residual	10.054	105	.096		
	Total	12.475	112			

a. Dependent Variable: PCW

b. Predictors: (Constant), MBS, MW, MSF, MSPE, MC, MPF, MTP

Source: (Fieldwork, 2025)

Table 4.28 showed that only three predictors had a statistically significant relationship with PCW. These were Mechanization in; Site Preparation and Earthworks (SPE), Scaffolding and Formwork (SF), and Concreting. However, two of these were found to have a negative relationship with PCW. This means that an increase in mechanization of SPE and Concreting works resulted in decreased PCW. The relationship between PCW and the Mechanization of SF works was positive meaning that an increase in the mechanization of SF works would improve the PCW. Mechanization in Walling, Finishes (Plastering, Flooring, Tiling, and Painting), and Building services was found to have no statistically significant effect on the PCW.

Table 4.28: Regression Analysis between PCW and Mechanization (Coefficients[a])

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.913	.716		4.071	.060
	MSPE	-.245	.132	-.164	-1.860	.066
	MSF	.271	.083	.331	3.266	.001
	MC	-.304	.093	-.331	-3.273	.001
	MW	.130	.083	.142	1.573	.119
	MPF	.053	.192	.025	.276	.783
	MTP	.090	.198	.042	.454	.651
	MBS	.370	.228	.150	1.621	.108

a. Dependent Variable: PCW

Source: (Fieldwork, 2025)

The following regression model, comprising only the statistically significant predictors, was formulated;

$$PCW = 2.913 - 0.245M_{SPE} + 0.271M_{SF} - 0.304M_{C}$$

The results for the effect of mechanization on the performance of construction workers presented in Tables 4.22-4.28 were mixed. There was an element of inconsistency. For example, while the descriptive comparison between labour efficiency and mechanization in various work categories (Table 4.22) showed that highly mechanized activities tended to have relatively higher labour efficiencies, the correlation analysis in Table 4.23 demonstrated that the only statistically significant relationship between mechanization and labour efficiency existed only in Concreting and happened to be negative, though the relationship was very weak. Further, a summary of the relationship between Mechanization and Labour efficiency (Table 4.24) indicated no statistically significant relationship between these two variables. This means that mechanization does not improve the labour efficiency of construction workers in Kenya's construction industry. The results did, however, show a statistically significant relationship between Mechanization and the Extent of Training, Skillset, and Development (TSD). Regression results (Table 4.28) showed that the performance of construction workers (PCW) was only affected by variations in the mechanization of

SPE, SF, and Concreting works. Two of these relationships were, however, found to be negative.

Previous research demonstrates the presence of a relationship between labour efficiency and mechanization. For example, Kapliński et al. (2002) notes that mechanization and automation significantly increase work efficiency. Further, Llale et al. (2020) note that automation and robotics in construction can potentially increase both efficiency and productivity on construction sites. The authors point out that, unlike human labour productivity, which can be negatively affected by factors such as tiredness, fatigue, and absenteeism, automation and robotics are more productive than human labour where bricklaying robotics can be able to build a complete house in two days, in comparison to weeks and months achieved by human labour.

4.8 Effect of Mechanization on the Quality of Work Life of Construction Workers

This study used correlations and multiple regression to establish the effect of mechanization on the Quality of Work Life (QWL) of construction workers on project sites. The findings have been presented and discussed in the following sections.

4.8.1 Correlations

Table 4.29 presents a Pearson's correlation matrix between Mechanization (M) and the four variables of Quality of Work Life (QWL) namely, Fairness of Compensation and Reward Systems (CRS), Quality of Working Conditions (WC), Quality of Health and Safety (HS), and Quality of Welfare and Social Integration (WSI). All the relationships were generally weak, and three out of the four correlations were statistically significant. The results indicate that the effect of mechanization on CRS (-0.219, p=0.02) and HS (-0.241, p=0.01) was negative. This means that increased mechanization tends to be accompanied by reduced remuneration and worsened health and safety conditions on construction sites. This could be attributed to the fact (or perception) that mechanization replaces human labour and also causes injuries, as it has been observed in many cases. However, the effect of mechanization on WC (0.274, p=0.003) was positive, meaning that increased mechanization led to improved working conditions for construction workers. The relationship between mechanization and WSI was not statistically significant. Also, all but one (CRS/WSI) of the correlations among the four aspects of QWL were positive. This is expected since the four variables explain the same construct.

Table 4.29: QWL of Construction Workers Vs Mechanization Correlation Matrix

		M	CRS	WC	HS	WSI
M	Coefficient	1	-.219*	.274**	-.241*	-.174
	Sig. (2-tailed)		.020	.003	.010	.066
CRS	Coefficient	-.219*	1	.475**	.305**	.151
	Sig. (2-tailed)	.020		.000	.001	.111
WC	Coefficient	.274**	.475**	1	.216*	.409**
	Sig. (2-tailed)	.003	.000		.022	.000
HS	Coefficient	-.241*	.305**	.216*	1	.345**
	Sig. (2-tailed)	.010	.001	.022		.000
WSI	Coefficient	-.174	.151	.409**	.345**	1
	Sig. (2-tailed)	.066	.111	.000	.000	

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Source: (Fieldwork, 2025)

Table 4.30 presents a summary of the correlation between Mechanization and QWL. The results indicate that though there is a statistically significant relationship, it is negative and very weak (-0.083, p=0.008) tending towards negligible. This means that only a large increase in mechanization would have some recognizable effect on QWL. This effect would, however, be negative, meaning that extensive use of mechanization would lead to a slight decrease in the QWL of construction workers in the construction industry of Kenya.

Table 4.30: Overall Correlation between Mechanization and QWL

		QWL	M
QWL	Pearson Correlation	1	-.083
	Sig. (2-tailed)		.008
M	Pearson Correlation	-.083	1
	Sig. (2-tailed)	.008	

Source: (Fieldwork, 2025)

4.8.2 Multiple Regression (QWL versus Mechanization)

In the multiple regression, the four aspects of QWL were aggregated to create one single variable, which was regressed on the levels of mechanization in different work categories. The results have been presented in Tables 4.31, 4.32, and 4.33.

As noted in Table 4.31, the R, R-squared, and the Adjusted R-Square values for the regression model were 0.44, 0.194, and 0.140, respectively. This means that Mechanization accounts for 15% of the variation in the QWL of construction workers in Kenya. Consequently, it means that 85% of the QWL is explained by factors other than Mechanization.

Table 4.31: Regression Analysis between Performance of Construction Workers and Mechanization (Model Summary)

Model	R	R Square	Adjusted R-Square	Std. Error of the Estimate
1	.451[a]	.204	.151	.37712

a. Predictors: (Constant), MBS, MW, MSF, MSPE, MC, MPF, MTP

Source: (Fieldwork, 2025)

The ANOVA test presented in Table 4.32 shows that the achieved regression model was statistically significant (p=0.001) and the model was fit to explain the relationship between QWL and the various levels of Mechanization in different work categories.

Table 4.32: Regression Analysis between QWL and Mechanization (ANOVA[a])

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.820	7	.546	3.837	.001[b]
	Residual	14.933	105	.142		
	Total	18.753	112			

a. Dependent Variable: QWL
b. Predictors: (Constant), MBS, MW, MSF, MSPE, MC, MPF, MTP

Source: (Fieldwork, 2025)

Table 4.33 showed that only two predictors had a statistically significant relationship with QWL. These were Mechanization in; Site Preparation and Earthworks (SPE), and

Scaffolding and Formwork (SF). However, one of these was found to have a negative relationship with QWL. This means that an increase in the mechanization of SPE resulted in decreased QWL. The relationship between QWL and the Mechanization of SF works was positive meaning that an increase in the mechanization of SF works would improve the QWL. Mechanization in Concreting, Walling, Finishes (Plastering, Flooring, Tiling and Painting), and Building services was found to have no statistically significant effect on the QWL.

Table 4.33: Regression Analysis between QWL and Mechanization (Coefficients[a])

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	5.349	9.639		.555	.618
	MSPE	-.512	.160	-.280	-3.190	.002
	MSF	.310	.101	.309	3.060	.003
	MC	-.217	.113	-.193	-1.919	.058
	MW	-.022	.101	-.019	-.216	.830
	MPF	.201	.234	.077	.860	.392
	MTP	-.240	.242	-.091	-.991	.324
	MBS	-.523	.278	-.172	-1.880	.063

a. Dependent Variable: QWL

Source: (Fieldwork, 2025)

The following regression model, comprising only the statistically significant predictors, was formulated;

$$QWL = 5.349 - 0.512M_{SPE} + 0.310M_{SF}$$

The analysis of the effect of mechanization on the Quality of Work Life (QWL) for construction workers in Kenya’s construction industry posted mixed results. The correlation analysis in Table 4.29 showed both positive and negative effects. While the working conditions of construction workers were positively affected, their remuneration, health, and safety conditions were negatively affected. This consequently led to the overall effect of mechanization on QWL (Table 4.30) being negative, though the relationship was very weak, tending towards negligible. Regression results (Table 4.33) showed that the QWL of construction workers was only affected by variation in the mechanization of SPE and SF works even though one of these relationships was found to be negative.

While there is agreement between the current and previous research on the effects of mechanization on various aspects of QWL, there exists some contrast. For example, the current study established that mechanization positively affects the quality of working conditions (WC) of construction workers in Kenya, Sharmila et al. (2018) notes that the introduction of machinery to construction projects has led to a surge in noise and air pollution. However, it could be argued that this is an aspect of health and safety that was established by this study to be negatively affected. The findings of this study agree with those of Kapliński et al. (2002) who assert that mechanization and automation significantly improve the working conditions of the builders.

Just as found in this study, previous research indicates a negative influence on health and safety by mechanization. For example, Idoro (2011) notes that mechanization is associated with hazards because the use of construction plant and equipment is prone to accidents and injuries. The author reports that increased mechanization in excavation and concreting works leads to increased numbers and severity of injuries which adversely affect health and safety in construction sites. However, there have also been contrasting findings indicating that increased mechanization leads to reduced accidents and injuries on construction sites (Sharmila et al., 2018). Kapliński et al. (2002) also points out that mechanization and automation significantly improve the safety of construction workers.

4.9 Qualitative Data Analysis

Three open-ended questions were included in the questionnaire to allow the researcher to collect views from respondents regarding the influence of mechanization on the performance and welfare of construction workers and the most effective ways in which mechanization can enhance the performance and welfare of workers on construction sites. This data was analyzed using word clouds and has been presented and discussed in the following sections.

4.9.1 Positive Influence of Mechanization on the Performance and Welfare of the Construction Workforce

In this section, respondents were asked in what ways mechanization in the construction project had positively affected the performance and welfare of the workforce. A total of 339 perceived benefits of construction mechanization were listed by the respondents. Figure 4.6 presents a word cloud of these perceived positive effects. A frequency analysis revealed the ten most used words to be: mechanization (128), construction (98), enhanced (92), use (91), improved (81), project (75), greater (67), management (63), increased (56), and mechanized (52). Certain common or expected words, which would not provide deep meaning, such as mechanization, construction, use, and project, among others, were, however, omitted from the presented word cloud.

Figure 4.6: Word Cloud for the Perceived Positive Effects of Mechanization on the Performance and Welfare of Construction Workers

The word "enhanced" was used in reference to; safety, quality of work, collaboration between teams, environmental sustainability through efficient resource management, tracking of project progress, employee morale, training programs for workers, job security, quality controls, maintenance of equipment, project visibility, reporting capabilities, project documentation, workforce diversity, design capabilities, project budgeting, emergency response capabilities, labour relations, site security due to automatic monitoring systems, project adaptability to modular construction, ability to track labour productivity, project scalability, collaboration with suppliers through technology integration, project delivery through just-in-time construction techniques, and workforce training programs, among others.

The word “increased” referred to; collaboration with technology partners, project planning capabilities, overall project performance, training opportunities for workers, project coordination, ability to conduct risk assessment, stakeholder trust, employee empowerment, collaboration with engineering teams, ability to conduct thorough project evaluations, ability to manage subcontractor performance, ability to monitor project progress remotely, and project documentation, among others.

The word “improved” referred to; precision in construction processes, communication among teams, accuracy in measurements, data collection for project analysis, health of workers due to reduced strain, employee retention due to enhanced working conditions, client satisfaction, site organization, stakeholder engagement, ability to handle multiple projects, decision-making capabilities, project timelines and resources, worker satisfaction through reduced physical strain, worker productivity and collaboration, project forecasting, labour management, and site cleanliness, among others.

The phrase “improved management” referred to; construction timelines, change orders, site conditions, safety, project resources, construction teams, equipment, quality, communication, budgets, logistics, contracts, risks, and standards, among others. The phrase “better management” referred to; resources, risks, waste, project budgets, labour, and site traffic, among others.

The word “better” was used in reference to; communication, working conditions, resource management, risk management, integration of safety measures, waste management strategies, integration of design and construction processes, project tracking, cost management, employee health, compliance with regulations, project scheduling, handling of complex projects, resource allocation, handling of hazardous materials and waste, engagement with stakeholders, handling of logistics, surveying methods, simulations of construction processes, and planning processes, among others.

The word "greater" was used in reference to; precision and accuracy, adaptability to project changes, innovation in construction techniques, ability to meet tight deadlines, emphasis on safety compliance, quality checks, innovation, skill diversification, learning, and continuous improvement, ability to implement safety measures, focus on employee well-being and development, ability to implement advanced construction techniques and methods, standards of workmanship, efficiency in material handling, construction activities and demolition, among others.

4.9.2 Negative Influence of Mechanization on the Performance and Welfare of the Construction Workforce

Respondents were asked in what ways mechanization in the construction project had negatively affected the performance and welfare of the workforce. A total of 241 perceived negative effects of construction mechanization were listed by the respondents. Given that the number of respondents was the same in this and the previous question, it is clear that construction workers have embraced mechanization in construction projects since more responses were provided regarding the positive effects compared to the negative effects.

Figure 4.7: Word Cloud for the Perceived Negative Effects of Mechanization on the Performance and Welfare of Construction Workers

Figure 4.7 presents a word cloud of these perceived negative effects. A frequency analysis revealed the ten most used words to be: increased (114), machinery (108), potential (79), greater (74), accidents (70), risk (64), equipment (60), operated (53), workers (51), and due (46). Just like in the previous section, certain common or expected words that would not provide deep meaning, such as machinery, equipment, operated, workers, and due, among others, were omitted from the presented word cloud.

The word “increased” was used in reference to; complexity in project management, worker dissatisfaction, likelihood of injuries, mental strain, need for safety briefings, pressure on workers, health issues from prolonged machinery noise, costs associated with training workers, insurance, repair and maintenance, need for specialized training, and complexity in project coordination, among others.

“Potential accidents” were noted to arise from the following ways of equipment operation; without proper safety gear, under stress, unsafe conditions, untrained personnel, without proper supervision, adverse weather conditions, high-traffic areas, in poorly lit areas, congested areas, unmaintained equipment, inexperienced workers, improperly calibrated equipment, setup and takedown, heavy equipment transportation, distracted operators, poor communication, improperly stored and secured equipment, and failure to adhere to manufacturer guidelines, among others.

The word “decreased” was used in reference to; job satisfaction among workers, collaboration among teams and workers, potential for quality control, productivity if equipment is not properly used or maintained, worker morale due to perceived job insecurity, focus on safety, physical fitness, teamwork, quality resulting from uncalibrated equipment, job variety, innovation in construction methods, and worker engagement, among others

The word “greater” referred to the risk and likelihood of accidents, reliance on technology leading to skill degradation, difficulty in maintaining equipment, and risk of heat stress, among others.

4.9.3 Effective Ways of Incorporating Mechanization to Enhance the Performance and Welfare of the Construction Workforce

In this question, respondents were required to suggest ways in which mechanization can be incorporated into the construction project in such a way that it promotes the performance and welfare of the workforce. A total of 178 strategies for optimizing the deployment of machines and manpower in construction projects were listed by the respondents.

Figure 4.8 presents a word cloud of these strategies. A frequency analysis revealed the ten most used words to be: systems (116), use (112), smart (58), implement (55), advanced (53), tools (49), safety (43), construction (40), project (37), and deployment (35).

Figure 4.8: Word Cloud for Effective Ways of Incorporating Mechanization to Enhance the Performance and Welfare of the Construction Workforce

Some of the "systems" suggested for 'deployment' in construction projects include; scaffolding, safety monitoring, automated material handling, quality control, energy monitoring, prefabricated, smart waste and water management, advanced HVAC systems, automated curing, inventory management and site monitoring, advanced formwork, automated concrete pouring, mobile payment, smart logistics, automated material ordering, smart building management, automated project reporting and compliance monitoring, smart scheduling and workforce management, and advanced site security among others.

The phrase "use of" was used in reference to; cranes for lifting heavy materials, automated surveying tools, 3D printing to reduce material waste, Building Information Modelling (BIM), compactors to ensure quality and reduce manual effort, robotic process automation, mobile construction applications for real-time communication and monitoring, Virtual Reality (VR) for training workers on equipment operation, advanced safety equipment and PPE, applicable construction software, sustainable construction processes, smart construction machinery, modular construction methods, IoT devices for real-time monitoring, advanced lifting equipment for safe and effective heavy lifting, cloud-based collaboration tools, drones to conduct safety inspections, smart lighting systems, Augmented Reality (AR) for on-site training, remote-controlled machinery, real-time feedback systems, electric machinery to reduce emissions and noise pollution, smart scheduling tools, robots for tasks such as plastering, remote monitoring cameras, smart communication tools, advanced construction costing tools, smart equipment tracking systems, automated safety alerts, and techniques that leverage technology among others.

Some of the "smart" tools, equipment, techniques and systems suggested for deployment in construction projects include; PPEs, construction machinery, lighting, waste management, scheduling, water management, project dashboards, communication tools, construction material, equipment tracking, logistics solutions, building technologies and construction techniques, inventory management, building management, energy management, construction management software, project tracking, labour management, and resource allocation among others.

4.10 A Framework for Optimizing the Level of Mechanization and Manpower in Construction Projects in Kenya

The aim of this framework is to optimize the level of mechanization and manpower in construction projects in Kenya thereby enhancing performance and improving the quality of work life for construction workers. The framework integrates various theoretical perspectives and practical approaches in exploiting the opportunities and addressing the challenges presented by mechanization in the construction industry.

4.10.1 Rationale for the Framework

The rationale for this framework is founded on the need to balance mechanization with human labour with the aim of improving productivity while ensuring the welfare of construction workers is taken care of. As seen in this research, mechanization leads to increased efficiency, increased precision and accuracy, and speedy construction. However, it also poses risks such as increased occupational hazards if not managed properly, reduced teamwork, and job displacement. Consequently, a structured approach is necessary to harness the benefits of mechanization while mitigating its adverse effects. The proposed framework is key to enhancing economic performance while prioritizing social responsibility within Kenya's construction industry. By addressing productivity challenges through optimum mechanization while simultaneously ensuring the welfare and safety of construction workers are guaranteed, this framework aims to create a balanced approach that fosters sustainable growth in the construction sector in Kenya. It further recognizes the complexities associated with integrating advanced technologies into traditional practices.

Therefore, the rationale for developing a framework to optimize the level of mechanization and manpower in construction projects in Kenya is multifaceted, addressing not only the economic and social aspects but also the operational dimensions of the construction industry. This rationale is informed by the various opportunities and challenges presented by construction mechanization, as well as the need for a sustainable approach that enhances both productivity and the welfare of workers.

a) Economic Significance

The construction sector is a vital contributor to Kenya's economy, accounting for approximately 5.6% of the Gross Domestic Product (GDP) (KNBS, 2023). As noted in various studies, mechanization plays a critical role in enhancing productivity and efficiency within this sector (Babatunde et al., 2019; Calvetti et al., 2021; Hwang et al., 2020; Iheama et al., 2017; Kamaruddin et al., 2016, 2018; Lamsal, 2024; Vidushi et al., 2022; Vishwakarma et al., 2022). The framework aims to leverage mechanization to:

i). **Increase productivity**: Mechanization can significantly reduce the time required to complete construction tasks, leading to faster project delivery. This is essential in Kenya, a country where infrastructure development is crucial for economic growth.

ii). **Cost efficiency**: By optimizing the use of mechanization, construction firms can achieve cost savings through reduced labour costs, reduced rework, speedy construction, and minimized waste.

iii). **Enhance competitiveness**: In today's globalized construction market, Kenyan construction firms have no choice but to compete with international players. Adopting advanced mechanization techniques can improve competitiveness by enabling construction firms to deliver higher-quality projects more effectively and efficiently.

b) Social Implications

While mechanization presents numerous advantages and benefits, it also introduces challenges related to human labour displacement and issues surrounding the welfare of workers. The framework addresses these concerns by emphasizing:

i). **Skill Development**: As the level of mechanization increases, construction workers should adapt by acquiring new skills required to operate and maintain construction machinery. The framework advocates for continuous training programs that empower construction workers with the necessary competencies. This enhances their employability in the ever-changing job market.

ii). **Quality of Work Life**: it is expected that the integration of mechanization in the construction process should not come at the expense of worker welfare. The framework incorporates measures to ensure safe working conditions, fair compensation schemes, reduced occupational hazards, and improved overall job satisfaction. By addressing these issues, the framework seeks to create a more sustainable and inclusive work environment within construction projects.

iii). **New jobs**: Though some jobs are displaced due to mechanization, new roles such as skilled operators and technicians emerge. The proposed framework encourages strategic workforce planning aimed at identifying new opportunities and preparing workers accordingly.

c) Operational Efficiency

The operational landscape of construction projects is highly dynamic and always evolving due to technological advancements. The proposed framework aims to enhance operational efficiency through:

i). **Optimized resource allocation**: By assessing the appropriate level of mechanization for different project types and sizes, managers can allocate resources more effectively. This ensures that the proper balance between men and machines is achieved for each specific project. This ensures problems associated with overspending on unnecessary machinery are avoided.

ii). **Improved construction project management**: Mechanization changes project management dynamics. The proposed framework encourages managers to adopt best practices in labour planning and management that align with the planned level of mechanization for the project.

d) Addressing Challenges

The construction industry faces several challenges related to mechanization. These include;

i). **Resistance to change**: there is fear among construction workers that they may lose their jobs and thus resist the adoption of new technologies. The framework highlights the benefits of mechanization for both productivity and worker welfare. The framework is also founded on the idea that mechanization is a necessary complement to manpower and should be applied to enhance the performance of construction workers.

ii). **Initial capital investment**: purchasing or leasing machinery requires high upfront costs which can deter firms from investing in mechanization. The proposed framework calls for comprehensive cost-benefit analyses that justify such investments based on both short and long-term gains.

iii). **Safety concerns**: according to various studies, increased mechanization has been reported to lead to new safety risks especially if not managed properly (Barbosa et al., 2017; Kamaruddin et al., 2016; Muro et al., 2019). The framework calls for training programs designed specifically for the safe operation of construction machinery, thereby minimizing accidents on site. This could be achieved using advanced techniques such as Augmented Reality (AR) for on-site training.

4.10.2 Theoretical Underpinnings

The proposed framework is anchored on the following theories which also happen to be the guiding blueprint for this study as demonstrated in the second chapter.

a) **Human Capital Theory**: this theory posits that investing in the development of workers' skills enhances productivity. The framework advocates for training programs that equip construction workers with the necessary skills required to operate and maintain construction equipment.
b) **Theory of Capitalism**: this theory underscores the role of capital investment in driving economic growth in any country. The framework encourages investment in mechanization as a means of enhancing productivity and competitiveness within the construction sector.
c) **Theory of Induced Innovation**: this theory suggests that technological advancements are driven by economic needs. In a construction project, mechanization can be viewed as an innovation that responds to efficiency demands.
d) **Socio-Technical Systems Theory**: This theory emphasizes the interdependence between social (human) and technical (mechanical) systems. In a construction project, there is a need for a harmonious relationship between workers and machines to optimize the performance of both for the benefit of the project and stakeholders.

4.10.3 Underlying Principles

The proposed framework for optimizing mechanization and manpower in construction projects in Kenya is built upon ten (10) foundational principles that guide its development and implementation. These principles are designed to promote a balanced approach that enhances productivity while improving the welfare and safety of construction workers.

1) **Complementarity rather than replacement**: The proposed framework emphasizes that instead of total replacement, mechanization should be used to complement human labour. This principle recognizes that the human element in construction projects is inevitable due to the unique skills and capabilities that workers possess. Such cannot be fully replicated by machines. Therefore, by integrating mechanization optimally, the framework aims to enhance productivity while preserving the essential role of human labour.
2) **Balanced work allocation**: The framework advocates for a strategic allocation of tasks between machines and workers. This means that the very nature and quantity of tasks determine if they will be assigned to machines of manpower. For instance, repetitive and physically demanding tasks should be mechanized, while complex decision-making processes that require fine motor skills are assigned to workers. Such balance not only improves efficiency in the construction project but also maintains job opportunities for skilled labour.
3) **Skill development and adaptability to technological changes**: mechanization creates a pressing need for workers to acquire new skills to operate and maintain construction equipment effectively. The proposed framework prioritizes continuous training programs tailored to the evolving technological landscape of the global construction industry. This ensures that construction workers remain competitive in a dynamic job market. This enhances their employability and job security.
4) **Safety first**: The framework places a strong emphasis on safety protocols associated with mechanization. This includes employing advanced and smart systems which ensure workers are safe in the construction environment. The

framework recognizes that while mechanization can reduce certain risks, it can also introduce new hazards.

5) **Quality of Work Life**: Beyond physical safety, the developed framework addresses the overall quality of work life for construction workers. This includes considerations such as compensation, working conditions, welfare and social integration. By fostering a conducive and supportive work environment, the framework aims to enhance morale and productivity of construction workers.
6) **Performance monitoring**: Establishing key performance indicators (KPIs) allows for ongoing assessment of both mechanization and worker performance. This principle ensures that adjustments can be made in real time based on empirical evidence rather than assumptions. Feedback is therefore provided for future projects on whether to deploy machines or manpower in certain situations.
7) **Feedback mechanisms**: Establishing channels for feedback allows construction project stakeholders to voice their concerns or suggestions regarding adopted mechanization practices. This ensures that the framework remains responsive to the needs of those directly affected by its implementation.
8) **Environmental impact awareness**: It has been established in previous research that mechanization has significant environmental implications. Therefore, the framework encourages practices that minimize ecological footprints such as electrical machinery instead of diesel-powered engines which emit toxic fumes. This principle aligns with global sustainability goals.
9) **Informed investment decisions**: A critical principle of the framework is conducting thorough cost-benefit analyses before implementing or adopting mechanization. This involves assessing both the financial implications and the potential impacts on productivity, worker satisfaction, and safety.

Strategic resource allocation: By understanding the costs associated with different levels of mechanization and the available options for adopting mechanization such as purchasing versus leasing, managers can make informed decisions that align with project goals while optimizing resource use.

4.10.4 Design and Development Process

The design and development of the proposed framework for optimizing mechanization and manpower in construction projects in Kenya involved a systematic approach that integrates theoretical insights, empirical data collected from this study, and stakeholder input provided during the validation exercise. This process was critical in ensuring that the developed framework was not only practical but also tailored to the unique challenges and opportunities present in the construction industry of Kenya. The proposed framework has been presented in Figure 4.9.

Figure 4.9: A Framework for Optimizing the Level of Mechanization and Manpower in Construction Projects in Kenya

The framework presents three (3) pathways between construction project planning and execution. These are; (A) leveraging on technology by adopting machines, (B) use of manpower, and (C) combined use of men and machines in construction projects.

A. Use of Manpower in Construction Projects

This option is founded on the Human Capital Theory which suggests that humans are the most important resources in a construction project. It is on this basis that the developed framework argues that the use of manpower in construction projects is inevitable.

However, the deployment of manpower in construction projects should **depend on** factors such as (i) Qualifications of the workers, (ii) Training received by the workers, (iii) their Productivity, (iv) Effectiveness, and (v) Costs associated with the workers among other factors. All these aspects were included in the data collection instrument for this research.

The **benefits** associated with the deployment of human labour have been derived from the negative effects of mechanization suggested by the respondents. The benefits include; (i) more Teamwork among construction workers, (ii) higher Job security, (iii) higher Job satisfaction, (iv) better Safety, (v) higher Physical fitness, and (vi) lower Cost of acquisition among others.

Aspects relating to the **Quality of Work Life** (QWL) of construction workers must be considered. These were established in this research to be fundamental in the quest for ensuring dignity for workers. These aspects include; (i) Compensation and reward, (ii) Working conditions, (iii) Health and safety, and (iv) Welfare and social integration among others.

B) Adopting Machines/Leveraging of Technology

This option is founded on the Capitalism Theory and Theory of Induced Innovation which advocate for mechanization in a construction project in a bid to enhance efficiency and maximize the profit realized from the project. The use of machines and advanced systems is the trend in today’s construction projects.

However, mechanization in construction projects should **depend on** factors such as (i) their Suitability, (ii) Functionality, (iii) their Productivity, (iv) embracing of Latest technology, and (v) Costs associated with the acquisition and maintenance among other factors.

The **benefits** associated with mechanization have been derived from the positive effects of mechanization suggested by the respondents. The benefits include; (i) more Precision/Accuracy, (ii) execution of Complex projects, (iii) speedy Project timelines, (iv) better Project tracking, (v) higher Client satisfaction, and (vi) higher Worker productivity among others.

The optimal **Level of Mechanization** in a construction project depends on; (i) the Type of project, (ii) the Size of the project, (iii) Site location, and (iv) the Availability of equipment among others. The goal of this is to ensure projects are correctly matched with the intended levels of mechanization in order to avoid overspending on unnecessary equipment.

C) Use of Machines to complement Manpower

This option is founded on the Socio-Technical Systems Theory which emphasizes the interdependence between social (human) and technical (mechanical) systems. It calls for a harmonious relationship between workers and machines to optimize the performance of both for the benefit of the project and stakeholders. It is the premise of this study.

This pathway incorporates all the aspects already discussed in the two previous options i.e., (A) manpower and (B) machines. This includes the considerations, benefits, level of mechanization, and aspects of QWL.

Further, this option provides several latest mechanical systems that enhance the Performance and QWL of construction workers as suggested by respondents. These include; (i) Smart construction machinery, (ii) Mobile construction applications, (iii) Virtual Reality (VR) for training workers on equipment operation, (iv) Augmented Reality (AR) for on-site training and to visualize construction plans in real-time, (v)

IoT Devices for real-time monitoring of equipment and site conditions, (vi) Cloud-based collaboration tools for better collaboration among project stakeholders, (vii) Drones for site surveys and inspections and Robots for plastering, (viii) Smart lighting systems, (ix) Remote-controlled machinery for hazardous tasks to protect workers, (x) Real-time feedback systems to enhance safety and increase efficiency, (xi) Electric machinery to prevent noise and harmful fumes, (xii) Automated safety alerts to improve the safety of workers, (xiii) Advanced/smart safety equipment (PPEs), (xiv) Smart equipment tracking systems, and (xv) Remote monitoring cameras among others.

4.10.5 Validation of the Framework

The validation of the framework was achieved through the administration of a questionnaire (Appendix IV). The survey was conducted on 30% of the 116 respondents who had participated in the initial survey. This was based on the suggestion provided by Dawood and Sikka (2009). Therefore, a sample size of 35 was adopted. Out of these, 30 responded, giving a response rate of 85.7%. The validation questions employed a 7-point Likert scale because it increases the variability of responses hence providing more research validity and reliability as asserted by Kim (2010). Since the information was being sought from respondents who had already participated in the main survey, background questions were not included and therefore the questionnaire only had one question. A section for general comments was however also provided.

The results presented in Table 4.34 showed that the perception of participants was very positive as seen in respondents' means which were placed close to the maximum rate of agreement. According to this, it is believed that the proposed framework is practical, clear, applicable, comprehensive, and suitable.

Table 4.34: Framework Validation Results

Criteria	N	Min.	Max.	Mean	Std. Dev
Clarity	30	5	7	6.68	0.352
Practicability	30	6	7	6.78	0.237
Applicability	30	6	7	6.75	0.445
Comprehensiveness	30	5	7	6.65	0.296
Suitability	30	6	7	6.79	0.319

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The aim of this research was to investigate the influence of construction mechanization on the quality of work life and the performance of workers on construction sites in Kenya. The study was guided by the following specific objectives; (i) to establish the level of quality of work life and the performance of workers on construction sites in Kenya, (ii) to establish the extent of mechanization in construction projects in Kenya, (iii) to establish the effect of mechanization on the quality of work life and the performance of construction workers on sites, and (iv) to formulate a framework for optimizing the level of mechanization and manpower in construction projects in Kenya. This last chapter presents a summary of the research findings, and presents the study's conclusions, recommendations and limitations. Also included in this chapter are possible areas of further study.

5.2 Summary of Findings

5.2.1 Performance of Construction Workers

The labour efficiency in the studied construction projects ranged between 64.8% (plumbing works) and 69.6% (concrete mixing) representing a small range of only 4.8%. However, aggregated labour efficiency values showed that these works have the lowest performance. The overall labour efficiency in the studied construction projects was 66.8%.

The quality of work produced by the construction workers was evaluated based on 5-point criteria namely; accuracy, workmanship, timeliness, minimal rework, and minimal supervision. The results ranged between 59.6% (accuracy) and 62.8% (minimal rework). The overall level of quality of work was found to be 60.6%.

The research also established the extent of training, skillset, and development among the construction workers. The measurement was based on five indicators namely, worker development, career growth, personal growth, new methods, and training. The results showed the leading indicator to be learning new methods (68.6%) while the lowest ranking was the possibility of career growth (65.4%). The range between these two was almost negligible (3.2%). The overall level of the extent of training, skillset, and development among the construction workers was found to be 67.2%. The extent of training, skillset, and development among the construction workers was relatively higher than the quality of work by these workers.

The findings indicated that the qualitative aspect (effectiveness) of construction worker performance was lower than the quantitative aspect (labour efficiency) by 4 percentage points. It is an indication that there is a higher emphasis on the quantity of output compared to the quality of the resulting work. Construction workers and perhaps their supervisors care more about the delivery of the job.

5.2.2 Quality of Work Life of Construction Workers

Results on the fairness of compensation and reward systems for construction workers showed the highest and the lowest ranked factors to be “timely payments” (68.8%) and “adequacy of wages” (60.8%) respectively. The overall extent of “fairness of compensation and reward systems” to the construction workers was established to be 64.4%.

Nine (9) factors were used to assess the quality of working conditions experienced by construction workers on sites. The scores ranged between 68.4% and 72.4%. There seems to be comparatively less involvement of construction workers in decision making as seen in the low ranking. Also, the work environment is not highly encouraging. The overall extent of quality of working conditions was established to be 72.6%.

The quality of health and safety experienced by the construction workers was evaluated based on 8-point criteria. The findings ranged between 65.8% and 76.2%. Lowly ranked factors included training in health and safety, safety and health of the physical environment, and reasonable working times. The overall level of the quality of health and safety experienced by the construction workers was found to be 72.6%.

The research established the extent of the quality of welfare and social integration. The results presented in the previous chapter showed the leading indicator to be fairness in workload distribution (74.2%) while the lowest ranking was a sense of one community (68.8%). The range between these two was low (5.4%). The overall extent of quality of welfare and social integration was found to be 71.0%.

5.2.3 Level of Mechanization in Construction Projects in Kenya

More than half (53%) of the activities in the building construction sector are carried out using Hand tools. This is then followed by Automated hand tools with an approximate usage of 31%. Completely manual methods and Machines (workstations) are used almost similarly at 9% and 7% respectively. None of the activities in construction are Completely automated (robotized). The three work categories with the highest level of mechanization were; Concreting, (64%), Site Preparation and Earthworks (52%) and Walling (48%). The least mechanized work categories were; Plastering and Flooring (41%), Building Services (39%), and Tiling and Painting (38%). The overall level of Construction Mechanization was established to be 47%.

5.2.4 Effect of Mechanization on the Performance of Construction Workers in Kenya

Before the correlation analysis was done, a comparison was made between the labour efficiency of construction workers and the extent of mechanization in construction projects based on their descriptive statistics. The data showed a possibility of some relationship especially based on the rankings. For example, both the labour efficiency and mechanization in Concreting, Scaffolding and Formwork had similar rankings meaning that high-ranked labour efficiency values were coupled with a high ranking of mechanization levels in the same work categories. The vice versa was also true.

However, the results of the correlation analysis generally indicated no statistically significant relationship between Mechanization and Labour efficiency. This means that mechanization does not improve the labour efficiency of construction workers in the construction industry of Kenya. The results indicate that out of the seven work categories, only Concreting demonstrated a statistically significant relationship (-

0.189, p=0.045) between its mechanization and labour efficiency. The relationship was very weak and negative.

Regression analysis showed that only three predictors had a statistically significant relationship with the performance of construction workers (PCW). These were Mechanization in; Site Preparation and Earthworks (SPE), Scaffolding and Formwork (SF), and Concreting. However, two of these were found to have a negative relationship with PCW. This means that an increase in mechanization of SPE and Concreting works resulted in decreased PCW. The relationship between PCW and the Mechanization of SF works was positive meaning that an increase in the mechanization of SF works would improve the PCW. Mechanization in Walling, Finishes (Plastering, Flooring, Tiling and Painting), and Building services was found to have no statistically significant effect on the PCW.

5.2.5 Effect of Mechanization on the Quality of Work Life of Construction Workers in Kenya

A correlation matrix between Mechanization (M) and the four variables of Quality of Work Life (QWL) revealed that three out of the four correlations were statistically significant. These relationships were however generally weak. The effect of mechanization on the quality of working conditions (0.274, p=0.003) was positive meaning that increased mechanization led to improved working conditions for construction workers. However, the effect of mechanization on compensation and rewards systems (-0.219, p=0.02) and quality of health and safety (-0.241, p=0.01) was negative. The relationship between mechanization and WSI (welfare and social integration) was not statistically significant. Also, all but one (CRS/WSI) of the correlations among the four aspects of QWL were positive. This is expected since the four variables explain the same construct.

Results of the regression analysis showed that only two of the four predictors had a statistically significant relationship with QWL. These were Mechanization in; Site Preparation and Earthworks (SPE), and Scaffolding and Formwork (SF). However, one of these was found to have a negative relationship with QWL. This means that an increase in mechanization of SPE resulted in decreased QWL. The relationship between QWL and the Mechanization of SF works was positive meaning that an increase in mechanization of SF works would improve the QWL. Mechanization in Concreting, Walling, Finishes (Plastering, Flooring, Tiling and Painting), and Building services was found to have no statistically significant effect on the QWL.

5.3 Conclusions of the Study

Based on the thesis findings, the following conclusions were made.

- **Current Industry Status:** Kenya's construction industry remains heavily manual, with 47% overall mechanization and 53% of activities still utilizing hand tools.
- **Performance Metrics:** The performance of construction workers is below par. There is a huge potential for improvement in the performance of construction workers in Kenya’s construction industry, which needs to be exploited in the push for improved delivery of construction projects. Labour efficiency (quantitative) ranges from 64.8% to 69.6%, but labour effectiveness (qualitative) lags behind by 4 percentage points, indicating that while work is being done, its precision and skill level are not yet optimized. There is a moderate level of training and skill development among construction workers (67.2%), with a particular emphasis on learning new methods. However, opportunities for career growth are limited, indicating a gap in long-term professional development.
- **Level of Mechanization:** At 47%, the overall level of Construction Mechanization in Kenya is low. Even in cases where more sophisticated machines would be best suited, most of the construction tasks are still being carried out using hand tools which tend to be less efficient.
- **Mixed Impact of Mechanization:** There are mixed results when it comes to the effect of mechanization on the performance of construction workers. The findings range from negative to positive and in some cases, no relationship. While mechanization significantly improves physical working conditions, it currently has a negative impact on worker compensation, health and safety perceptions, and social integration.

- **Sectoral Imbalance:** A structural gap exists where mechanization is introduced to boost speed but often neglects the socio-technical needs of the workforce, such as training and fair reward systems.

5.4 Recommendations of the Study

The study recommends a transition from viewing mechanization solely as a productivity tool to treating it as a **socio-technical system** that balances machine efficiency with human welfare. Further, the following recommendations have been made

1. Strategic Workforce Training

- **Specific Strategy:** Establish "Continuous Professional Development" (CPD) modules specifically for machine operation and maintenance.
- **Implementation:** Utilize Augmented Reality (AR) for on-site training to simulate high-risk machine operations in a safe environment before actual deployment.

2. Performance-Linked Compensation Models

- **Specific Strategy:** Restructure wage systems to reward workers who acquire technical skills or achieve higher precision through mechanized tools.
- **Implementation:** Conduct regular cost-benefit analyses to redistribute a portion of the savings gained from mechanized efficiency (e.g., reduced rework or faster delivery) back to the workers in the form of technical skill premiums.

3. Integrated Health, Safety, and Environment (HSE) Protocols

- **Specific Strategy:** Develop safety protocols specifically tailored to the noise, dust, and mechanical hazards introduced by new machinery.
- **Implementation:** Deploy IoT devices and smart sensors for real-time monitoring of site conditions and equipment tracking to prevent accidents before they occur.

4. Collaborative Project Management

- **Specific Strategy:** Adopt a "Participative Design" approach where workers are consulted on the selection and deployment of machines.

- **Implementation:** Use Building Information Modelling (BIM) and cloud-based collaboration tools to involve technical staff in the planning phase, ensuring that the chosen level of mechanization aligns with the available human skill sets.

5. Framework-Driven Resource Allocation

- **Specific Strategy:** Use a structured framework to determine the "Optimum Mechanization Level" for each project phase rather than applying a blanket approach.
- **Implementation:** Managers should evaluate project size and complexity to decide between manual labour for detail-oriented tasks (like tiling or painting) and high mechanization for heavy tasks (like earthworks or hoisting) to prevent overspending and unnecessary job displacement.

5.5 Contribution to Knowledge

This thesis significantly enhances the understanding of construction mechanization's impact on both the quality of work life (QWL) and the performance of construction workers (PCW) in Kenya. By analyzing various levels of mechanization across different construction activities, the research identifies specific areas where mechanization can lead to improved productivity and worker satisfaction. This contribution is crucial for stakeholders in the construction industry, as it highlights the relationship between mechanization practices and worker performance metrics, thereby informing future research and practice.

5.5.1 Contribution to Theory

This research contributes to existing theories related to construction project management and labour productivity by integrating concepts such as induced innovation and socio-technical systems. The study posits that mechanization not only serves as a tool for enhancing productivity but also reshapes the work environment and construction worker dynamics. By applying these theoretical frameworks, the thesis offers a nuanced perspective on how technological advancements in construction can lead to both positive and negative outcomes for construction workers.

This theoretical contribution encourages further exploration into the socio-economic implications of mechanization within the broader context of labour studies especially in construction projects.

By employing socio-technical systems theory, the research highlights the interdependence between technology (mechanization) and human factors (workers' skills, attitudes, and well-being). This contribution emphasizes that the successful implementation of mechanization requires a balance between technological advancements and workforce capabilities. The findings suggest that neglecting the human aspect in mechanization efforts can lead to adverse effects on worker performance and morale, thus advocating for a holistic approach in construction project management.

The research also contributes to the theory of induced innovation by illustrating how changes in mechanization levels can drive innovations in construction practices. The thesis posits that as construction firms adopt more advanced machinery, they are prompted to innovate not only in their operational processes but also in workforce training and development strategies. This perspective encourages managers to view mechanization as a catalyst for broader organizational change rather than just an operational adjustment.

Finally, the thesis proposes a framework for strategic workforce planning that incorporates mechanization as a critical variable. This framework guides construction project managers in aligning workforce skills with technological requirements, ensuring that human resources are effectively utilized alongside mechanized processes. By addressing workforce planning through this lens, the research contributes to theoretical discussions on human resource management within construction project management, emphasizing the need for adaptive strategies in response to technological advancements.

These theoretical contributions collectively enhance the understanding of how mechanization influences various aspects of construction project management, offering valuable insights for both academic research and practical application within the industry.

5.5.2 Contribution to Methodology

The methodological approach adopted in this thesis is noteworthy for its comprehensive use of mixed methods, combining both quantitative and qualitative data. This dual approach allows for a richer understanding of the complexities surrounding mechanization in construction. Most importantly, this thesis introduces the application of the Mechanization Index Assessment Tool (MIAT) in Kenya or any other developing country for that matter, which serves as a theoretical model for assessing the extent of mechanization in construction projects. This tool provides a systematic method for determining the levels of mechanization across various work categories in a building construction project. The MIAT can be utilized by researchers and practitioners alike to benchmark mechanization practices across various projects, facilitating comparative studies and enhancing understanding of mechanization's role in construction project management.

5.6 Implications of the Study

5.6.1 Practical Implications

The findings from this research have significant practical implications for the construction industry in Kenya. By demonstrating that higher levels of mechanization correlate with improved labour effectiveness and QWL, construction firms can strategically invest in machinery that enhances productivity while simultaneously improving worker conditions. The study also outlines specific recommendations for implementing mechanization practices effectively, which can help contractors streamline operations, reduce costs, and ultimately achieve better project outcomes.

5.6.2 Managerial Implications

For construction project managers, this thesis underscores the necessity of adopting strategic workforce planning in light of increasing mechanization. Managers are encouraged to conduct thorough cost-benefit analyses when considering investments in machinery, factoring in not only purchase or rental costs but also maintenance and training needs for staff. The research highlights that effective management of mechanization requires a long-term perspective on workforce development, including skill enhancement and capacity building. By aligning workforce capabilities with technological advancements, managers can foster a more efficient and motivated workforce, ultimately leading to enhanced project performance and worker satisfaction.

5.7 Area of Further Study

The researcher suggests the following as areas of further study;

1) Assessing the level of mechanization in road projects in Kenya. This is based on the discussion regarding the limitations of this research.
2) Evaluating the extent of the adoption of green mechanization in construction projects in Kenya. Green mechanization refers to the environmental friendliness and sustainability of technologies and practices in the mechanization processes. It aims to minimize the environmental impact of machinery and equipment used in various sectors while enhancing productivity and efficiency.
3) Exploring why construction mechanization did not have any effect on the performance of construction workers.

REFERENCES

Abbas, R., & Michael, K. (2023). Socio-Technical Theory: A review. In S. Papagiannidis (Ed.), *TheoryHub Book*. https://open.ncl.ac.uk/

Abdu, D. (2019). *Assessment of Quality of Construction Work in Mass Housing Project with Multiple Contractors in Kano, Nigeria*. Department of Building, Ahmadu Bello University.

Adebowale, O. J., & Agumba, J. N. (2023). A scientometric analysis and review of construction labour productivity research. *International Journal of Productivity and Performance Management*, *72*(7), 1903–1923. https://doi.org/10.1108/ IJPPM-09-2021-0505

Afshar, M. R., Alipouri, Y., Sebt, M. H., & Chan, W. T. (2017). A Type-2 Fuzzy Set Model for Contractor Prequalification. *Automation in Construction*, *84*(1), 356–366. https://doi.org/10.1016/j.autcon.2017.10.003

Agrawal, K., & Baruah, S. (2018). A measurement-based model for parallel real-time tasks. In S. Altmeyer (Ed.), *30th Euromicro Conference on Real- Time Systems (ECRTS 2018)* (pp. 1–19). Schloss Dagstuhl-Leibniz-Zentrum fuer Informatik.

Ahrens, R. D. B., Lirani, L. D. S., & de Francisco, A. C. (2020). Construct validity and reliability of the work environment assessment instrument WE-10. *International Journal of Environmental Research and Public Health*, *17*(20), 1–19. https://doi.org/10.3390/ijerph17207364

Amae, K. K. D. (2020). Determinants of Labour Productivity of Site Operatives in Ghana: Perception of the Site Managers. *Project Management Scientific Journal*, *4*(8), 61–80.

Appelbaum, S. H. (1997). Socio-technical systems theory: an intervention strategy for organizational development. *Management Decision*, *35*(6), 452–463. https://doi.org/10.1108/00251749710173823

Autor, D. H., & Handel, M. J. (2013). Putting tasks to the test: Human capital, job tasks, and wages. *Journal of Labor Economics*, *31*(S1), S59–S96. https://doi.org/https://doi.org/10.1086/669332

Azman, M., Ahamad, M., & Hussin, W. (2012). Comparative study on prefabrication construction process. *International Surveying Research Journal*, *2*(1), 45–58.

Babakus, E., & Mangold, W. G. (1992). Adapting the SERVQUAL Scale to Hospital Services: An Empirical Investigation. *Health Services Research*, *26*(6), 767–780.

Babatunde, L. A., Adegoke, B. F., Adejumobi, M. K., & Olukoya, B. F. (2019). Professionals View on The Effects of Mechanization On Construction Cost Of Building Projects In Nigeria. *Technology (ICONSEET)*, *4*(13), 103–111.

Baik, S. H., Fox, R. S., Mills, S. D., Roesch, S. C., Sadler, G. R., Klonoff, E. A., & Malcarne, V. L. (2019a). Reliability and validity of the Perceived Stress Scale-10 in Hispanic Americans with English or Spanish language preference. *Journal of Health Psychology*, *24*(5), 628–639. https://doi.org/10.1177/1359105316684938

Baik, S. H., Fox, R. S., Mills, S. D., Roesch, S. C., Sadler, G. R., Klonoff, E. A., & Malcarne, V. L. (2019b). Reliability and validity of the Perceived Stress Scale-10 in Hispanic Americans with English or Spanish language preference. *Journal of Health Psychology*, *24*(5), 628–639.

Bamfo-Agyei, E., Aigbavboa, C., & Didibhuku, T. W. (2019). Measuring labour productivity in labour intensive works on the road construction in Ghana. In *Advances in Intelligent Systems and Computing* (Vol. 788, Issue October 2018). Springer International Publishing. https://doi.org/10.1007/978-3-319-94199-8_50

Bamfo-Agyei, E., Thwala, D. W., & Aigbavboa, C. (2022a). Performance Improvement of Construction Workers to Achieve Better Productivity for Labour-Intensive Works. *Buildings*, *12*(10), 1–18.

https://doi.org/10.3390/buildings12101593

Bamfo-Agyei, E., Thwala, D. W., & Aigbavboa, C. (2022b). The effect of management control on labour productivity of labour-intensive works in Ghana. *Acta Structilia*, *29*(1). https://doi.org/10.18820/24150487/as29i1.1

Barbosa, F., Woetzel, J., & Mischke, J. (2017). *Reinventing Construction: A Route of Higher Productivity*. McKinsey Global Institute.

Bartlett, J. E., Kotrlik, J. W., & Higgins, C. C. (2001). Organizational Research: Determining Appropriate Sample Size in Survey Research. *Information Technology, Learning, and Performance Journal*, *19*(1), 43–50.

Bartoschek, P. M., & Kirchev, F. K. (2021). *Labor Productivity Influence in the Construction Industry; An interpretive approach to project success*. Unpublished Masters Thesis, Jonkoping University.

Baxter, G., & Sommerville, I. (2011). Socio-technical systems: From design methods to systems engineering. *Interacting with Computers*, *23*(1), 4–17.

Becker, G. (1962). Investment in human capital: A theoretical analysis. *Journal of Political Economy*, *70*(5), 9–49.

Bednar, P. M., & Welch, C. (2020). Socio-Technical Perspectives on Smart Working: Creating Meaningful and Sustainable Systems. *Information Systems Frontiers*, *22*(2), 281–298.

Beekun, R. I. (1989). Assessing the effectiveness of sociotechnical interventions: Antidote or fad? *Human Relations*, *42*(10), 877–897.

Bertalanffy, L. (1950). The theory of open systems in physics and biology. *Science*, *111*(1), 23–29.

Blair, F. (2018). The Trouble with Human Capital Theory. *International Journal of Business and Management*, *4*(2), 91–112. https://rwer.wordpress.com/comments-on-rwer-issue-no-86/

Bommet, M., Wambua, J., & Chebet, F. (2020). *Building, Mining & Construction: Sector Profile*. https://kam.co.ke/wp-content/uploads/2021/04/Buildind-and-Construction-sector-2020.pdf#:~:text=In 2019%2C the construction%2C mining,billion in 2019(KNBS)

Bontis, N., Dragonetti, N., Jaconsen, K., & Roos, G. (1999). The knowledge toolbox: a review of tools available to measure and manage intangible resources. *European Management Journal*, *17*(4), 391–402.

Boserup, E. (1965). *The Condition of Agricultural Growth: The Economics of Agrarian Change under Population Pressure*. Allen and Unwin, London.

Boudah, D. J. (2011). *Conducting Education Research*. SAGE Publications. Los Angeles.

Braun, E. (2017). The theory of capital as a theory of capitalism. *Journal of Institutional Economics*, *13*(2), 305–325.

Brosnan, L. (2023). *Heavy Equipment Site Preparation for Construction*.

Bryman, A. (2012). *Social Research Methods* (4th ed.). Oxford University Press. London.

Calvetti, D., Mêda, P., Gonçalves, M. C., & Sousa, H. (2020). Worker 4.0: The future of sensored construction sites. *Buildings*, *10*(10), 1–22. https://doi.org/10.3390/BUILDINGS10100169

Calvetti, D., Mêda, P., Gonçalves, M. C., & Sousa, H. (2021). Mechanization of Construction Tasks: Level Assessment and Craft Workforce Awareness. *Proceedings of the European Conference on Computing in Construction*, *July*, 342–349. https://doi.org/10.35490/EC3.2021.172

Camarini, G., Leite Júnior, J. A. P., Perez, J. F., & Chamon, E. M. Q. O. (2020). Quality of Work Life: A Study on Civil Construction Workers. *International Journal of Social Science Studies*, *8*(4), 66–81.

https://doi.org/10.11114/ijsss.v8i4.4820

Campbell, F. (2006). *Occupational Stress in the Construction Industry*. Chartered Institute of Building. Berkshire, UK.

Caunedo, J., & Kala, N. (2021). *Mechanizing Agriculture: Impacts on Labor and Productivity* (1050). https://www.atai-research.org/wp-content/uploads/2020/12/MechanizingAg_Nov_2020.pdf

Chai, S., & Kim, M. (2012). A socio-technical approach to knowledge contribution behavior: An empirical investigation of social networking sites users. *International Journal of Information Management*, *32*(2), 118–126.

Chia, F. C., Skitmore, M., Gray, J., & Bridge, A. (2018). International comparisons of nominal and real construction labour productivity. *Eng. Constr. Archit. Manag*, *25*(7), 896–915.

Chudley, R., & Greeno, R. (2016). *Building Construction Handbook*. CRC Press.

Ciborra, C., Migliarese, P., & Romano, P. (1984). A methodological inquiry of organizational noise in sociotechnical systems. *Human Relations*, *37*(8), 565–588.

Clark, J. B. (1899). *The Distribution of Wealth.* Macmillan. New York.

Clarke, S. (1989). The basic theory of capitalism: A critical review of Itoh and the Uno School. *Capital & Class*, *13*(1), 133–149. https://doi.org/10.1177/030981688903700108

Clegg, C. W. (2000). Sociotechnical principles for system design. *Applied Ergonomics*, *31*(1), 463–477.

Cochran, W. G. (1977). *Sampling techniques* (3rd ed.). John Wiley & Sons. New York.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education* (6th ed.). Routledge. London.

Cooper, D. R., & Schindler, P. S. (2006). *Business Research Methods* (9th ed.). Mcgraw Hill. New York.

Crossan, F. (2003). Research philosophy: towards an understanding. *Nurse Researcher*, *11*(1), 40–46.

Dancey, C., & Reidy, J. (2004). *Statistics without Maths for Psychology: using SPSS for Windows.* Prentice Hall, London.

Daum, T., & Birner, R. (2020). Agricultural mechanization in Africa: Myths, realities and an emerging research agenda. *Global Food Security*, *26*(1), 350–393.

Davis, L. E. (1977). Evolving alternative organization designs: their sociotechnical bases. *Human Relations*, *30*(3), 261–273.

De Stefano, V. (2019). Negotiating the algorithm: Automation, artificial intelligence and labour protection. *Comparative Labor Law & Policy Journal*, *41*(1), 1–12.

Dozzi, S. P., & AbouRizk, S. M. (2014). *Productivity in Construction*. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001138.

Driskell, J. E., & Mullen, B. (2005). Social Network Analysis. In N. A. Stanton (Ed.), *Handbook of human factors and ergonomics methods* (pp. 58.1-58.6). CRC Press. London.

Easton, S. A., & Van Laar, D. L. (2018). *User manual for the Work-Related Quality of Life (WRQoL) scale: A mesure of quality of working life* (2nd ed.). University of Portsmouth All. https://doi.org/10.17029/EASTON2018

Elizur, D., & Shye, S. (1990). Quality of work life and its relation to quality of life. *Applied Psychology: An International Review*, *39*(3), 275–291. https://doi.org/10.1111/j.1464- 0597.1990.tb01054.x

Faatih Suwandi, G., & Tentama, F. (2020). The Quality of Work Life Scale: A Psychometric Study and its Application for the Employee. *International*

Journal of Sciences: Basic and Applied Research (IJSBAR) International Journal of Sciences: Basic and Applied Research, *50*(1), 68–81. http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

Fernández-Macías, E., & Bisello, M. 2022. (2022). A comprehensive taxonomy of tasks for assessing the impact of new technologies on work. *Social Indicators Research*, *159*(1), 821–841. https://doi.org/https://doi.org/10.1007/ s11205-021-02768-7

Field, A. (2005). *Discovering Statistics Using SPSS* (2nd ed.). Sage Publications. London.

Fischer, G., & Herrmann, T. (2011). Socio-Technical Systems. *International Journal of Sociotechnology and Knowledge Development*, *3*(1), 1–33.

Fleischhauer, K.-J. (2011). A Review of Human Capital Theory: Microeconomics. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.957993

Food and Agriculture Organization. (2024). *Preparation of the Construction Site*.

Frohm, J., Lindstr€om, V., Winroth, M., & Stahre, J. (2008). Levels of Automation in Manufacturing. *International Journal of Ergonomics and Human Factors*, *30*(3), 1–28.

Fu, Z., Chen, Z., Sharif, A., & Razi, U. (2022). The role of financial stress, oil, gold and natural gas prices on clean energy stocks: Global evidence from extreme quantile approach. *Resources Policy*, *78*(1), 1–20. https://doi.org/https://doi.org/10.1016/J.RESOURPOL.2022.102860

Funk, P. (2002). Induced innovation revisited. *Economica*, *69*(273), 155–171.

Ganapathi, R. (2016). A study on quality of work life of workers in construction industry in Madurai district. *Journal of Management Research and Analysis*, *3*(2), 63–66. https://doi.org/10.5958/2394-2770.2016.00010.7

Ghate, P. R., More, A. B., & Minde, P. R. (2016). Importance of Measurement of

Labour Productivity in Construction. *International Journal of Research in Engineering and Technology*, *05*(07), 413–417. https://doi.org/10.15623/ijret.2016.0507065

Ghauri, P. N., & Grønhaug, K. (2005). *Research Methods in Business Studies: A Practical Guide*. Pearson Education. London.

Goldkhul, G. (2012). Pragmatism vs interpretivism in qualitative information systems research. *European Journal of Information Systems*, *21*(2), 135–146.

Greener, S. (2008). *Business Research Methods*. Ventus Publishing. New York.

Grover, P., & Solanki, S. K. (2023). Effects of Mechanization on Resource Productivity. *Journal of Engineering Analysis and Design*, *5*(1), 1–17.

Grund, C., & Przemeck, J. (2012). Subjective performance appraisal and inequality aversion. *Applied Economics*, *44*(17), 2149–2155. https://doi.org/https://doi.org/10.1080/00036846.2011.560109

Hans-Hermann, H. (2010). *A Theory of Socialism and Capitalism*. Kluwer Academic Publishers 101 Philip Drive Assinippi Park Norwell, Massachusetts 02061 USA.

Hasan, A., Baroudi, B., Elmualim, A., & Rameezdeen, R. (2018). Factors affecting construction productivity: A 30 year systematic review. *Engineering Construction and Architectural Management*, *25*(1), 916–937.

Haupt, T. C., Akinlolu, M., & Raliile, M. T. (2020). Emerging Technologies in Construction Safety and Health Management. *International Conference on Innovation, Technology, Enterprise and Entrepreneurship*, 413–420. https://www.researchgate.net/publication/338990941

Hirschhorn, L., Noble, P., & Rankin, T. (2001). Sociotechnical systems in an age of mass customisation. *Journal of Engineering and Technology Management*, *18*(1), 241–252.

HM Government. (2014). *First Findings from the UK Innovation Survey 2013*.

Hsu, M.-Y. (2016). A quality of working life survey instrument for hospital nurses. *Journal of Nursing Research*, *24*(1), 87–99. https://doi.org/10.1097/jnr.0000000000000098

Huck, S. W. (2012). *Reading Statistics and Research* (6th ed.). Pearson. Tennessee, United States of America.

Hughes, P., & Ferrett, E. D. (2012). *Introduction to health and safety in construction*. Routledge. New York.

Hwang, B. G., Shan, M., Ong, J. J. M., & Krishnankutty, P. (2020). Mechanization in building construction projects: assessment and views from the practitioners. *Production Planning and Control*, *31*(8), 613–628. https://doi.org/10.1080/09537287.2019.1667547

Ibem, E. O., Anosike, M. W., Azuh, D. E., & Mosaku, T. E. (2011). Work stress among professionals in the building construction industry in Nigeria. *Australasian Journal of Construction Economics and Building*, *11*(3), 45–57.

Idoro, G. I. (2011). Effect of mechanisation on occupational health and safety performance in the Nigerian construction industry. *Journal of Construction in Developing Countries*, *16*(2), 27–45.

Iheama, N. B., Alinta-Abel, U., & Ezeokoli, O. (2017). Evaluation of mechanization in building production as a way of cost reduction: A study of some construction sites in Enugu South local Government area. *British Journal of Environmental Sciences*, *5*(2), 14–30.

Indimuli, R., Torm, N., Mitullah, W., Riisgaard, L., & Kamau, A. W. (2023). Informal workers and Kenya’s National Hospital Insurance Fund: Identifying barriers to voluntary participation. *International Social Security Review*, *76*(1), 79–107. https://doi.org/https://doi.org/10.1111/issr.12316

Jagtap, D., & Tidke, A. (2019). Factor Affecting Labour Productivity. *Journal of Emerging Technologies and Innovative Research*, *6*(3), 162–166.

Jalalzadeh, B., Borghei, A. M., & Almassi, M. (2016). Modeling the Effect of Mechanization Level Index on Crop Yield Approaching System Dynamics Methodology. *Journal of Experimental Biology and Agricultural Sciences*, *4*(2), 169–179. https://doi.org/10.18006/2016.4(2).169.179

Jang, H., Kim, K., Kim, J., & Kim, J. (2016). Labour productivity model for reinforced concrete construction projects. *Construction Innovation*, *11*(1), 92–113. http://www.emeraldinsight.com/doi/abs/

Janmohammadi, B., Shahmandi, E., Khooravesh, M., & Ghanizadeh, P. (2015). Study of the Dimensions of Quality of Work Life and Organizational Productivity of the Staff of Tax Organization of Alborz Province. *Indian Journal of Fundamental and Applied Life Sciences*, *5*(1), 297–308.

Jarkas, A., & Bitar, C. (2012). Factors affecting construction labor productivity in Kuwait. *Journal of Construction Engineering Management*, *138*(7), 811–820.

Jayaraman, S., George, H. J., Siluvaimuthu, M., & Parayitam, S. (2023). Quality of work life as a precursor to work–life balance: Collegiality and job security as moderators and job satisfaction as a mediator. *Sustainability*, *15*(13), 9936. http://www.ncbi.nlm.nih.gov/pubmed/25926610%5Cnhttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC4492060%0Ahttp://www.sciencedirect.com/science/article/pii/S0160738315000444

Jenkins, G. D., & Taber, T. D. (1977). A Monte Carlo Study of Factors Affecting Three Indices of Composite Scale Reliability. *Journal of Applied Psychology*, *62*(4), 392–400. https://doi.org/10.1037//0021-9010.62.4.392.

Jerome, H. (1934). Chapter 10: The Effects of Mechanization. In H. Jerome (Ed.), *Mechanization in Industry: Vol. I* (pp. 365–418). NBER Publishing. http://www.nber.org/chapters/c5249

Jerome, S. (2013). A Study on Quality of Work Life of Employees at Jeppiaar Cement Private Ltd: Perambalur. *International Journal of Advance Research in Computer Science and Management Studies, 1*(4), 49–57. https://doi.org/10.52783/tjjpt.v44.i4.1966

Jessica. (2021). *How Does A Plastering Machine Work?*

Johannesson, P., & Perjons, E. (2014). Research Strategies and Methods. In *An Introduction to Design Science* (pp. 39–73). Springer International Publishing. https://doi.org/10.1007/978-3-319-10632-8_3

Kamaruddin, S. S., Mohammad, M. F., & Mahbub, R. (2016). Barriers and Impact of Mechanisation and Automation in Construction to Achieve Better Quality Products. *Procedia - Social and Behavioral Sciences*, *222*(1), 111–120. https://doi.org/10.1016/j.sbspro.2016.05.197

Kamaruddin, S. S., Mohammad, M. F., Mahbub, R., & Ahmad, K. (2018). The Mechanisation and Automation of the IBS Construction Approach in Malaysia. *Asian Journal of Environment-Behaviour Studies*, *3*(10), 167–177. https://doi.org/10.21834/aje-bs.v3i10.324

Kapliński, O., Werner, W., Kosecki, A., Biernacki, J., & Kuczmarski, F. (2002). Current state and perspectives of research on construction management and mechanisation in poland. *Journal of Civil Engineering and Management*, *8*(4), 221–230. https://doi.org/10.1080/13923730.2002.10531282

Karras, D. J. (1997). Statistical methodology: II. Reliability and validity assessment in study design, Part A. *Academic Emergency Medicine*, *4*(1), 64–71. https://doi.org/10.1111/j.1553-2712.1997.tb03646.x

Kelly, J. E. (1978). A reappraisal of sociotechnical systems theory. *Human Relations*, *31*(12), 1069–1099.

Kemei, R. K., Kaluli, J. W., & Kabubo, C. K. (2016). Assessment of Occupational Safety and Health in Construction Sites in Nairobi County, Kenya.

Association of Engineers of Kenya, 1–13.

Kioko, R. K. (2020). *Stress Levels among Construction Workers in Kibera Resettlement Action Plan Project in Nairobi City County, Kenya*. Unpublished Masters Thesis, Kenyatta University.

KNBS. (2023). *Economic Survey 2022*.

Kombo, D. K., & Tromp, D. (2006). *Proposal and Thesis Writing: An Introduction* (6th ed.). Paulines Publications Africa.

Koonmee, K., Singhapakdi, A., Virakul, B., & Lee, D. (2010). Ethics institutionalization, quality of work life, and employee job-related outcomes: A survey of human resource managers in Thailand. *Journal of Business Research*, *63*(1), 20–26. https://doi.org/10.1016/j.jbusres.2009.01.006

Koppel, B., & Oasa, E. (1987). Induced Innovation Theory and Asia's Green Revolution: A Case Study of an Ideology of Neutrality. *Development and Change*, *18*(1), 29–67. https://doi.org/https://doi.org/10.1111/j.1467-7660.1987.tb00262.x

Koslowski, P. (2013). *The theory of capitalism in the german economic tradition: historism, ordo-liberalism, critical theory, solidarism.* Springer Science & Business Media.

Kothari, C. (2012). Research Methodology: An introduction. In *Research Methodology: Methods and Techniques*. New Age International Publishers. https://doi.org/Goddard, W. & Melville, S.

Kuruga, F. N. (2017). *Labour productivity and performance of building projects in Nairobi county, Kenya*. Unpublished Masters Thesis, Kenyatta University.

Lamsal, E. (2024). *Mechanization and Its Level*.

Leedy, P. D., & Ormrod, J. E. (2010). *Practical Research: Planning and Design* (9th ed.). Pearson Education, Inc., Upper Saddle River.

Liu, Q., Zhong, Z., & Li, Y. (2025). Research on construction workers' job well-being and unsafe state: From the perspective of Maslow hierarchy of needs. *Medicine*, *104*(31), e43605. https://doi.org/10.1097/MD.0000000000043605

Llale, J., Setati, M., Mavunda, S., Ndlovu, T., Root, D. S., & Wembe, P. T. (2020). The Construction Industry in the Fourth Industrial Revolution. *The Construction Industry in the Fourth Industrial Revolution*, *3*(1), 1–11. https://doi.org/10.1007/978-3-030-26528-1

Love, P. E. D., Teo, P., Ackermann, F., Smith, J., Alexander, J., Palaneeswaran, E., & Morrison, J. (2018). Reduce Rework, Improve Safety: An Empirical Inquiry into the Precursors to Error in Construction. *Production Planning & Control*, *29*(5), 353–366. https://doi.org/10.1080/09537287.2018.1424961

Mahbub, R. (2008). *An investigation into the barriers to the implementation of automation and robotics technologies in the construction industry*. Unpublished Doctoral dissertation, Queensland University of Technology.

Makoto, I. (1988). *Basic Theory of Capitalism; Forms and Substance of the Capitalist Economy*. Palgrave Macmillan London. https://doi.org/https://doi.org/10.1007/978-1-349-19107-9

Martel, J.-P., & Dupuis, G. (2006). Quality of work life: Theoretical and methodological problems, and resentation of a new model and measuring instrument. *Social Indicators Research, 77*(2), 333–368. https://doi.org/10.1007/s11205-004-5368-4

Matache, I. C. (2023). Human Capital Theory – One Way of Explaining Higher Education Massification. *Journal of Public Administration, Finance and Law*, *29*(29), 363–371. https://doi.org/10.47743/jopafl-2023-29-30

McCracken, M., McIvor, R., Treacy, R., & Wall, T. (2017). *Human capital theory: assessing the evidence for the value and importance of people to organisational success*. https://www.cipd.co.uk/Images/human-capital-theory-assessing-the-evidence_tcm18-22292.pdf

Mekgwe, M. C. (2016). *Effects of Construction Plants' Usage (Machinery) On Project Performance In South African Construction Industry*. Department of Construction Management and Quantity Surveying at the University of Johannesburg, Republic of South Africa.

Merritt, F. S., & Ricketts, J. T. (2001). *Building Design and Construction Handbook* (6th ed.). McGraw-Hill.

Merwe, A. Van Der. (2010). Does Human Capital Theory Explain The Value Of Higher Education? *American Journal of Business Education*, *3*(1), 107–118.

Mincer, J. (1958). Investment in human capital and personal income distribution. *The Journal of Political Economy*, *66*(4), 281–302.

Mitullah, W. (2021). Construction workers in Kenya: Straddling with formal and informal social protection models. In L. Riisgaard, W. Mitullah, & N. Torm (Eds.), *Social Protection and Informal Workers in Sub-Saharan Africa Lived Realities and Associational Experiences from Kenya and Tanzania* (pp. 197–219). Routledge. New York. https://doi.org/10.4324/9781003173694-9

Mitullah, W., Riisgaard, L., Torm, N., Gervas, A., Indimuli, R., Kamau, A. W., & Kinyondo, G. (2021). Convergence and divergence of workers' environment, associations, and access to social protection Sectoral and country comparisons. In L. Riisgaard, W. Mitullah, & N. Torm (Eds.), *Social Protection and Informal Workers in Sub-Saharan Africa Lived Realities and Associational Experiences from Kenya and Tanzania* (pp. 220–239). Routledge. New York. https://doi.org/10.4324/9781003173694-10

Mučenski, V., Peško, I., Velkovski, T., Čaloska, J., Vujkov, A., & Bibić, D. (2018). Impact of construction machinery and tools on non-fatal injuries in the building processes. *Tehnički Vjesnik*, *25*(6), 1680–1689.

Mugenda, O. ., & Mugenda, A. . (2003). *Research methods: Quantitative and Qualitative Approaches*. African Centre for Technology Studies. Nairobi.

Munderu, P. M. (1990). *An investigation into the poor standards of workmanship in construction projects in rural areas: A case of Aguthi location, Nyeri District*. University of Nairobi.

Muro, M., Maxim, R., Whiton, J., & Hathaway, I. (2019). *Automation and artificial intelligence: How machines are affecting people and places* (Issue January). https://www.brookings.edu/wpcontent/uploads/2019/01/2019.01_Brookings Metro_Automation-AI_Report_Muro-Maxim-Whiton-FINAL-version.pdf

Mwitari, D. (2018). *The Standard. No 'fundi': Firms step in to fill skills gap*.

National Construction Authority. (2021). *Apprenticeship Programmes*.

Ndaiga, H. (2016). *Nairobi firms train youths to boost construction skills*. Construction Kenya.

Ndinyo, C. S., Wachira, I. N., & Mbatha, C. M. (2023). Employees' Role in Health and Safety Committees : *Africa Habitat Review Journal*, *18*(2), 2614–2625.

Ndoka, G. R. (2007). *An investigation into the quality of workmanship on construction sites; A case study of construction sites in Nairobi*. Department of Real Estate and Construction Management. University of Nairobi.

Neuman, W. L. (2020). *Social Research Methods: Qualitative and quantitative approaches* (8th ed.). Pearson. Boston, MA.

Nguyen, V. T., Nguyen, Q. T., Dinh, T. H., & Nguyen, L. D. Q. (2021). Critical factors affecting construction labor productivity: A comparison between perceptions of project managers and contractors. *Cogent Business and Management*, *8*(1), 1–17. https://doi.org/10.1080/23311975.2020.1863303

Ntuli, B., & Allopi, D. (2014). Impact of Inadequate Experience and Skill on the Construction Sector in KwaZulu-Natal, South Africa. *Engineering, Technology & Applied Science Research*, *4*(1), 570–575. https://doi.org/10.48084/etasr.371

Nurhendi, R. N., Khoiry, M. A., & Hamzah, N. (2022). Conceptual Framework Factors Affecting Construction Labour Productivity. *Jurnal Kejuruteraan*, *34*(1), 89–99. https://doi.org/10.17576/jkukm-2022-34(1)-08

Orkun, B. (2021). *The Theory of Capitalism:* https://doi.org/10.4324/9780203759264-14

Otzen, T., & Manterola, C. (2017). Sampling techniques on a population study. *Int. J. Morphol*, *35*(1), 227–232.

Pan, M., Linner, T., Pan, W., Cheng, H., & Bock, T. (2018). A Framework of Indicators for Assessing Construction Automation and Robotics in the Sustainability Context. *Journal of Cleaner Production*, *182*(1), 82–95. https://doi.org/10.1016/j.jclepro.2018.02.053

Phelps, E. S. (1999). Lessons from the corporatist crisis in some Asian nations. *Journal of Policy Modeling*, *21*(3), 331–339.

Rajabhat, J. (2017). Human capital theory_The theory of HRD implications and future. *Rajabhat J. Sci. Humanit. Soc. Sci.*, *18*(2), 240–253.

Raykov, T. (2012). Scale construction and development using structural equation modeling. In *Handbook of structural equation modeling.* (pp. 472–492). The Guilford Press.

Raykov, T., & Marcoulides, G. A. (2012). Evaluation of validity and reliability for hierarchical scales using latent variable modeling. *Structural Equation Modeling*, *19*(3), 495–508. https://doi.org/10.1080/10705511.2012.687675

Razali, N. M., & Wah, Y. B. (2011). Power comparisons of shapiro-wilk, kolmogorov-smirnov, lilliefors and anderson-darling tests. *Journal of Statistical Modeling and Analytics, 2*(1), 21–33.

Razi, U., Afshan, S., Cheong, C. W. H., & Sharif, A. (2024). Dynamic connection between energy prices, Malaysia's economic growth, and ecological footprint: An evidence from Morlet wavelet approach. *Geological Journal*, *59*(3), 1000–1017. https://doi.org/10.1002/gj.4906

Reder, M. W. (1967). Gary Becker's Human Capital: A Review Article. *The Journal of Human Resources*, *2*(1), 90–97. https://doi.org/10.2307/144593

Reimer, B. (1984). Farm Mechanization: The Impact on Labour at the Level of the Farm Household. *The Canadian Journal of Sociology/Cahiers Canadiens de Sociologie*, *9*(4), 429–443. https://doi.org/10.2307/3340528

Riisgaard, L., Mitullah, W., & Torm, N. (2021). Social Protection and Informal Workers in Sub-Saharan Africa: Lived Realities and Associational Experiences from Kenya and Tanzania. In *Social Protection and Informal Workers in Sub-Saharan Africa Lived Realities and Associational Experiences from Kenya and Tanzania*. Routledge. New York. https://doi.org/10.4324/9781003173694

Royuela, V., López-Tamayo, J., & Suriñach, J. (2008). The institutional vs. the academic definition of the quality of work life. What is the focus of the European Commission? *Social Indicators Research*, *86*(3), 401–415. https://doi.org/10.1007/s11205-007-9175-6

Ruttan, V. W. (1977). Induced innovation and agricultural development. *Food Policy*, *2*(3), 196–216. https://doi.org/https://doi.org/10.1016/0306-9192(77)90080-X

Ruttan, V. W. (1997). Induced Innovation, Evolutionary Theory and Path Dependence: Sources of Technical Change. *The Economic Journal*, *107*(444), 1520–1529. http://www.jstor.org/stable/2957751

Ruttan, V. W., & Hayami, Y. (1984). Toward a theory of induced institutional innovation. *The Journal of Development Studies*, *20*(4), 203–223. https://doi.org/10.1080/00220388408421914

Ruttan, V. W., & Hayami, Y. (2011). 10Induced Innovation Theory and Agricultural

Development: A Personal Account. In K. Otsuka & C. F. Runge (Eds.), *Can Economic Growth Be Sustained?: The Collected Papers of Vernon W. Ruttan and Yujiro Hayami* (p. 0). Oxford University Press. https://doi.org/10.1093/acprof:osobl/9780199754359.003.0002

Ryan, G. (2018). Introduction to positivism, interpretivism and critical theory. *Nurse Researcher*, *25*(4), 41–49.

Sahota, G. S. (2024). Review of Agricultural Development: An International Perspective. *Economic Development and Cultural Change*, *21*(4), 722–731. http://www.jstor.org/stable/1152701

Saleh, F., & Ryan, C. (1991). Analysing Service Quality in the Hospitality Industry Using the SERVQUAL Model. *The Service Industries Journal*, *11*(3), 324–345. https://doi.org/10.1080/02642069100000049.

Samuel, J., Naga, M., Shankar, S., & Nishanth, A. (2022). Factors Influencing Quality Of Work Life: An Analysis On Registered Construction Workers In Tirunelveli District Of India. *Seybold*, *17*(10), 666–674. https://doi.org/10.5281/zenodo.7220713

Saunders, M., Lewis, P., & Thornhill, A. (2019). *Research Methods for Business Students* (8th ed.). Prentice Hall. London, UK.

Schultz, T. (1961). Investment in human capital. *The American Economic Review*, *51*(1), 1–17.

Sekaran, U. (2003). *Research Methods for Business: A Skill Building Approach* (2nd ed.). John Wiley & Sons, Inc. New York.

Shaban, N. (2024). *Inflation rallies to two-month high on higher food costs*. Business Daily Africa.

Shanmugam, B., & Ganapathi, R. (2017). A Study on Quality of Work Life and Job Performance of Construction Workers in Chennai. *International Journal of*

Scientific Research and Modern Education, *2*(1), 68–72. https://doi.org/10.18843/ijms/v6si5/04

Sharabiani, V. R., & Ranjbar, I. (2008). Determination of the Degree, Level and Capacity Indices for Agricultural Mechanization in Sarab Region. *Journal of Agricultural Science and Technology*, *10*(3), 215–223.

Sharma, H., Ghuman, K., & Kumar Sharma, D. (1970). Quality of Work Life& Its Key Dimensions: a Cross-Sectional Analysis of Private, Public Sector and Foreign Banks in India. *Amity Journal of Management Amity Business School*, *4*(1).

Sharmila, S., Devadoss, R. S., & Mathew, F. (2018). Impact of mechanisation in construction projects in India. *International Journal of Civil Engineering and Technology*, *9*(13), 1998–2008.

Shehata, M. E., & El-Gohary, K. M. (2011). Towards improving construction labor productivity and projects' performance. *Alexandria Engineering Journal*, *50*(4), 321–330. https://doi.org/10.1016/j.aej.2012.02.001

Sinval, J., Sirgy, M. J., Lee, D. J., & Marôco, J. (2020). The Quality of Work Life Scale: Validity Evidence from Brazil and Portugal. *Applied Research in Quality of Life*, *15*(5), 1323–1351. https://doi.org/10.1007/s11482-019-09730-3

Sirgy, M. J. (2001). *Handbook of quality-of-life research: An ethical marketing perspective*. Springer Netherlands. https://doi.org/10.1007/978-94-015-9837-8

Soundarya, P. M. G., & Anandh, K. S. (2024). Exploring the Determinants of Quality of Work Life in the Construction Industry: A Quantitative Approach. *Buildings*, *14*(6). https://doi.org/10.3390/buildings14061607

Srisompun, O., Athipanyakul, T., & Somporn, I. (2019). *The adoption of mechanization , labour productivity and household income : Evidence from rice production in Thailand* (WP-016).

Swathi, R. (2017). A Study on Dimensions of Quality of Work Life of Employees. *International Journal and Magazine of Engineering, Technology, Management and Research*, *4*(9), 187–196.

Sweetland, S. R. (1996). Human capital theory: Foundations of a field of inquiry. *Review of Educational Research*, *66*(3), 341–359. https://doi.org/10.3102/00346543066003341

Thomas, A., & Sudhakumar, J. (2013). Critical analysis of the key factors affecting construction labour productivity -an Indian perspective. *Int. J. Constr. Manag.*, *13*(4), 103–125.

Thomas, H. R., & Sakarcan, A. S. (1994). Forecasting labour productivity using the factor model. *Journal of Construction Engineering and Management*, *120*(1), 228–239. https://doi.org/https://doi.org/10.1061/(ASCE)0733-9364(1994)120:1(228)

Tolfo, S. R., & Piccinini, V. C. (2011). Quality of work life in the best companies to work for in Brazil: mismatches between theory and practice. In A. S. Sant'Anna & Z. M. Kilimnik (Eds.), *Quality of work life: approaches and fundamentals* (pp. 85–112). Elsevier.

Trist, E. L., & Bamforth, K. W. (1951). Some Social and Psychological Consequences of the Longwall Method of Coal-Getting. *Human Relations*, *4*(1), 3–38.

Tsehayae, A. A., & Fayek, A. R. (2016). System model for analysing construction labour productivity. *Construction Innovation*, *16*(2), 203-228. https://doi.org/https://doi.org/10.1108/CI-07-2015-0040

Vadukkumchery, A. S., & Myneni, K. K. (2023). Assessment of Impact of Mechanization in Construction Projects in India. *Indian Journal Of Science And Technology*, *16*(10), 727–743. https://doi.org/10.17485/ijst/v16i10.1467

Vetrimani, M., & Maheswari, K. K. (2014). A Study on Quality of Work Life Among The Employees of Cement Industry. *Journal of International Academic*

Research for Multidisciplinary, *4*(12), 184–186.

Vidushi, Paul, V. K., & Solanki, S. K. (2022). Framework for rehabilitation of buildings to improve health, hygiene. *International Journal of Town Planning And Management*, *9*(1), 38–46. https://doi.org/10.37628/IJTPM

Vishwakarma, K., Sushil, ;, & Solanki, K. (2022). Mechanization and Automation in Construction. *International Journal of Advances in Engineering and Management (IJAEM)*, *4*(5), 2395–5252. https://doi.org/10.35629/5252-04053856

Wachira, I. N. (1999). Labour productivity in the Kenyan construction industry. In P. Bowen & R. Hindle (Eds.), *CIB W55 & W65 Joint Triennial Symposium* (Issue September, pp. 1–9). http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:LABOUR+PRODUCTIVITY+IN+THE+KENYAN+CONSTRUCTION+INDUSTRY#1

Wage Indicator Foundation. (2024). *Building construction labourers*.

Walker, G. H., Stanton, N. a., Salmon, P. M., & Jenkins, D. P. (2008). A review of sociotechnical systems theory: A classic concept for new command and control paradigms. *Theoretical Issues in Ergonomics Science*, *9*(6), 479–499. https://doi.org/10.1080/14639220701635470

Walton, R. E. (1973). Quality of working life: what is it? *Sloan Management Review, 15*(1), 11–21.

Wandia, L., & Ralwala, A. (2024). Evaluation of On-Site Training and Certification Programmes for Semi-Skilled Construction Workers in Kenya: The Case of Nairobi City County. *Journal of the Kenya National Commission for UNESCO*, *4*(1), 1–18. https://doi.org/10.62049/jkncu.v4i1.58

Watts, A. (2016). *Modern Construction Handbook*. Birkh€auser.

Wetangula, J., & Mazurewicz, M. (2017). *Market Research Preliminary Report: The Construction Market in Kenya*.

Wicksteed, P. (1894). *An Essay on the Co-ordination of the Laws of Distribution*. London School of Economics, London.

Willis, R. (1875). *Principles of Mechanism: Designed for the Use of Students in the Universities and for Engineering Students Generally*. Wiley.

Workplace Health and Safety Queensland. (2023). *Working at heights remains a leading cause of work fatalities*. WorkSafe. d-events/newsletters/esafe-newsletters/esafe-editions/esafe-construction/march

Wu, G., Zhao, X., & Zuo, J. (2017). Relationship between Project's Added Value and the Trust–Conflict Interaction among Project Teams. *Journal of Management in Engineering*, *33*(4), 100–109. https://doi.org/10.1061/ (ASCE)ME.1943-5479.0000525.

Yadav, R., Khanna, A., & Panday, P. (2019). Dimensions of Quality of Work Life affecting Commitment and Performance: A Theoretical Framework. *Pacific Business Review International*, *12*(1), 125–137.

Yahya, M. Y., Abba, W. A., Mohamed, S., & Md. Yassin, A. (2019). Contributing Factors of Poor Construction Project Performance in Nigeria. *International Journal of Property Sciences*, *9*(1), 1–11. https://doi.org/10.22452/ijps.vol9no1.1

Yi, W., & Chan, A. (2014). Critical Review of Labor Productivity Research in Construction Journals. *Journal of Management in Engineering*, *30*(2), 214–225. https://doi.org/https://doi.org/10.1061/(ASCE)ME.1943-5479.0000194

Yip, B., Rowlinson, S., Kvan, T., & Lingard, H. (2005). Job burnout within the Hong Kong construction industry: A cultural perspective. *Proceedings of the CIB W92/T23/W107 International Symposium on Procurement Systems Held at Las Vegas, Nevada, USA*.

Zamora, B. (2007). New Discussion of the Human Capital Theory in the Methodology of Scientific Research Programmes. *Journal of Accounting and Organizational Change, 5*(3), 1–19.

Zhadanovsky, B., & Sinenko, S. (2018). The methodic of calculation for the need of basic construction machines on construction site when developing organizational and technological documentation. *E3S Web of Conferences*, *33*(1), 1–5. https://doi.org/10.1051/e3sconf/20183303077

Zhang, J., Long, Y., Lv, S., & Xiang, Y. (2016). BIM-enabled modular and industrialized construction in China. *Procedia Engineering*, *145*(1), 1456–1461.

Zheleznyak, A. M. (2014). *Munich Personal RePEc Archive A New Theory of Capitalism : Key Moments and General Logic A New Theory of Capitalism : Key Moments and General Logic*.

Zhu, R., Hu, X., Wei, A., Yang, W., & Ji, F. (2024). Measuring safety performance of construction employees using data envelopment analysis: A case in Australia. *Journal of Safety Research*, *88*(November 2023), 293–302. https://doi.org/10.1016/j.jsr.2023.11.016

Zin, R. M. (2004). Perception of professional engineers toward quality of worklife and organizational commitment. *Gadjah Mada International Journal of Business*, *6*(3), 323–334. https://journal.ugm.ac.id/gamaijb/article/view/5553/4524

Zoega, G., & Phelps, E. (2004). The European Labour Markets-The Search for Routes to Better Economic Performance in Continental Europe. *CESifo Forum*, *5*(1), 3–11.

APPENDICES

Appendix I: Letter of Introduction

DENNIS MUMO NDOLO**,**
P.O BOX 62000-00200,
NAIROBI, Kenya.
Tel: +254 (0) 712554532,
Email: dennohmumo@gmail.com
Date: ………………………………………………………………

Dear Sir/Madam,

RE: INVITATION TO PARTICIPATE IN A RESEARCH PROJECT

I am a PhD student at the Jomo Kenyatta University of Agriculture and Technology (JKUAT) in the School of Architecture and Building Sciences (SABS). I am currently conducting a study on the way mechanization can be optimized within construction projects so that it does not adversely affect labour but at the same time, the project efficiently benefits from the use of machines, in partial fulfillment of the requirements for the award of Degree of Doctoral of Philosophy (PhD) in Construction Project Management.

The study aims to investigate the influence of construction mechanization on the quality of work life and the performance of workers on construction sites in Kenya. The specific objectives include; (i) To establish the level of quality of work life and the performance of workers on construction sites in Kenya, (ii) To establish the extent of mechanization in construction projects in Kenya, (iii) To establish the effect of mechanization on the quality of work life and the performance of construction workers on sites, and (iv) To formulate a framework for optimizing the level of mechanization and manpower in construction projects in Kenya.

Being a key player in the construction sector, you have been identified by the researcher through a random sampling procedure to help provide the information required to address the study objectives, as outlined in the attached questionnaire. The data collected shall only be used for academic purposes and will be treated as confidential. This exercise has been sanctioned by the National Council of Science, Technology & Innovation (NACOSTI) and the JKUAT.

Thank you very much for your valued time.

Yours faithfully,

<u>DENNIS MUMO NDOLO</u>

PhD Candidate; Reg. No. ABS431-1563/2020

Appendix II: Questionnaire (Site Managers/Site Agents/Clerks of Works)

Kindly answer the following questions to the best of your knowledge

Part I: Background Information

1) What is the level of your experience working in the construction industry?

[ ] 1-5 Years [ ] 6-10 Years [ ] 11-15 Years [ ] 16 -20 [ ] Above 20

2) Kindly indicate the project value in KShs.

[ ]101 to 200million [ ] 201 – 300million [ ] 301 – 400million

[ ] 401 – 500million [ ] Above 500million (Specify)……………………..

3) Kindly indicate the planned project duration.

[ ] Up to 9months [ ]10-18months [ ] 19-27months [ ] 28-36months

[ ] Above 36months

Part II: Performance of Construction Workers

4) How would you describe the level of ***labour efficiency*** or ***productivity rate*** in the following work categories and tasks?

Work Category	**Task**	**0-20%**	**21-40%**	**41-60%**	**61-80%**	**81-100%**
Site Preparation and Earthworks	Site clearance (m^2/hr)					
	Setting out (m^2/hr)					
	Earthworks (m^3/hr)					
Scaffolding and Formwork	Erecting lifts (m^2/hr)					
	Installing deck (m^2/hr)					
	Dismantling scaffold (m^2/hr)					
	Formwork (fixing/removing) (m^2/hr)					
Concreting	Rebar preparation (kgs/hr)					
	Material batching (m^3/hr)					
	Mixing (m^3/hr)					
	Concrete pouring (m^3/hr)					
	Vibrating (m^3/hr)					
Walling	Preparation (m^3/hr)					
	Stone laying (m^2/hr)					
Plastering and Flooring	Plastering and Screeding (m^3/hr)					
	Terrazzo flooring (m^3/hr)					
Tiling and Painting	Tiling (m^3/hr)					

Work Category	Task	0-20%	21-40%	41-60%	61-80%	81-100%
	Painting (m^3/hr)					
Building Services	Plumbing works (piping)(m/hr)					
	Electrical works (conduits)(m^3/hr)					

5) How would you describe the ***effectiveness*** of workers on this construction site based on the following criteria and statements? (FD=Fully Disagree, SD=Somewhat Disagree, N=Neutral, SA= Somewhat Agree, FA=Fully Agree)

No	Quality of Work	FD	SD	N	SA	FA
a)	Workers' level of accuracy is satisfactory					
b)	Workers' level of workmanship is satisfactory					
c)	Workers complete their assigned tasks on time					
d)	There's minimal rework on this site					
e)	Workers need minimal supervision					

No	Training, Skillset, and Development	FD	SD	N	SA	FA
a)	The work facilitates the development of workers					
b)	There is a possibility of career growth					
c)	The work helps the personal growth of workers					
d)	There are chances to learn new methods					
e)	Workers are trained at regular and frequent intervals					

Part III: Quality of Work Life of Construction Workers

6) How would you describe the ***Quality of Work Life*** for workers on this construction site based on the following criteria and statements? (**FD**=Fully Disagree, **SD**=Somewhat Disagree, **N**=Neutral, **SA**= Somewhat Agree, **FA**=Fully Agree)

No	Compensation and Reward Systems	FD	SD	N	SA	FA
a)	Wages for site workers are fairly adequate					
b)	Wages for site workers are regularly increased					
c)	Workers are paid on time					

d)	Workers are adequately rewarded for exemplary work					
e)	There is equity of remuneration within this site					
f)	Wage is as good as in most other construction sites					

No	Working Conditions	FD	SD	N	SA	FA
a)	The site has a favourable work environment					
b)	The work environment is encouraging					
c)	There are adequate facilities for workers e.g. toilets					
d)	It is easier to receive materials for efficient work					
e)	There is adequate job security					
f)	Workers are self-motivated for the job					
g)	Worker grievances are resolved amicably					
h)	Workers are involved in the decision-making process					
i)	Relationship between supervisors and workers are good					

No	Health and Safety	FD	SD	N	SA	FA
a)	Management puts emphasis on worker health and safety					
b)	Working times are reasonable					
c)	The site is a safe and healthy physical environment					
d)	Workers are sufficiently provided with necessary PPEs					
e)	There is adequate barricading and safety signage					
f)	Health and safety inspections are conducted regularly					
g)	Workers are frequently trained in health and safety					
h)	Noise levels on site are within normal range					
No	**Welfare and Social Integration**	**FD**	**SD**	**N**	**SA**	**FA**
a)	The rights of workers are protected					
b)	Workers are provided with means of transport to work					
c)	There is a sense of one community					
d)	There is a sense of equality					
e)	There is a sense of teamwork					
f)	There is a sharing of feelings and ideas					
g)	Workers are mutually helpful					

h)	There is a fair distribution of workloads					

Part IV: Level of Mechanization

7) Please indicate whether or not the operations below are mechanized in the project you are currently working on.

Mechanization Level	**Definition**	**Example**
Completely manual	Workers are on-site and use non-machineries or simple tools without mechanisms to work	Shovel, saw, and hammer, etc.
Hand tool	Workers are on site and use equipment with mechanisms (but not machines)	Hand winch, claw hammer, and spirit level, etc.
Automated hand tool	Workers are on site and use machinery to work on the construction project	Electric laser leveler, electric drill, electric bolt wrench, etc.
Machine/Workstation	Workers operate a machine/workstation to complete the construction task	Crane, excavator, and pump, etc.
Completely automated/Robotized	Workers are not required to operate or monitor the machine and the machine will complete the work activities by itself.	Robotic tiling machine, bricklaying robot, etc.

7a) Site Preparation and Earthworks (SPE)

Task	Subtask	Completely Manual	Hand Tool	Automated Hand Tool	Machine/ Workstation	Robotized
Site clearance	e) Barricading out worksite					
	f) Cutting the vegetation					
	g) Removing tree stump					
	h) Light demolition works					
Setting out	d) Site clearance					
	e) Excavations					
	f) Foundations					
Earthworks	e) Trench excavation					
	f) Column base excavation					
	g) Basement excavation					
	h) Transporting soil/rock offsite					

7b) Scaffolding and Formwork (SF)

Task	Subtask	Completely Manual	Hand Tool	Automated Hand Tool	Machine/ Workstation	Robotized
Erecting base lift and subsequent lifts	h) Soil compaction					
	i) Laying sole plates					
	j) Placing standards into jacks					
	k) Fitting transoms to standards					
	l) Inserting and connecting ledgers to the base of the scaffold					
	m) Installation of diagonal bracing					
	n) Tying scaffold to building					
Installing deck	d) Securing deck to standards, transoms, and ledgers					
	e) Installing toe boards					
	f) Installing guardrails					
Dismantling scaffold	e) Clearing loose materials on platform					
	f) Removal of hessian net					

Task	Subtask	Completely Manual	Hand Tool	Automated Hand Tool	Machine/ Workstation	Robotized
	g) Dismantling of deck, transom, ledgers, and standards					
	h) Hoisting of materials down to the ground					
Formwork (fixing and removing)	e) Foundations formwork					
	f) Columns formwork					
	g) Lift shafts formwork					
	h) Beams & Slab formwork					

7c) Concreting (C)

Task	Subtask	Completely Manual	Hand Tool	Automated Hand Tool	Machine/ Workstation	Robotized
Rebar preparation	f) Cutting					
	g) Bending					
	h) Tying					
	i) Hoisting					
	j) Placing					
Material batching	f) Ballast					
	g) Sand					
	h) Cement					
	i) Water					
	j) Additives and admixtures					
Mixing	b) Concrete mixing					
Concrete pouring	d) Hoisting					
	e) Transporting horizontally					
	f) Placing concrete					
Vibrating	b) Vibrating concrete					

7d) Walling (W)

Task	Subtask	Completely Manual	Hand Tool	Automated Hand Tool	Machine/ Workstation	Robotized
Preparation	e) Setting out					
	f) Mortar preparation					
	g) Mortar transportation					
	h) Placing and removing excess mortar					
Stone laying	d) Hoisting and transporting					
	e) Aligning					
	f) Cutting					

7e) Plastering and Flooring (PF)

Task	Subtask	Completely Manual	Hand Tool	Automated Hand Tool	Machine/ Workstation	Robotized
Plastering and Screeding	e) Mortar batching and mixing					
	f) Mortar transportation					
	g) Plastering and screeding surfaces					
	h) Cleaning plastered surfaces					
Terrazzo flooring	h) Shot blasting					
	i) Floor preparation and leveling					
	j) Design layout					
	k) Mixing terrazzo					
	l) Pouring terrazzo					
	m) Grinding the floor surface					
	n) Polishing the terrazzo floor					

7f) Tiling and Painting (TP)

Task	Subtask	Completely Manual	Hand Tool	Automated Hand Tool	Machine/ Workstation	Robotized
Tiling	g) Setting out					

Task	Subtask	Completely Manual	Hand Tool	Automated Hand Tool	Machine/ Workstation	Robotized
	h) Hoisting and transporting materials					
	i) Mortar preparation and placing					
	j) Placing and leveling of tiles					
	k) Grouting					
	l) Cleaning tiled surfaces					
Painting	h) Hoisting and transporting materials					
	i) Protecting surfaces not to be painted					
	j) Smoothing and cleaning surface					
	k) Mixing of paint					
	l) Application of sealer coat					
	m) Application of paint					
	n) Elevating painters to higher grounds					

7g) Building Services (BS)

Task	Subtask	Completely Manual	Hand Tool	Automated Hand Tool	Machine/ Workstation	Robotized
Plumbing works	g) Setting out					
	h) Hoisting and transporting materials					
	i) Pipe cutting					
	j) Pipe installation					
	k) Installing fixtures					
	l) Testing					
Electrical works	h) Hoisting and transporting materials					
	i) Pipe cutting					
	j) Smoothing and cleaning surface					
	k) Mixing of paint					
	l) Application of sealer coat					
	m) Application of paint					
	n) Elevating painters to higher grounds					

Part V: Open-Ended Questions

8) How do you think mechanization in the construction project has ***positively*** affected the performance and welfare of the workforce?

____

____

____

How do you think mechanization in the construction project has ***negatively*** affected the performance and welfare of the workforce?

____

____

____

9) In which ways do you think mechanization can be incorporated into the construction project in such a way that it promotes the performance and welfare of the workforce?

Thank you for your time!!!

Appendix III: NACOSTI Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Ref No: 593798

Date of Issue: 11/September/2023

RESEARCH LICENSE

This is to Certify that Mr.. Dennis Muuo Ndolo of Jomo Kenyatta University of Agriculture and Technology, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Nairobi on the topic: ASSESSMENT OF IMPACT OF MECHANIZATION AND AUTOMATION ON CONSTRUCTION WORKERS' WELFARE IN KENYA for the period ending : 11/September/2024.

License No: NACOSTI/P/23/29318

593798

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

See overleaf for conditions

Appendix IV: Questionnaire (Framework Validation)

Thank you for participating in the initial survey.

The research has been able to develop the attached framework for optimizing the level of mechanization and manpower in construction projects in Kenya.

The purpose of this brief questionnaire is to validate the developed framework

To what extent do you agree with the following statements regarding the attached framework?

	Not Agree	**Slightly Agree**	**Somewhat Agree**	**Moderately Agree**	**Agree**	**Very Agree**	**Extremely Agree**
The developed framework is clear							
The developed framework is practical							
The developed framework is applicable							
The developed framework is comprehensive							
The developed framework is suitable							

General comments

___

___

___

Thank you for your participation