AN ASSESSMENT OF THE ADOPTION OF HIGH-DENSITY POLYETHYLENE, HDPE (WEHOLITE) TECHNOLOGY IN CONSTRUCTION PROJECTS IN TANZANIA

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By

Dominic Justin Hando

A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Construction Economics and Management of Ardhi University.

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CERTIFICATION

The undersigned certifies that he has read and hereby recommends for acceptance by the Ardhi University a dissertation entitled: ***"An Assessment of the Adoption of High-Density Polyethylene, HDPE (Weholite) Technology in Construction Projects in Tanzania"*** in partial fulfillment of the requirements for the degree of MSc. in Construction Economics and Management, Ardhi University.

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Dr. Harriet Eliufoo

(Dissertation Supervisor)

Date…………………………………………….

DECLARATION AND COPYRIGHT

I, **Hando, Dominic J.**, hereby declare that the contents of this dissertation are the results of my own study and findings and to the best of my knowledge have not been presented to any other university for similar or any other degree award.

Signature………………………………….

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Foremost, I would like to thank God for being with me throughout the entire time that I was pursuing my master's degree.

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May God bless you all.

DEDICATION

This dissertation report is dedicated to my lovely wife, Evancia Nicodem and my beautiful daughter – Reina.

ABSTRACT

Over the years, advances have been made to provide reliable construction materials and technologies altogether with the aim to improve project performance. It is notable that the construction industry worldwide is plagued by poor project performance and previous studies have indicated that adoption of new technologies is pivotal to project success. This study aimed at assessing the adoption of high-density polyethylene, HDPE (Weholite) technology in construction projects in Tanzania and using findings to develop a framework for adoption of the technology. The research adopted a descriptive research design with simple random sampling technique used for contractors and a snowball sampling for consultants. Structured questionnaires were used for data collection and interviews were done for framework validation.

Findings from the study indicate sufficient knowledge and awareness of the technology with responses indicating that the technology is very effective with durability, material service life, light weight, superior hydraulic properties, superior quality and flexibility seen as major performance characteristics in use and adoption of the technology. An overall indication from both contractors and consultants attributed reduction in installation time, overall reduction in project labour costs, increase in project efficiency, easiness of transport and handling and reduction in work program with merit to project performance and objectives. Further to this, an evaluation of barriers in adoption of the technology revealed that for both contractors and consultants, major barriers are insufficient incentives for adoption of emerging technologies in the construction industry, insufficient knowledge on Weholite as a construction material, inadequate knowledge on the design aspects of Weholite and that the current construction industry culture inherently slows down the adoption of the technology.

Both contractors and consultants indicated strategies for increased adoption of the technology as the use and application of Weholite technology should be taught and illustrated to construction industry professionals, project consultants to specify Weholite as a material option where applicable, developing training approach prior to introduction of new technology, project concept design to factor the usability of Weholite and integrating technology deployment with change management. These findings were crucial in developing a framework for adoption of the technology in construction projects in Tanzania.

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LIST OF ABBREVIATIONS

ABM&Ts – Appropriate Building Materials and Technologies

AWDF – Average Dry Weather Flow

ERB – Engineers Registration Board

HDPE – High-Density Polyethylene

MS – Mean Score

PE – Polyethylene

R&D – Research and Development

SPSS – Statistical Package for the Social Sciences

UV – Ultraviolet

CHAPTER ONE
INTRODUCTION

1.1 Background Information

The construction industry is evolving every day with the introduction of new technologies which gives added values through increased performance and functionality. In addition to higher accuracy, improved performance, and increased building speed, the employment of innovative technologies can also save money in the long run. The construction industry's evolution has shown a constant quest for more efficient materials, and in recent years, environmental implications and sustainability in the business have become increasingly prominent and several new materials sciences and building technologies have been established as a result (Delgado et al., 2015). According to Grant (2013), there is a current trend toward moving away from fundamentally distinct types of materials, such as metals, polymers, or ceramics, and toward other classes of materials, such as energy, finished components, and systems, which rely on a new integration of the most advanced materials developments.

Each year, new construction materials are developed, allowing engineers to better fulfill their visions and reinforce structures with increased flexibility, strength, and longevity (White, 2018). The development industry is changing quickly, and modern materials and innovations are being presented on a customary premise making the execution of development ventures and their convenient conveyance a prime concern for developers. Moreover, rising mechanical, private and commercial development is driving request for speedier development and high-quality finish. It has hence gotten to be basic to utilize more up to date items and advances to meet this expanding request. The development industry nowadays is at the cusp of troublesome alter with unused materials and building innovation changing the way we conceptualize, construct, and utilize our buildings.

Developers are persistently investigating unused advances that improve the quality, strength and safety of the structures. These technologies are not only cost-effective, but offer advantages such as minimal labour required, environmentally friendly, more durability and lower maintenance and as such, not only reduce the turnaround time but also improve the quality and durability of construction. The demand for efficiency in the building process is apparent, and emerging technologies may offer the best chance to advance the process through improved integration and efficiency. Although technology has simplified the construction process, it has yet to reach the productivity improvements that are achievable due to a lack of integration (Gallaher et al., 2004).

Clients and engineering experts agree that polyethylene (PE) is the best pipe material for a wide range of pressure and non-pressure applications, including water distribution, gravity sewers, rehabilitation projects, manholes, and marine pipelines. in response to client demand for large diameter lightweight low-pressure pipes and fittings, PLASCO LTD manufactures Weholite – a pipe built utilizing a patented high-quality structured wall method that allows for diameters up to 3000 mm. WEHOLITE is a smooth internal and external structured-wall pipe made by welding an extruded, spirally wound profile of high-density polyethylene (HDPE) into a pipe. Weholite combines raw material qualities with innovative manufacturing techniques to offer a lightweight designed solution with greater loading capacity, chemical inertness, and a 100-year design life (PLASCO, 2020). Weholite structured-wall pipe offers all of the technical benefits of identical solid-wall HDPE pipes, but at a lower weight, resulting in better ease of installation and cost savings. Weholite pipe is a flexible pipe with a structural integrity based on pipe stiffness rather than strength.

A flexible pipe's load carrying capability is nearly entirely determined by the strength of the embedment soil. Weholite installation is referred to as a soil-pipe system because the structural stability of the system is derived from the soil envelope. Even in difficult ground conditions, installation is rapid and reliable. Weholite pipe has a natural tendency to "flex," allowing it to react to various loading situations, vibrations, stress, and soil movements without causing structural damage. Weholite pipe can be designed and manufactured for gravity and low-pressure applications with internal pressures up to 1.0 bar and has a variety of jointing methods to meet the needs of various applications. Speed and economy of installation together with product quality and durability has been recognized in both the public and private sector. It is evident that the adoption of Weholite in the Tanzanian construction industry is still low despite its performance characteristics, and this shows that there is a need for construction professionals to understand the need for adoption of new technologies in construction projects towards improving project performance. Specifically, this study sought to assess the adoption of HDPE (Weholite) technology in construction projects in Tanzania in view of establishing a framework for its adoption in the construction industry (PLASCO, 2020).

Previous studies related to technology adoption in construction projects have been carried out by different researchers as follows. Nnaji et al., (2018) researched on a theoretical Framework for improving the adoption of safety Technology in the construction industry in which the study investigated the determining factors that drive technology adoption and a theoretical framework was developed based on literature review only but the research does not show integration into construction projects; Khudzari et al., (2021) undertook a research on the factors affecting the adoption of emerging technologies in the Malaysian construction industry in which the study aimed at investigating the factors affecting the adoption of emerging technologies in the Malaysian construction industry but did not cover the barriers to technology adoption or use and no framework for adoption of technology was discussed; Benmansour & Hogg (2002), conducted a research on investigation into the barriers to innovation and their relevance within the construction sector in which the study investigated the benefits and barriers to innovation within the construction sector but the study focused only on benefits and barriers to innovation and developed framework was not focused on integration into projects.

Furthermore, Olaniyan, R. (2019) assessed barriers to technology adoption among construction project managers in Nigeria in which the study aimed at assessing the perceptions of construction managers towards barriers to technology adoption in Nigeria. However, the study only assessed barriers to technology adoption and no technology adoption framework developed. Moreover, Sepasgozar & Davis (2018), conducted research on Construction Technology Adoption Cube: An Investigation on Process, Factors, Barriers, Drivers and Decision Makers using NVivo and AHP Analysis in which the study explored how companies make decisions to uptake new technology; developed 'cube' for investigating the Construction Technology Adoption Process but research did not cover an evaluation of use of technologies but rather focused on end-user; no framework for technology adoption was developed.

Finally, researchers Mule, B. (2012) and Hatoum et al. (2020) researched factors affecting the adoption of appropriate building materials and technologies (ABM&Ts) programme in northeastern province of Kenya and a holistic framework for the implementation of Big Data throughout a construction project lifecycle respectively but in both studies only factors affecting technology adoption were discussed and a framework for technology adoption was not established. Table 1.1 displays the summary of previous studies relating to technology adoption in the construction industry. In disparity to the previous studies, this research aimed to develop a framework for technology adoption in the construction industry to assist the stakeholders in establishing a road map for technology adoption in construction projects in Tanzania.

Table 1.1: Summaries of previous studies relating to technology adoption in the construction industry

Title	Author(s)	Year	Key Issues Researched	Remarks
Theoretical Framework for Improving the adoption of Safety Technology in the Construction Industry	Nnaji et al.	2018	The study investigated the determining factors that drive technology adoption; a theoretical framework is developed by literature review only	The study emanated from evaluation of Literature only and the developed technology adoption framework does not show integration into construction projects
Factors Affecting the Adoption of Emerging Technologies in the Malaysian Construction Industry	Khudzari et al.	2021	The study aimed at investigating the factors affecting the adoption of emerging technologies in the Malaysian Construction Industry	The research did not cover the barriers to technology adoption or use and no framework for adoption of technology was discussed.
An Investigation into the Barriers to Innovation and their Relevance within the Construction Sector	Benmansour & Hogg	2002	The study investigated the benefits and barriers to innovation within the construction sector	The study focused only on benefits and barriers to innovation and developed framework was not focused on integration into projects.
Barriers to Technology adoption among Construction Project Managers in Nigeria	Olaniyan, R.	2019	The study aimed at assessing the perceptions of Construction Managers towards Barriers to technology Adoption in Nigeria	Only barriers to technology adoption are examined and no technology adoption framework developed.
Construction Technology Adoption Cube: An Investigation on Process, Factors, Barriers, Drivers and Decision Makers using NVivo and AHP Analysis	Sepasgozar & Davis	2018	The study explored how companies make decisions to uptake new technology; developed ‘cube’ for investigating the Construction Technology Adoption Process	The research did not cover an evaluation of use of technologies but rather focused on end-user; no framework for technology adoption was developed

Factors Affecting the Adoption of Appropriate Building Materials and Technologies (ABM&Ts) Programme in North Eastern Province of Kenya	Mule, B.	2012	The study aimed at determining the factors affecting the adoption of appropriate building materials and technology through a review of literature	Only factors affecting technology adoption were discussed; a framework for technology adoption was not established
A Holistic Framework for the Implementation of Big Data throughout a Construction Project Lifecycle	Hatoum et al.	2020	The study explored the implementation of Big Data throughout the different phases of a construction project	Factors affecting technology adoption were not discussed but rather the research focused on implementation of Big Data in construction

1.2 Statement of the Problem

The use of Weholite technology has been minimal due to a lack of knowledge and understanding on the usability, applicability and other aspects of the technology in construction projects and while research has shown HDPE's suitability for a variety of construction projects, further research is needed to help users, developers, and designers better grasp its contribution towards increasing project efficiency and performance. In Tanzania, most construction projects have demonstrated serious weakness in project performance resulting generally from poor quality of works, cost overruns, project delays and inefficiencies coupled with aversion of technology deployment and integration. More often, achievement of the project quality, safety, time, cost and environmental sustainability are the key factors for indicating success of a project performance (Zhou et al., 2007) and while technological advances have proven to foster project performance and efficiency (Holt et al., 2015), the integration of emerging technologies in construction projects is minimal.

Conventionally, most engineers do not study plastics as a construction material whereas concrete and other material knowledge is readily available and researched. As an engineer, it is paramount to understand a wide range of construction materials properties. Furthermore, it is evident that advancements in technology have led to development of vast materials that are used today in construction projects (Mule, 2012). Despite previous studies done about technology in the construction industry such as Nnaji et al. (2018), Khudzari et al. (2021), Olaniyan, R. (2019) and Sepasgozar & Davis (2018), authors have failed to provide a detailed approach that can be followed by construction stakeholders to foster technology adoption in construction projects. Therefore, this research proposed to develop a framework that will assist stakeholders in the construction sector in adopting Weholite technology.

1.3 Objectives of the Study

1.3.1 Main Objective

The main objective of the study is to assess the adoption of High-Density Polyethylene, HDPE (Weholite) and to develop a framework for adoption of the technology in construction projects in Tanzania.

1.3.2 Specific Objectives

The research focused on four specific objectives:

1. To evaluate the use of HDPE (Weholite) technology in construction projects in Tanzania.
2. To examine the influence of performance characteristics and evaluate the benefits achieved in the adoption of HDPE (Weholite) technology in construction projects in Tanzania.
3. To assess the barriers toward adoption of HDPE (Weholite) technology and evaluate strategies for mitigation in construction projects in Tanzania.
4. To develop a framework for adoption of HDPE (Weholite) technology in construction projects in Tanzania.

1.4. Research Questions

1. To what degree is HDPE (Weholite) used in construction projects in Tanzania?
2. How do the performance characteristics and benefits derived from the use of HDPE (Weholite) influence its adoption in construction projects in Tanzania?
3. What are the barriers facing the adoption of HDPE (Weholite) technology in construction projects in Tanzania and what strategies can be used to foster adoption?

4. In what way can framework for the adoption of HDPE (Weholite) technology be developed?

1.5 Significance of the Study

Slow technology adoption is largely due to the construction industry's inherent resistance to change, but regardless of the cause, construction professionals have a responsibility to drive change. To aid in the improvement of the construction industry through the adoption of technology, construction industry professionals should be exposed to new technologies so that future advancements are more quickly absorbed and implemented in the construction process (Holt et al., 2015). It thus remains imperative for designers to continually learn and research about material properties of available new construction products, be aware of all relevant standards and understand the proper installation requirements.

This research will contribute to the development of a body of knowledge on the use and adaptation of Weholite systems for various infrastructure projects due to its myriad benefits and performance characteristics. With Weholite, all projects' components are designed to optimized pipe lengths to ensure efficient installation and value engineering. Contractors undertaking projects that can utilize the functions of Weholite systems will be able to gain knowledge through this study.

1.6 Scope of the research and Limitations of the study

The study aimed at assessing the adoption of HDPE (Weholite) in construction projects in Tanzania with broader focus on projects that have utilized the technology. The study was limited to Local Civil and Structural Consulting firms in Dar es Salaam altogether with Contractors that adopted the use of HDPE (Weholite) in construction projects – a reason for selection of these contractors is because they have first-hand experience on the adoption of HDPE (Weholite). Dar-es-salaam city was selected for the purpose of having manageable research with respect to time, convenience, availability of data and resource constraints.

The researcher has found the study with limitations. Foremost, the research has shown that a greater number of respondents showed application of the technology in 1 to 3 projects and this number of projects is still low to fully realize the potential of adoption of Weholite technology in construction. Nevertheless, this limitation was overcome by assessing other attributes for adoption of the technology such as familiarity, awareness, application, effectiveness and future use.

Secondly, the research was conducted almost 5 years after introduction of the technology and whilst the population sample was sufficient for analysis, the researcher found this time period limiting. Hence, further research proposed to evaluate the rate of adoption of the technology over a longer period – and this limitation was overcome by decisive selection of respondents during data collection in order to obtain sufficient and accurate response with regard to technology adoption.

1.7 Organization of the Dissertation

This research report is organized in five chapters, references, and appendices. The first chapter gives the introduction of this research, statement of the problem, research objectives, the significance, scope and limitation of the study and the organization of the dissertation.

The second chapter begins by giving an overview of construction industry followed by an assessment of technology in the construction industry while focusing on material advancements. It is then followed by a review of factors affecting technology adoption in the construction industry. HDPE (Weholite) is then elaborated and finally the barriers in the adoption of construction technology are reviewed altogether with strategies necessary for increased adoption of the technology in construction.

The third chapter explores the tools, methods and techniques that will be used in this study for sample selection, collection and data analysis.

The fourth chapter depicts the analysis of the data collected through questionnaires with regard to influence of performance characteristics of the technology, benefits derived from using the technology, barriers and strategies toward enhancing adoption of HDPE (Weholite) in construction projects in Tanzania. A framework for technology adoption is also established.

Lastly, the fifth chapter gives the conclusions and recommendations and provides areas for further research of the study.

1.8 Chapter Summary

This chapter established the background of the study by reviewing the construction industry with relation the technology adoption and provided a brief introduction on HDPE (Weholite) technology altogether with a summary of previous studies relating to technology adoption in the construction industry. The problem statement has been provided based on the lack on knowledge of the technology in construction and research objectives have been defined accordingly. Research questions have been poised to aid in research methodology and data collection. Furthermore, significances of the study have, scope of the research and limitations of the study have been discussed.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

This chapter examines the notion of technology in the construction industry, as well as the qualities, applications, and benefits of structured-wall high-density polyethylene, HDPE (Weholite) technology. The usage of technology in the construction sector will be explored further, followed by an assessment of the factors that influence technology adoption in the industry. The focus of this chapter is on Weholite technology, which is evaluated for its many qualities to establish its suitability for construction. This chapter also discusses barriers to technology adoption in the construction sector altogether with strategies for mitigation. Finally, a conceptual model of the study is established.

2.2 Overview of Tanzania's Construction Industry

The construction industry has been identified as one of the major sectors of the economy that is able to change different resources into constructed physical economic and social infrastructure needed for the major growth of a country's economy. In comparison to other industries, the construction industry can be regarded as unique. This is because construction projects are complex and one-of-a-kind. Each project, for example, has a unique nature of labor, workplace, staff, turnover, and product and service types. The construction business is a sector of the economy that converts various resources into built physical, economic, and social infrastructure, hence accelerating a country's and its people's socioeconomic growth. This sector adopts a methodology in which the physical infrastructure is organized, formulated, procured, constructed, transformed, retained and dismantled. This sector is also considered as the engine of economic growth.

Tanzania has the second largest construction market in Eastern Africa behind Ethiopia and the market is estimated to be growing persistently for the next ten years as the forecast of 2015 (CSP, 2016). According to CSP (2016), the construction industry in Tanzania is the second-largest driver of the economy behind information and communication with the growth rate contribution of 14%. Despite the promising growth, the sector encounters various setbacks which hinder its development and performance. The industry has encountered constraints such as inefficient procurement systems, irregular work programs, poor working environment, low technological equipment, inadequate skill level, insufficient capital, financial mismanagement and insufficient planning (Kikwasi and Escalante, 2018). In Tanzania, the Ministry of Infrastructure Development governs the construction industry through supervision of all construction activities taking placing within the country. The major aim of the ministry is to spearhead that the industry's growth and subsequently foster economic development.

2.3 Technology adoption in the construction industry

The construction industry differs from the other industries due to issues such as low productivity, construction material waste, and worker accidents caused by labor-intensive work performed on the jobsite under built-to-order production supported by various types of project participants. To address the issues, sophisticated manufacturing technologies have been established, together with associated concepts and methods for improving quality and productivity. The demand for efficiency in the building process is apparent, and rising technology offers some of the best potential to improve the process through improved integration. (Holt et al., 2015).

In the Tanzania construction industry, the uptake of new technologies becomes a merely part of long-standing, broader pattern of technological changes that encompass both frontier and non-frontier technologies hence in lower-income countries therefore, emerging technologies will impact economies greatly since jobs are being replaced, and the structure of production is already shifting. Essentially, an innovation system is called for such that through a system of incentives, technological change can be effected in construction projects. The introduction of new technologies in the Tanzania construction industry aimed at fostering project performance should also focus on construction stakeholder involvement.

2.3.1 Integration of technology in Construction

There have been significant attempts to build technologies for integrated construction environments as well as the procedures required to increase construction professional collaboration. The development of technology and its effective implementation are two concerns that might be major contributors to this. (Alshawi & Faraj, 2002). It is thus imperative that construction professionals differentiate themselves from their competitors to avoid selection by owners based on commodity-type selection (i.e., lowest cost wins) alone (Ahn et al., 2012). Below are key factors necessary for efficient technology integration in construction.

i. Technology Fusion

Technology fusion is a method of transforming core technologies through a process of combining aided by technical advancements. It is critical to foster technological fusion in a systematic manner with a clear purpose, vision, and strategy (Yamakazi, 2004). Technology fusion in the construction industry refers to combining construction activities and materials with the most recent breakthroughs and material technologies in order to boost productivity and project performance.

ii. Knowledge Fusion

Knowledge fusion is an approach for improving an organization's ability to create knowledge by dynamically altering the organization's implicit and explicit knowledge. Knowledge fusion has been introduced to the construction sector as activities of organizational knowledge generation, as opposed to technological fusion. When it comes to building construction, socialization refers to the transmission of expert skills and implicit knowledge from a professional engineer to an unskilled engineer through actual employment. Externalization is the process of documenting and standardizing one's or a group's knowledge (Yamakazi, 2004).

iii. Training, Awareness and Acceptance

Technology propagation in the construction industry is contingent on user awareness, acceptance to adopt the technology and sufficient training to ensure appropriate use of technology. This is an essential step towards integrating technologies in construction by providing trainings prior to introduction of new technologies and evaluating the readiness of the construction industry. This ensures a development of skills required to adopt the technology.

iv. Technology Implementation

The process of using the specified technology for construction is known as technology implementation. It is influenced by building industry policies and strategies regarding the usage of developing technology. Monitoring and evaluating the effectiveness of adopted technology is also part of the technology implementation process.

2.3.2 Factors Affecting Technology Adoption in Construction Industry

Sepasgozar & Bernold (2012) argue that understanding the technology adoption decision-making process is critical when someone wants to enhance their current position. When it comes to future approaches or new procedures, construction is widely seen as a risk-averse industry, and corporations will typically adopt technology only after another company, particularly a competitor, has done so successfully. Furthermore, before adopting construction technology, contractors demand factual data from suppliers, such as better productivity, safety, and waste reduction. (Holt et al., 2015). The variables affecting technology adoption in the construction sector are listed below, and they are classified into two categories: internal and external factors.

2.3.1.1 Internal Factors Affecting Technology Adoption in Construction Industry

i. Labour-related internal factors

Workers' competencies and project stakeholder technology skills are two human-related internal elements that drive technology adoption. In general, professionals in the construction sector must be informed, enthusiastic, and well-trained in order to handle a particular technology.

ii. Cost-related internal factors

High expenses of technology adoption and the company's eagerness to cut costs are examples of cost-related internal factors. According to Holt et al. (2015), the initial cost or budget is the most limiting factor in adopting innovative technology. Although budget constraints are the primary impediment to new technology adoption, as technology prices fall and productivity returns rise, more construction professionals will integrate technology into their processes (Fernandes et al., 2006).

iii. Time-related internal factors

Internal time-related factors include the requirement for more time to implement evolving technologies in building projects, which necessitates construction businesses providing training to their personnel to grasp the technology.

iv. Technology’s adaptability internal factors

Internal elements affecting technology's adaptation include technologies that are simple to use and adaptable in any situation or even geographical location.

Such technology must be adaptive and simple to use in order to be successful in its adoption phase.

v. Technology’s quality-related internal factors

Internal variables for technology's quality-related internal factors include technology that has the potential to alter the quality of projects or products.

2.3.1.2 External Factors Affecting Technology Adoption in Construction Industry

i. Third-party related internal factors

This includes the government and other important agencies involved in building development and regulations, as well as other elements that can influence the success of adopting new technologies.

There are several ways to accomplish this, including the government's influence by raising technology awareness among owners, developers, consultants, and contractors, as well as government funding for emerging technologies.

ii. Leader’s opinion-related external factors

External elements affecting the leader's opinion include persuading stakeholders of the technology's benefits and assuring the technology's continuous use. It's clear that persuading consultants and developers that new technology will benefit a wide range of stakeholders will be difficult, as they tend to turn away when the word "high cost" is used. This is due to apprehension over whether new and emerging technologies can give better results than traditional technologies in terms of cost, timeliness, and project schedule.

2.4 Weholite

Weholite is a high-density polyethylene structured wall pipe or structural panel (HPDE). Weholite pipes provide a reliable, long-term service durability, and cost-effective solution for a wide range of piping applications, including gas, municipal, industrial, storm water attenuation, mining, landfill, and electrical and communications duct applications, to designers, owners, and contractors. Large diameter HDPE pipes have seen increased acceptance and utilization in recent years, particularly in the water sector, where innovation combined with the best value is an imperative necessity and research suggests they can contribute significantly towards achieving this aim on major turnkey projects in the construction industry.

2.4.1 Benefits of Weholite

Weholite pipes are made of high-density polyethylene – HDPE – and have played a key role in the development of thermoplastic pipe systems. Because of their good physical, hydraulic, and mechanical capabilities, thermoplastic pipes are an interesting alternative in the design of water distribution systems. Weholite pipes, which are made of corrosion-resistant HDPE, perform differently than typical steel, ductile iron, concrete, and other pipe systems. Weholite pipe features have a slew of important advantages for piping systems, including:

a. Light Weight

Because of its light weight, Weholite is a great choice. The pipes are easily carried to the jobsite, even in bad ground conditions, making installation rapid and dependable. Because Weholite does not apply as much load to its bedding as heavier pipe materials, light pipe materials have a significant benefit for foundation work.

b. Easy Installation and Handling

Weholite piping is simple and straightforward to install. The pipe's light weight, simplicity of handling, transport to the worksite, and installation procedure are all important considerations. Longer pipe lengths save installation times, reduce the number of joints, and lower installation costs.

c. Durability and Reliability

Weholite pipes are extremely dependable and long-lasting. When compared to standard pipe materials, they offer corrosion-free installation, good chemical resistance, and improved abrasion-resistant properties, giving them both reliability and longevity. The fact that Polyethylene (PE) pipes have been used widely in the mining industry for many years backs up these statements.
PE piping systems, when installed appropriately, can have a useful life of more than 100 years.

d. Superior Hydraulics

Gravity and low-pressure applications are ideal for Weholite pipes. HDPE's anti-corrosive and anti-abrasion qualities make it a long-lasting pipe. With a Roughness Coefficient (ks) of 0.03 mm (Manning's 0.009), flow rates for Weholite can be computed using the Colebrook White formula. Other materials do not readily connect or cling to polyethylene hence siltation and sliming do not occur in the same way as they do in traditional materials, and long-term flow properties do not change.

e. Roughness Coefficient (Ks)

Full scale field hydraulic studies for the technology yielded a Roughness Coefficient (ks) of 0.03mm for the Colebrook formula and a Manning's value (n) of 0.009.

f. Chemical Resistance

Within the regular spectrum of use, Weholite pipes are chemically inert for all practical purposes. Unlike pipes composed of traditional pipe building materials, they are resistant to most chemical substances.

g. Abrasion Resistance

In the Darmstadt abrasion test, samples of commonly used pipe materials are filled with a sand and water combination and then rocked for a set number of times. The thickness of the abraded pipe material is then measured at regular intervals, revealing an extraordinarily high abrasion resistance in the case of polyethylene (PE) pipe materials, as illustrated in fig 2.1 below.

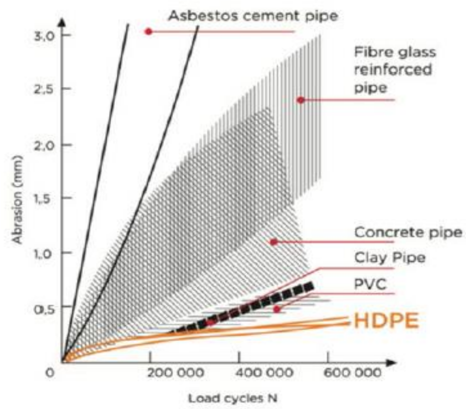


Figure 2.1 HDPE Pipe Abrasion Resistance

h. Physiologically Safe

When utilized for liquids or other food-related goods intended for human or animal consumption, Weholite pipes are physiologically safe. Weholite pipe features a smooth inner surface that does not absorb chemicals from the stored liquids or dissipate impurities.

i. Carbon Credentials

Weholite has the potential to dramatically reduce carbon emissions. This is owing to the lightweight nature of the product, which reduces transportation emissions. Furthermore, due to the convenience of construction, installation time is reduced, and carbon emissions are reduced significantly.

j. Using Weholite Eliminates System Infiltration

Infiltration is defined as storm or groundwater that indirectly enters the system through cracks and failed joints in pipes, lateral connections and manholes. Infiltration is characterized by an increase in sewerage flow during rain events followed by a much slower return to average dry weather flow (AWDF). Infiltration is a major problem facing water authorities and local communities across East Africa. Weholite pipes, manholes and fittings do not suffer the same effects that other materials and types of systems do.

2.4.2 Weholite Pipe Range

Weholite is designed and certified to meet the material and performance criteria of ISO 21138 (parts 1&2) and EN 13476 (parts 1&2). Pipe sizes, standard lengths, and pipe stiffness class (as defined by ISO 21138-2/EN 13476-2) are listed in the table below.

Table 2.1: Weholite Pipe Sizes

Internal Diameter (mm)	Standard Pipe Length (m)	Pipe Stiffness Class (kN/m²)
350	6, 12	4,8
400	6, 12	4,8
450	6, 12	4,8
500	6, 12	2, 4, 8
600	6, 12	2, 4, 8
700	6, 12	2, 4, 8
800	6, 12	2, 4, 8
900	6, 12	2, 4, 8
1000	6, 12	2, 4, 8
1200	6, 12	2, 4, 8
1500	6, 12	2, 4, 8
1800	6, 12	2, 4, 8
2000	6, 12	2, 4
2200	6, 12	2, 4

Source: PLASCO Weholite Technical Manual (2020)

Because of the unique nature of the Weholite manufacturing process, pipes can be run in one piece in lengths ranging from 300mm to 30m. To ensure efficient installation and value engineering, all projects are planned to optimize pipe length. It is also notable that the manufacturer, PLASCO LTD may provide pipe stiffnesses exceeding SN8 class upon specific request.

2.4.3 Structural Design of Weholite Pipes

2.4.3.1 Design consideration for pipe deflection

A flexible pipe, such as Weholite, deflects when subjected to external loads (traffic, ground water changes, frost activities, soil settlement, and so on), as opposed to a rigid pipe that carries all external stresses alone. A flexible pipe's degree of deflection is determined by its stiffness, support from the surrounding soil, and external loads. The deflection of underground flexible pipelines can be calculated using a variety of approaches. The Spangler formula is used in the majority of them given as:

$$Deflection\ (\%) = \frac{Vertical\ Load\ on\ Pipe}{Pipe\ Stiffness + Soil\ Stiffness}$$

Depending on the backfill material, quality of backfill compaction operations, and external loads, the maximum deflection can be obtained within 1–3 years after installation. Depending on national standards, the maximum permitted deflection is 5–10 percent.

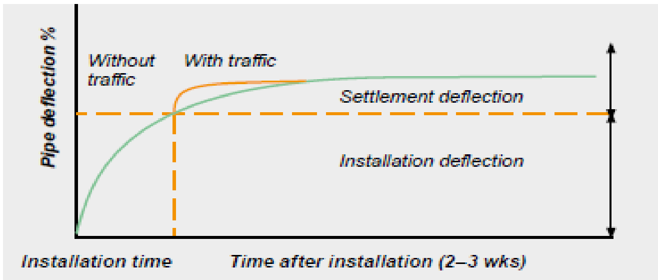


Figure 2.2: Weholite Pipe Deflection

External loads are absorbed by a flexible pipe, which deforms to some amount. A rigid pipe, on the other hand, is incapable of deformation. The rigid pipe will eventually crack and lose its rigidity as external loads increase.

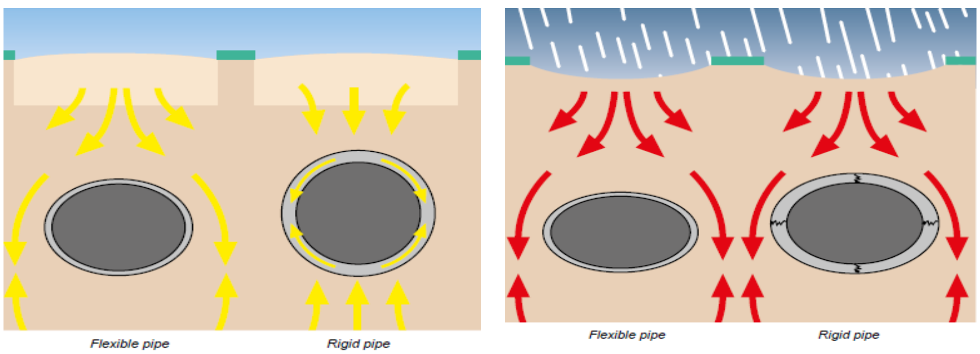


Figure 2.3: Flexible vs Rigid Pipe

The above illustration of flexible pipes vs rigid pipes shows the impact of overloading, where the flexible pipe just deforms further while the rigid pipe cracks. Several elements influence the design of any buried flexible pipe, including pipe stiffness, trench width, native ground qualities, and the kind and degree of compaction of the bed and surrounding material. A buried pipe and its surrounding soil will attract earth and live loads based on a fundamental structural principle: stiffer elements will attract greater proportions of shared load than more flexible elements – the more flexible pipe will attract less crown load than the rigid pipe of the same outer geometry. The figure below further demonstrates this.

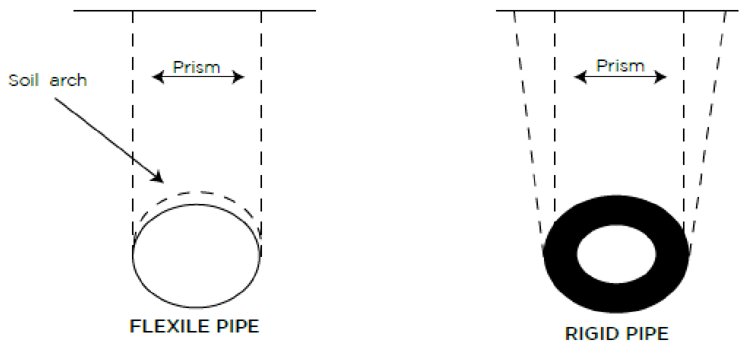


Figure 2.4: Pipe Loading Effects

2.4.3.2 Design consideration for Groundwater Floatation

High groundwater levels can cause buried pipe to float, triggering catastrophic upheaval as well as upward movement off-grade. This isn't just a problem with plastic pipes. When metal or concrete pipes are empty, they may float at shallow water depths. When ground water surrounds a pipe, it produces a buoyant force that is greater than the sum of the downward forces produced by the soil weight on top, the pipe's weight, and the weight of its contents. The following is a diagram showing ground water flotation forces.

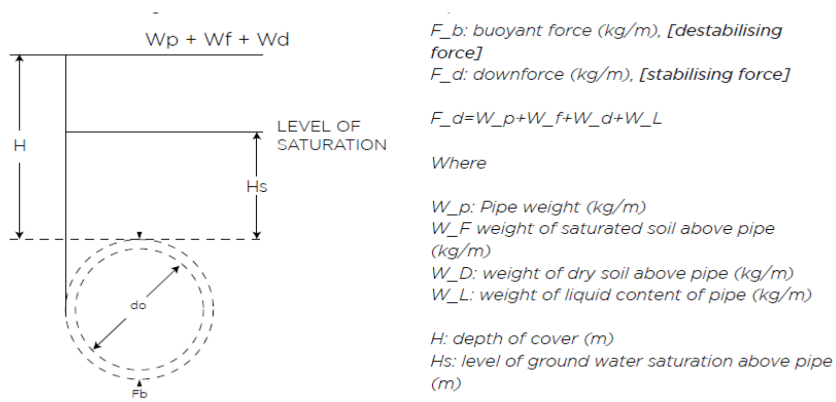


Figure 2.5: Pipe Groundwater Design Considerations

2.4.4 Bedding and Backfill Materials

To transport dead and live loads to the native soil adjacent to the pipe, flexible pipes require the support of bedding and surround material. Imported granular material is typically used for pipe bedding and surrounds. The following characteristics should be included in the optimum mattress and surround material:

- It should be able to be compacted to the required density with minimal effort.
- The largest particle size should not be excessive in relation to the pipe diameter.

- The grading should be such that water will not pass through, causing fines migration, which could result in the pipe losing support, and it should be chemically inert.

Backfill materials are classified as follows:

1. Pipe Bedding

Within the pipe trench's width, the bedding soil must be clear of stones. A 100-150mm thick bedding layer is created on the trench bottom and mechanically compacted. The pipe outside diameter must be at least 400mm wider than the bedding. A geotextile is placed under the bedding in soft/wet soil installations to keep bedding and native materials separate.

2. Primary Backfill

Friction dirt or macadam shall be used as the principal backfill material. The backfill material should be compacted in layers of 150-300mm. The primary backfill's final layer must extend 300mm above the pipe crown. The usage of frozen soil material is disallowed. Until the backfill reaches 300mm above the pipe crown, no compaction should be done directly above the pipe.

3. Final Backfill

For traffic load zones and non-traffic load areas, the requirements for the final backfill material are varied. The process of compaction is done in layers. The final backfill material must be compactable as well as digging materials. However, the material must be devoid of stones.

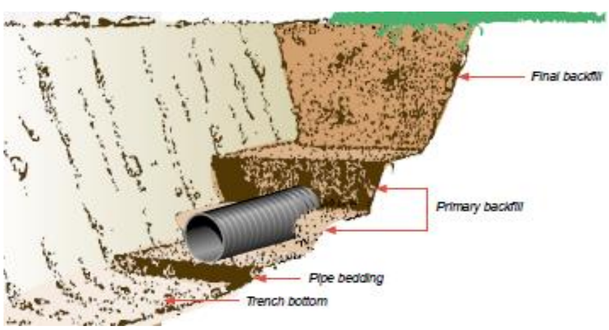


Figure 2.6: Pipe Backfill and Bedding

2.5 Barriers of Technology Adoption in the Construction Industry

The construction industry's project-based nature, the extremely complicated communication structure on projects, and the vast amount of data consultants and contractors deal with all point to the need for efficiency in project management. The construction industry has a reputation for being resistant to change (Friedman, 2015). Furthermore, construction workers have the belief that those who do not perform activities directly on the jobsite do not comprehend the nature of the profession (Usrey, 2011). This perspective may lead to opposition to new technologies and practices that require a shift in the traditional way of doing things. As a result, the construction industry's general aversion to change and technology continues to be a barrier to technology adoption (Lin et al., 2014). This broad view of the construction business implies that some individual and organizational characteristics in the sector impede practitioners' adoption and acceptance of innovative technologies. The challenges to technology adoption in the construction industry are discussed below.

2.5.1 Construction Industry Culture

Because the construction sector is extremely competitive, productivity is a determining factor for company decision-making when it comes to technology adoption (Welch et al., 2015). Furthermore, despite an organization's decision to adopt an invention, how personnel apply it determines its real use (Talukder, 2012). Understanding the elements that influence a person's desire to use technology can help managers develop ways to promote and improve technology adoption and improve the innovation adoption process (Sargent et al., 2012). Aside from the general aversion to change in the construction industry, confusion about the practicality and benefits of new technologies is seen as a barrier to the introduction and development of innovative construction technologies (Lin et al., 2014). When compared to other industries, the construction industry is considered a late adoption of new technologies (Smith, 2015). As a result, such risks create a barrier to technology adoption when the advantages of new technologies are yet unknown. When the cost of some existing advancements is out of reach for small and medium-sized businesses, the uncertainty of reaping the advantages of these advances causes people to be hesitant to invest in new technology. According to several studies, a company's financial situation has a substantial impact on the technology adoption process (Jacobsson et al., 2010).

2.5.2 Individual Factors

Adopting new technologies may cause unforeseen changes in how activities are completed. Workplace organization, culture, and productivity can all be affected by these changes (Welch et al., 2015). According to previous studies, the amount to which users must adjust their current processes and procedures in order to integrate the new technology has a direct impact on their willingness to use the tool (Sargent et al., 2012). The amount of training required to enhance people's skills and learn how to embrace and use new technologies could be a barrier to technology adoption. In certain cases, experienced personnel are eager to adopt innovative ideas, but the cost of acquiring the skills needed to successfully implement these solutions creates barriers to adoption (Abrahamse et al., 2011). Furthermore, people's ability to apply innovation increases their desire to use a technology and speeds up the adoption process (Sargent et al., 2012; Adriaanse et al., 2010). Another aspect that influences consumers' perceptions of technical advantage and ease of use is their prior experience with the technology (Talukder, 2012). Previous studies have shown that consumers' experiences with new technology might influence future adoption of that technology in both positive and negative ways (Venkatesh et al., 2000; Abrahamse et al., 2011).

Aside from the barriers described above, social factors have an impact on people's willingness to use new technologies. The amount to which members of a social group influence one another's adoption behavior is known as social influence. When a corporation adopts a beneficial new method, it's likely that the company will maintain the invention as a competitive advantage and not spread information (Welch et al., 2015). An effective support system and a general attitude to both invest in new technologies and give appropriate training to improve users' abilities are required for successful technology adoption in a business. As a result, top management support has a substantial impact on an organization's decision to transfer technology, as well as its users' willingness to adopt new technologies (Sargent et al., 2012; Abrahamse et al., 2011; Venkatesh et al., 2003). Although the technical components of technology application may be difficult for some users, previous research has revealed that organizational and cultural factors, rather than technical factors, are the most important factors in technology adoption.

2.6 Strategies for Mitigating Factors that Hinder Technology Adoption in the Construction Industry

Technology implementation and adoption are management-intensive activities that require strong commitment and will of the top management. In this regard, top management holds power to devise and implement strategies for overcoming barriers to technologies implementation in the construction sector. Discussed below are strategies for mitigating factors that hinder technology adoption in the construction industry.

2.6.1 Management Support

The support system in a construction firm can be shaped by coordination of senior managers, project managers, and training staff. The support system should be designed in a manner that it motivates employees for exploring and using new technology. Furthermore, employees should be offered adequate technical and organizational support. Hence, personal learning coupled with organizational support will encourage employees to interact with new technologies in an efficient manner.

2.6.2 Trainings and Learning

Research suggests that in order to inhibit barriers to technology implementation at the individual level, adequate training, technical support, and senior management support are inevitable (Thamhain, 2013; Smith & Love, 2004). Through personal training, employees shall develop a rudimentary understanding of basic technology concepts and usage. It should be noted that trainers have to maintain a fine balance between technical and personal training.

2.6.3 Change Management

Change management is a term that refers to the planning and assistance that is required when an organization undergoes a transformation. It offers a method for individuals, teams, and entire organizations to change their approach, attitude, position, and duties within a company. It may be used to aid in the reorganization or redefining of budget allocations, resource utilization, business processes, and the transition to/adoption of new technologies.

2.6.4 Implementation strategies toward new technologies

Because of the high amount of uncertainty involved with creative construction, many construction companies opt to use traditional construction procedures and materials (Motawa et al., 1999). Experimentation, iteration, and refining of activities are common in the implementation of construction innovation. Many aspects must be considered while deciding to adopt a new idea. Risks and uncertainties, as well as cost/benefit aspects, must all be examined.

2.6.5 Technologies Performance Metrics

Construction companies are under constant pressure to enhance their productivity and performance due to slow economic growth, fierce competition, and industry reorganization. At the project level, many research on performance measurement have been conducted. However, in recent years, there has been an increase in the demand for performance evaluation and management at the company level (Hany et al., 2013). In order to monitor technology deployment and effectiveness, it is necessary to set performance measures to govern the implementation of the technology in construction projects.

2.5.6 Evaluating Products Inefficiencies

Construction project management must actively pursue the most effective use of labor, materials, and equipment. Those in charge of cost control of constructed facilities should be concerned about increasing labor productivity on a regular basis. Organizations that fail to recognize the impact of various advances and fail to adapt to changing surroundings have been rightfully pushed out of the construction industry (Hendrickson, 2008).

2.7 Conceptual Framework

A conceptual framework is a framework that the researcher believes best explains the natural course of the subject under investigation (Camp, 2001). The conceptual framework describes the relationship between a study's primary concepts from a statistical standpoint. It is organized in a logical order to aid in the creation of a picture or visual representation of how the ideas in a study are related to one another (Grant & Osanloo, 2014). The framework allows the researcher to specify and clarify topics inside the study's problem (Luse et al., 2012). The conceptual framework benefits a research in several ways: it aids the researcher in identifying and constructing his or her worldview on the phenomenon under investigation (Grant & Osanloo, 2014); it highlights the reasons why a research topic is worth studying, the researcher's assumptions, the scholars with whom s/he agrees and disagrees, and how s/he conceptually grounds his or her approach and it emphasizes the reasons why (Evans, 2007). Conceptual frameworks, according to Ravitch and Carl (2016), are generative frameworks that represent the thinking throughout the entire research process. The independent, intermediate, and dependent factors are outlined in the conceptual framework for this study. Technology context, organizational context, environmental context, and individual context are the independent factors, whereas technology adoption in the Tanzanian construction sector is the dependent variable. Technological and knowledge fusion, training, awareness and acceptance, and technology deployment are the intermediate variables. The independent variables are crucial in establishing the framework for the construction industry's adoption of emerging technologies. Technology context aims at establishing the views/ perceptions of users of emerging technologies, the usability of such technology, need for research and development in construction enterprises as well as assessing the existing technology infrastructure necessary for supporting new technologies.

The organizational context focuses on the company. It is evident that decision making for adopting new technologies is contingent on management support in various organizations. This is done depending on resource availability, organization size and characteristics. The environmental context is aimed at evaluating the influences of technology adoption, market competitiveness, compliance to standards, readiness of the market to adopt new technologies and innovation requirements necessary for technology infrastructure. It covers the environment necessary to enable the integration of new technologies. Finally, the individual context focuses on the person using the technology. It consists of personality traits, skill level, culture and learning. Users of new technologies require knowledge and training to facilitate change management and ease of use. Intermediate variables focus on the process of integrating new technologies. It comprises of technology fusion, which is a process for integrating promising technologies across several disciplines - this is seen as an effective way to help construction enterprises adjust to the challenging environment in which they operate. Knowledge fusion, on the other hand, is an approach for improving an organization's ability to create information that was brought to the construction sector to dynamically transform implicit and explicit knowledge.

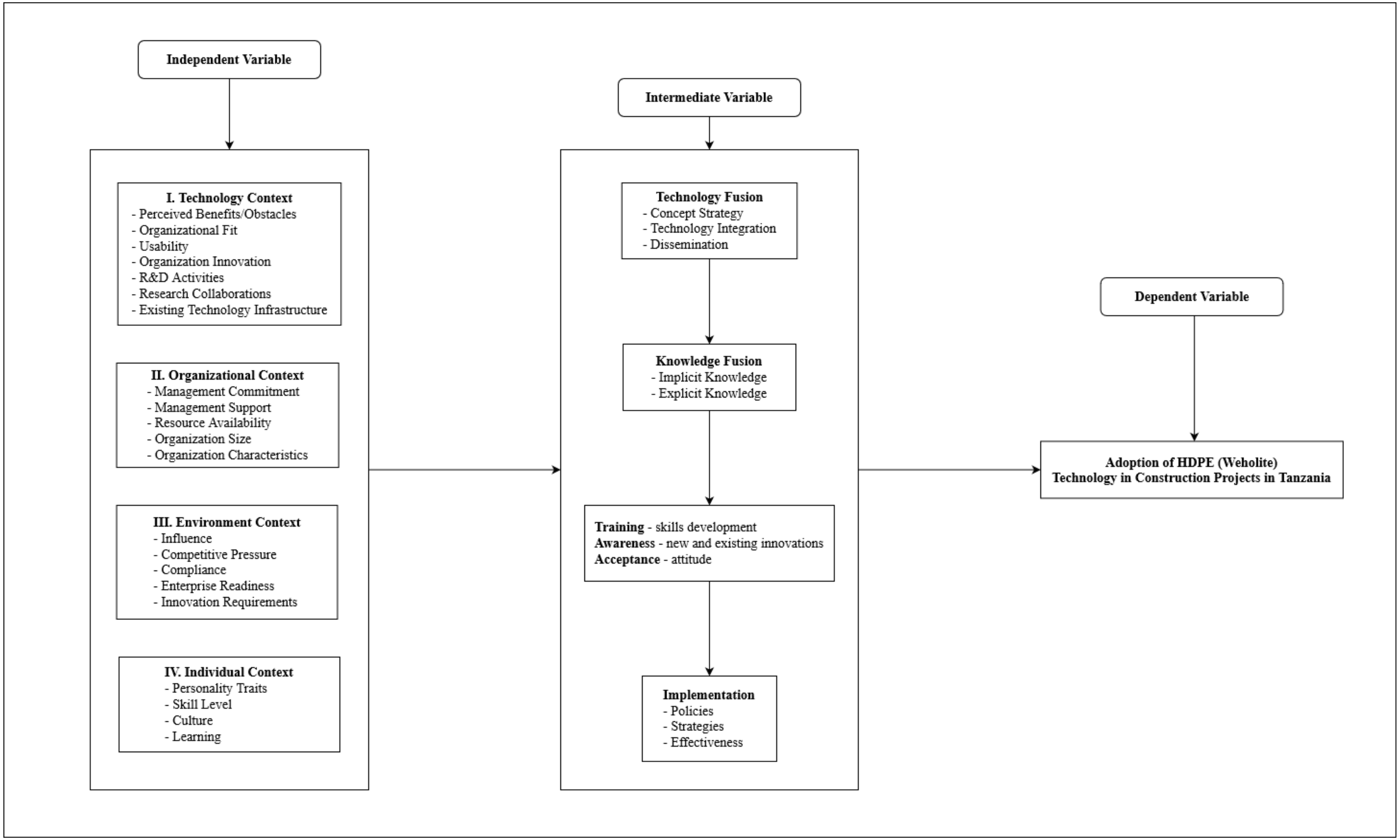


Figure 2.7: Conceptual Framework for the Research

2.8 Chapter Summary

This chapter discussed the overview of the construction industry and technology in the construction industry. Factors for technology adoption in the construction industry were reviewed to establish the drivers for technology adoption in the construction industry. Furthermore, a detailed review of high-density polyethylene, HDPE (Weholite) technology was done to establish performance characteristics, properties and benefits of the technology with the aim to understand it's application in construction. Moreover, barriers towards technology adoption in the construction industry are discussed with mitigation and finally, a conceptual framework of the study is explained and illustrated.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Introduction

The approach that was employed in the study is presented in this chapter. The research method, research design, study area, study population, sample design, sampling technique, data collection methods and instruments, and reasons for the methodologies utilized are all covered here. According to Kothari (2004), research methodology is a method for solving a research topic in a methodical manner. It can be thought of as a science that studies how scientific research is carried out. Furthermore, aspects of research validity, reliability and ethical considerations have been presented altogether with detailed discussion on the establishment of framework for HDPE (Weholite) technology adoption.

3.2 Research Method

The nature of this study is both quantitative and qualitative. The quantitative method has been used in this research in collecting data that was quantifiable and used for analysis through questionnaires whereas qualitative method was done for framework validation using interviews. Qualitative research method enables for the collection of detailed information and the investigation of "real-world" behavior and aids in the deep comprehension of subject matter; some topics are better examined utilizing a qualitative technique, which tries to deepen the researcher's understanding of what is going on (Golafshani, 2003). The current research objectives and questions need a detailed understanding of the user’s perception in utilizing/specifying HDPE (Weholite) technology in construction projects and strategies towards increased utilization and specification of the same thus the researcher needs to explore participants views. The quantitative method was appropriate for this study because it involves testing theories and correlating relationships using quantifiable data (Harkiolakis, 2017; Kumar, 2019). Furthermore, using a mixed method approach that included both qualitative and quantitative data was effective because both categories of data were required to answer the study questions (Brannen, 2017; Bryman & Bell, 2015). The qualitative method used is descriptive (Bryman & Bell, 2015), and it aids a researcher in gaining a better knowledge of how a problem in the actual world occurs (Burkholder et al., 2016; Robson & McCartan, 2016).

3.3 Research Design

This can be defined as a framework of research methods chosen by a researcher to undertake the study. The research design is the conceptual framework for conducting research; it serves as the blueprint for data collecting, measurement, and analysis. The research was conducted using a descriptive research approach. Descriptive research comprises a variety of surveys and fact-finding inquiries. The most important goal of descriptive research is to describe the current state of circumstances. The descriptive research design was chosen for the study because it is an appropriate choice when the goal of the research is to identify characteristics, frequencies, trends, or categories. It was also appropriate for evaluating the use of HDPE (Weholite) technology, the influence of performance characteristics, barriers, and strategies for increased adoption of the technology in construction. Any form of research has a structure called a research design It is the glue that connects the aspects of a research project together, and it should be structured to show how all of the primary parts of the research project work together to address the central research question (Kombo & Tromp, 2006).

The following steps were used for the research design of the study. Firstly, formulating research problem which was accompanied with background, main objective and specifics objectives. Specific objectives were used to formulate research questions. Secondly, literature review was done based on what have been written with regard to emerging technologies in the construction industry; evaluation of barriers and strategies of adopting technologies in the construction industry and an extensive evaluation of HDPE (Weholite) technology – properties, merits and uses. Thirdly, questionnaires were formulated and used as design instrument for data collection. These questionnaires were formulated from literature review, personal experience and previous studies done on the adoption of new technologies in construction (Nnaji et al., 2018; Hatoum et al., 2020; Khudzari et al., 2021; Waziri et al., 2017; Meng et al., 2018). Questionnaires were distributed to local civil/structural consultants and contractors who have utilized the technology. This was followed by data analysis by the use of Microsoft Excel software and SPSS version 23. The data was analyzed for the aim of interpretation, presentation of data and drawing conclusion. Finally, conclusion and recommendations are provided using analyzed data and areas for further research are given by the researcher.

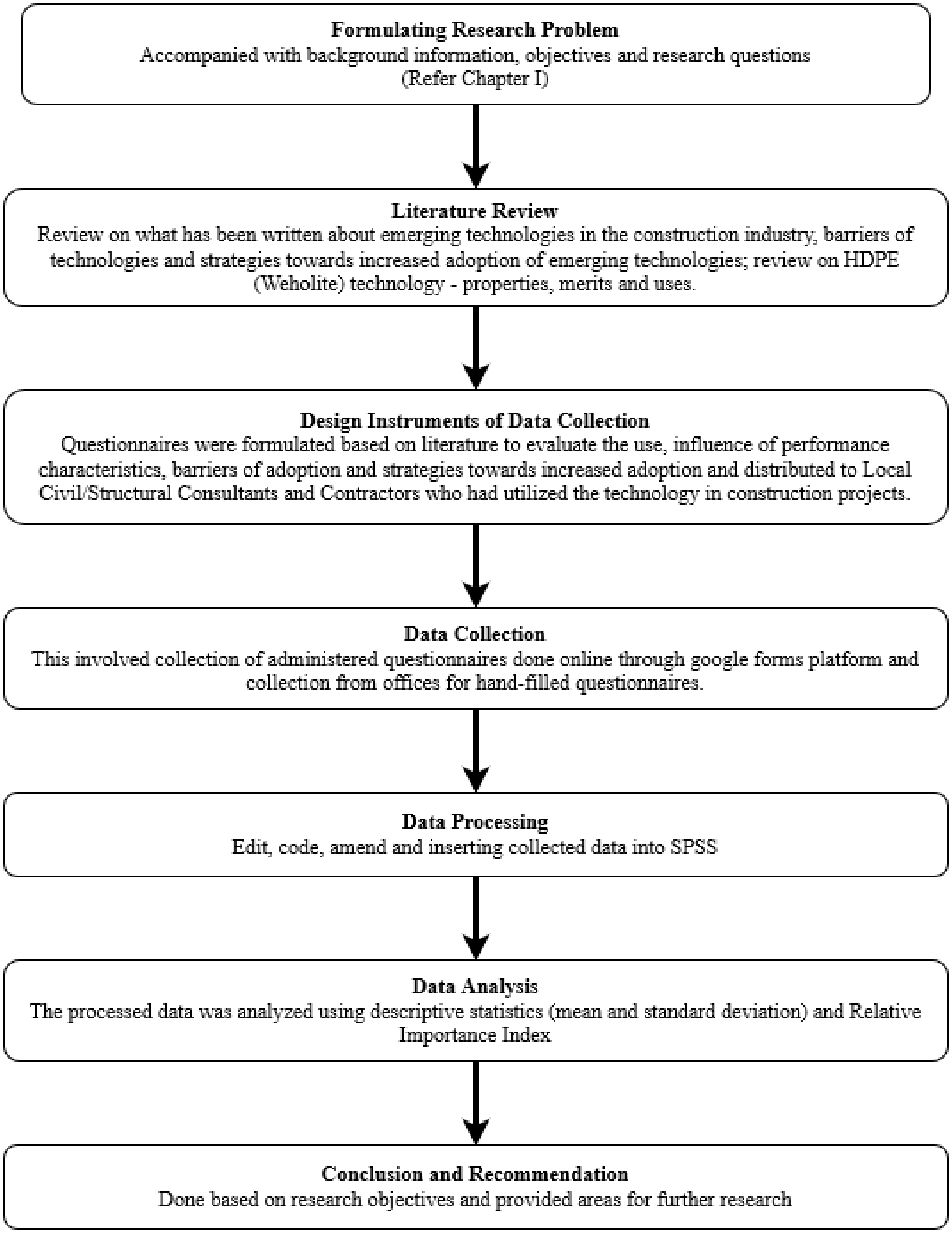


Figure 3.1: Framework of the research

3.4 Study Area and Population

This research was conducted in Dar es Salaam, Tanzania which has been define as the study area. The researched aimed at obtaining data from two population groups – local civil/structural consulting firms and local contractors who have used HDPE (Weholite) technology in construction projects. The subject of the study was consulting engineers in these groups aimed to assess their knowledge on the use of the technology as well as contracting engineers aimed at evaluating their experience in utilizing the technology in construction projects in Tanzania. The total number of local civil/structural consulting firms obtained from the Engineer's Registration Board is 129 whereas data obtained from the manufacturer of HDPE (Weholite) in Tanzania – PLASCO Limited lists 49 contractors who have utilized the technology to date. The construction project engineer in Tanzania was the unit of analysis, which in a study can be a person, event, entity, or other unit of analysis (Noor, 2008). In this case, a construction project engineer is defined as a construction professional who is responsible for all technical and engineering aspects for planning, designing, construction and management of a project.

Table 3.1 Population distribution

Firm/Company	**Population**
Civil/Structural Consultant	129
Contractor	49
Total	178

Source: Authors' calculations based on ERB (2020) and PLASCO (2021)

3.5 Sample Size and Sampling Technique

A sampling design is a method for acquiring a sample from a population with a high degree of certainty. It could relate to the method through which the researcher selects objects for the sample. The sample size and sample design were chosen before data was collected, and the sample design may also specify the number of items to be included in the sample (Kothari, 2004).

3.5.1 Sample Size

A sample size is a subset of a sampling unit from a population (sampling units that do not make up the entire set of sampling units that has been specified as the population). This specifies the total number of population items from which data should be gathered. This study's proposed sample size was determined using a statistical method. The goal of this strategy is to have an acceptable, dependable, and representative sample size in order to get reliable results. Thus, according to Kothari (2004), the following formula was used to compute sample size:

$$n = \left[\frac{z^2pqN}{[e^2(N-1) + Z^2pq]}\right]$$

Where n is the proposed sample size; Z is the confidence level (the study used confidence level at 90%0; p is the degree of variability (given as p = 50%); q = (1 – p); e is the margin of error (the study assumed a 10%) and N is the population size.

Table 3.2 Sample size for each category of respondents

Firms/Company	**Population**	**Proposed Sample**
Civil/Structural Consultants	129	45
Contractors	49	29
Total	178	74

Source: Data Survey, 2021

Table 3.2 shows that a total sample of 74 was obtained from the population of 178. This sample size consists of 29 contractors and of 45 civil/structural local consulting firms in Dar es Salaam. The data employed in sampling are confidence level (Z) - 90% (1.645) and sampling error (e) - 10%.

Calculation:

i. Civil/Structural Consultants

$$n = \left[\frac{[(1.645)^2 x\ (0.5)\ x\ (1-0.5) x\ 129]}{[(0.1)^2\ x\ (129-1)] + [(1.645)^2\ x\ (0.5)\ x\ (1-0.5)]}\right]$$

= 45

ii. Contractors

$$n = \left[\frac{[(1.645)^2 x\ (0.5)\ x\ (1-0.5) x\ 49]}{[(0.1)^2\ x\ (49-1)] + [(1.645)^2\ x\ (0.5)\ x\ (1-0.5)]}\right]$$

= 29

3.5.2 Sampling Technique

The study is based on a sample of the population from which inferences about the behavior of the entire population were derived. Because testing the entire population is impracticable and impractical, sampling design is employed to gather objects that reflect the entire population.
(Kothari, 2004; Kombo and Tromp, 2006). The two types of sampling designs are probability and non-probability. The probability sampling method is based on a random selection method in which respondents are chosen at random from the population. Each unit has an equal chance of being chosen. In contrast to probability sampling, non-probability sampling is a sampling approach in which not all individuals of the population have an equal chance of participating in the study. For this study, a simple random sampling technique has been adopted for contractors and a snowball sampling for consultants. Random sampling, also known as chance sampling (Kothari, 2004), is a probability sampling method in which each and every item in the population has an equal chance of being included in the sample and each of the possible samples, whereas snowball sampling is a non-random sampling method in which a few cases are used to encourage other cases to participate in the study, thereby increasing sample size. Both probability and non-probability sampling techniques were used in this study. Foremost, a simple random sampling was applied to the contractor population who were involved in construction projects that have utilized HDPE (Weholite) technology. Secondly, snowball sampling as used to draw sample from the consultant's population. The researcher purposely selected consulting firms as these are engaged in the project design and material specification and have the technical knowhow and their views are imperative for the study data. Contractors were selected by the virtue of their first-hand experience in utilizing HDPE (Weholite) technology.

3.6 Data Collection Methods

Data collection is a technique for gathering information in order to serve or prove a fact. The gathering of data aided in the clarification of the facts. Data collection can be divided into two types: primary data and secondary data, both of which are used to gain information. Data collection tools involved designing questionnaires for contractors – having utilized the technology already, as well as consultants – to ascertain their knowledge, experience and perceptions on the technology. This research utilized both primary (using questionnaires) and secondary methods of data collection.

3.6.1 Questionnaire Survey

This primary form of data collecting is one of the best since it can be applied to a large number of respondents in a short period of time (Kothari, 2004). This method of data collecting was used to get the opinions and impressions of the respondents. Self-administered semi-structured questionnaires were prepared and delivered to both contractors and local civil/structural consultants in Dar es Salaam, Tanzania with the advantage of being flexible because they contain both open and closed-ended questions for gathering comprehensive information to ensure relevancy and consistency of information gathered to evaluate the user experience and performance characteristics of HDPE (Weholite) and to assess barriers and implementation strategies for adoption in construction projects . A total of 74 questionnaires were issued local civil/structural consulting firms and contractors that have undertaken projects specified with HDPE (Weholite). Questionnaire survey was adopted since the method is confidential, saves a lot of time and limits the ability to get unwanted information. Questionnaires were hand delivered and distributed using google forms to facilitate a greater reach of respondents.

Both questionnaires issued to contractors and consultants were made up of four sections whereby each section was aimed at collecting respondent's views whilst reflecting on the research objectives. For contractors, the questions were such as to evaluate their experience in adopting the technology whereas for consultants, the questions were geared toward obtaining their perceptions and views on the technology; tabulated questionnaire sections required the respondent to select a choice on a 5-point Likert scale.

Section I comprised of three questions on demographic details and identification information of the respondent – name of the company, position in the company and years of experience in the construction industry.

Section II had 5 questions aimed at assessing the use of HDPE (Weholite) technology in construction projects by assessing the familiarity, awareness, type and number of projects that utilized the technology and user experience and likelihood of adopting the technology.

Section III of the questionnaire comprised of two tables. The first table contained a list of performance characteristics of HDPE (Weholite) against ranking. This section aimed at assessing the influence of performance characteristics of HDPE (Weholite) in construction projects in Tanzania; the second table contained a list of benefits derived from the use of the technology and a ranking to evaluate the impact of such benefits on the overall project performance and objectives.

Section IV of the questionnaire contained two tables. The barriers of adopting the technology were tabulated in the first table and the respondent was required to give his/her opinion by selecting a ranking. The second table lists the strategies that can be implemented toward increased adoption of the technology and aimed at assessing the need and integration of the technology in the Tanzanian construction industry. The final question was open ended and this was included to capture respondents' views on the approaches/strategies that could be adopted to facilitate the use/specification of the technology in construction projects.

3.6.2 Secondary Data Collection

This method of data collection is referred to data which has previously been gathered and analyzed by another researcher whose source provides reliable, adequate and suitable reference. This study used both published and unpublished data on identifying and assessing the adoption of HDPE (Weholite) in construction projects which included journals, product technical manuals, websites, reports prepared by research scholars, unpublished and published dissertations. Secondary sources of data allow broadening of the research by providing background information, analysis and perspectives on research elements. This was adopted in the research to foremost obtain the performance characteristics of HDPE (Weholite) technology, to extract the merits derived from the use of the technology in construction projects; to obtain literature on barriers faced by emerging technologies and derive strategies towards increased adoption of the technology. This data was essential in evaluating the influence of emerging technologies in the construction industry.

3.7 Data Analysis Method

Analysis is a collaborative process that examines responses to see if they are relevant to each research question. Data analysis is categorized into two groups which are descriptive and inferential analysis. Statistical inference utilizes the data obtained on the targeted population under study to draw conclusions concerning the population from which the sample was obtained (Quinlan, 2011). Inferential statistics use measurements from a sample to compare and make generalizations about the study population which helps to suggest explanations for a situation or phenomenon (Kuhar, 2010). It allows a researcher to draw conclusions based on extrapolations and is in that way fundamentally different from descriptive statistics which summarizes data that has been measured (Chin & Lee, 2008). Descriptive statistics was used to determine the factors with the highest influence in the tabulated questions as well as evaluating the response percentages to show distribution of variables in each category. Inferential approach was employed to derive the meaning of the data as a generalization of the whole population i.e., responses generated from the data were inferred to represent the characteristics of the population – both consultants and contractors. Inferential statistics was used to make reliable conclusion from the data. Furthermore, descriptive statistics such as: frequencies, mean, mode were calculated to generate graphs for representation of data since the research generated masses of data which had to be summarized so that the reader may have an idea of the typical values of what was referred to. The analyzed data was presented in the form of tables, graphs and charts to ease understanding.

The raw data collected from the questionnaires was carefully structured in a way that made analysis easier. Editing, coding, tabulation, data reduction, data distinction, and explanation were all part of the data cleaning process. Completed questionnaires were double-checked for accuracy and consistency. The information gathered from the questionnaire's closed ended items was given numerical values (coded), double-checked for errors, and then analyzed using the Statistical Package for the Social Sciences (SPSS) version 23. By assigning proper coding to all of the responses to open-ended questions, the responses were classified and categorized. The collected data was analyzed by calculation of mean scores for each factor by using the formula below. Afterwards ranking of the tabulated items pertaining to users influence, benefits of HDPE (Weholite) technology, barriers to adoption of the technology and strategies towards increased adoption was respectively established based on mean values of each factor. The mean score was calculated as follows:

$$Mean\ Score = \left[\frac{\Sigma\ \mathrm{FxS}}{N}\right]$$

Where: F = Frequency of response for each score, S is the given score (i.e., 5, 4, 3, 2, 1) and N is the total number of respondents.

3.8 Validity and Reliability

When choosing a survey instrument, reliability and validity are critical considerations. The term "reliability" refers to the instrument's capacity to produce consistent findings across several trials. The amount to which the instrument measures what it was supposed to measure is referred to as validity. Validity refers to how well the information gathered is relevant to the investigation (Ghauri & Gronhaug, 2005).

3.8.1 Test of Validity

The extent to which data gathering methods accurately measure what they were designed to assess is referred to as validity (Saunders et al., 2007). The validity of the data in this study was ensured via a pilot study. The questionnaires were given to potential responders in order to assess their comprehension, perception, and interpretation of the questions. By conducting a pilot study on 15 randomly selected construction experts in Dar es Salaam, the researcher validated the questionnaires' validity. The researcher purposefully chose the location for the pilot trial to save expenses. The questionnaires were then improved for data collection afterwards. Furthermore, a Cronbach's alpha test was conducted for the questionnaires yielding a value of 0.92. The acceptance value for an alpha value is 0.70 and above. This shows that the data collected from the questionnaires is highly reliable.

Table 3.3 Cronbach's Alpha Value for Research Questionnaire

Cronbach's Alpha	Number of items
0.92	92

Source: Data Survey, 2021

3.8.2 Test of Reliability

The degree to which research instruments give/yield consistency/the same results or data when delivered repeatedly is referred to as instrument reliability (Mugenda & Mugenda 2003). It refers to the degree to which a data collection technique or procedure will produce consistent results (Saunders et al., 2007). To ensure that the data collected is consistent and dependable, the researcher conducted a test-retest. This was accomplished by giving respondents questionnaires twice, with a two-week gap between each test. This was further analyzed using Spearman's rank correlation coefficient and gave values ranging from 0.86 to 0.91. The questionnaires' internal consistency and test-retest reliability were determined to be satisfactory. Following that, the researcher modified the questionnaires whenever there appeared to be inconsistencies in the pre-test results to guarantee that the correct data was collected. Furthermore, respondents' construction industry experience was considered as a measure of data reliability for the study.

3.9 Development of Framework for HDPE (Weholite) Technology Adoption

Part of the aim of this research was to develop a framework for HDPE (Weholite) technology adoption in the Tanzania construction industry. This framework was developed by using the analysis of data obtained from the first, second and third research objectives with additional knowledge of other concepts and theories from literature on other technology adoption models and frameworks. The following methods have been used in the development of the framework for the study.

3.9.1 Sampling and Sample Size for Validation

Validation is critical, especially when an instrument is being constructed to measure a construct in the context of the concepts being examined (Polit & Beck, 2006), because untested data may need to be revised in a future study if it is not validated (Coombes, 2001). To validate the suggested framework, the study used "expert validation." An expert review is a procedure in which experts are asked for their ideas, suggestions, feedback, or remarks. A total of six (6) experts – four (4) from the construction industry (2 contractors and 2 consultants) were invited to participate in framework validation for the study. The respondents from contractors and consultants were obtained from the study sample based on their experience in the construction industry, knowledge and familiarity with Weholite technology. The remaining two (2) respondents were sought from the manufacturer of the technology in Tanzania – PLASCO LTD. These had adequate knowledge on the technology as well as its use in construction. Respondents were called and asked to participate in a follow-up interview to validate the suggested framework of adoption of HDPE (Weholite) technology; consent forms were sought and subsequently signed by the experts and the interview was carried out for respective respondents. Table 4.14 below further indicates that the respondents had sufficient knowledge and expertise to aid in validation the framework for integration into construction.

Experts from the construction industry were selected randomly from the research sample of respondents respectively generally considering their years of experience in construction and adequate knowledge on HDPE (Weholite) technology and use in construction projects. Respondents from the manufacture were also selected randomly based on their expertise in construction and application of the technology in construction projects. Respondents' selection was done to provide maximum variation in respondents' opinions on the proposed framework and to create variability in responses in respective professions through structured interviews with open and close-ended questions. Interview questions were structured with regard to the proposed framework of adoption and derivatives from research questionnaire. Responses from experts were used to map project concepts and refine the framework. Results from experts were triangulated based on existing models and technology adoption frameworks, literature review and user evaluation. This was done to ensure credibility of the results (Cohen & Manion, 2000; Altrichter et al., 2008).

3.9.2 Methods of Data Collection for Validation

For the purpose of validation of the proposed framework for adoption of HDPE (Weholite) technology in construction projects in Tanzania, the researcher used interviews for data collection since the framework required discussion on its usability and applicability in the industry and the interview was divided into general questions – which established respondents background, experience and professional background. After respondents were asked general background questions, the proposed framework was presented and explained to them, and then they were asked to comment/suggest on the applicability of the framework in integrating the technology in construction. This was done to obtain information from respondents on the process of integration of the technology in construction projects. Responses were recorded, discussed and used to improve the proposed research framework.

3.9.3 Data Analysis for Validation

Data analysis for framework validation was based on mean score comparison and correlation analysis for data obtained from both consultants and contractors. Furthermore, data obtained from the interviews was used to refine the proposed framework.

3.9.3.1 Analysis for Mean Score Comparison

This was done to analyze the mean scores of the respondents with a view of establishing a mean rating point for each group of respondents. The mean score values were categorized into three groups – 4.00 to 5.00 for high mean scores, 3.00 to 3.99 for medium/ moderate mean scores and 1.00 to 2.99 for low mean scores. This was useful in analysis of responses from both contractors and consultants with a view to establish general response from both groups. The mean score value comparison table has been modified from (Jongo et al., 2019) as shown below.

Table 3.4 Mean Score Comparison

S/N	Mean Score (MS)	Ranking	Color Code
1	$4.00 \leq MS \leq 5.00$	High Mean Score	
2	$3.00 \leq MS \leq 3.99$	Medium/Moderate Mean Score	
3	$1.00 \leq MS \leq 2.99$	Low Mean Score	

Source: Modified from Jongo et al., 2019

3.9.3.2 Correlation Analysis (Spearman's Rank Correlation)

In order to improve the research findings' reliability and validity, the opinions of consultants and contractors were compared in order for the researcher to determine a correlation between respondent groups. The comparison entails matching the sets of ranks derived from consultant and contractor responses. Naoum (2003) recommends using the spearman correlation test to determine whether the researcher's findings are significant or due to chance. The following equation is used to calculate the spearman rank correlation coefficient (rho):

$$\text{Rho} = 1 - \frac{6 * \text{Sum of } di^2}{N (N^2-1)}$$

Where di is the difference in ranking between each pair of factors and N is the number of factors/observations

In the test of significance of the computed value of Spearman rank correlation coefficient, the null hypothesis (H_O) assumes that no significant correlation exists between the two sets of ranks of n attributes computed from the ratings of consultants and contractors. In statistical terms, this implies that the computed rho (P) is less than the critical rho (P_α) from the table of critical values of rho (P_α). In the study, an alternative hypothesis (H_A) is chosen for one-tailed test which assumes that a significant and positive correlation exist. At 5% level of significance, both H_O and H_A could be stated statistically as follows:

H_O: $P < P\alpha$ (i.e. no significant correlation exits); H_A: $P \geq P\alpha$ (i.e. significant and positive correlation exits

3.10 Ethical Considerations

Ethical concerns are misgivings and dilemmas that develop regarding the best way to conduct research while also avoiding creating stressful situations for the research topics (Schurink 2003). This study was carried out with a clear knowledge of the responsibility to be sensitive to and respectful of research participants' basic human rights, as well as to follow general ethical code. The research was carried out in order to assure the following: everyone involved in the research was made aware of the research's goal and objectives and it was made clear that participation in this study was voluntary, and that if the participant had a cause to withdraw at any point, they had the freedom to do so; their anonymity was preserved at all times, and all information was handled as confidential.

3.11 Chapter Summary

The research design, sample methodology, data collecting, and tools that were used to conduct this study are all described in this chapter. The chapter goes on to explain the data analysis approach employed and why it was thought to be appropriate for this study - how the data is presented and evaluated in order to answer the research objectives. An establishment of a framework for HDPE (Weholite) technology is also discussed.

CHAPTER FOUR
DATA COLLECTION AND ANALYSIS

4.1 Introduction

This chapter discusses the data gathered during the field survey. It considers the complete process of gathering data, presenting it, and analyzing the results. The main focus of this chapter is on the research's predetermined specific objectives. This study's data was gathered through questionnaires that were given to respondents in a particular manner in order to answer the research questions. The analysis and discussion in this chapter is divided into the following: responses from the questionnaires, use of high-density polyethylene, HDPE (Weholite) technology, influence of performance characteristics of, HDPE (Weholite) technology, barriers towards the adoption of HDPE (Weholite) technology and strategies towards increased adoption of HDPE (Weholite) technology in construction project in Tanzania.

4.2 Response Rate

The study targeted two groups (local contractors and civil/structural consulting firms) of respondents in order to acquire the desired information (contractors and engineering consulting firms). Out of 74 questionnaires distributed manually and online, 57 questionnaires were returned (contractors – 23 and consulting engineering firms – 34) within the specified time frame equivalent to 77.3% of the total response (contractors – 79.3% and civil/structural consulting firms – 75.6%). A response rate of 77.3% is sufficient as supported by Mugenda (2003) who recommended that a response rate of 70% and above is adequate. The response rate is further illustrated in Table 4.1 below.

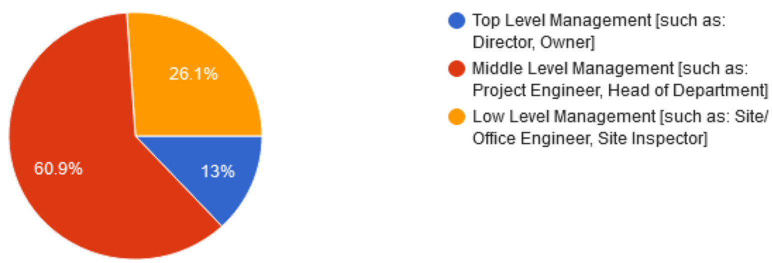
Table 4.1: Response Rate

Respondent	Distributed	Returned	Percentage of Success
Civil/Structural Consultant	45	34	75.6%
Contractors	29	23	79.3%
TOTAL	74	57	77.3%

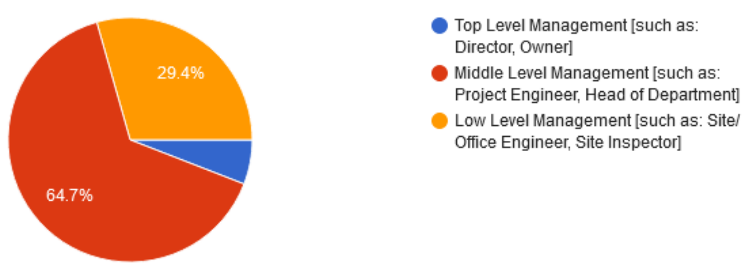
Source: Data Survey, 2021

4.3 Position of respondents in the organization/construction firm

A question was asked to determine the position of the respondents in the construction firm in order to understand the perspective of workers on the research issue under study. Furthermore, it is evident that decision making for adoption of technology in organizations is contingent upon management support/approval hence evaluating this response was key in establishing the level of decision making in technology adoption and implementation. The respondents' position on the contractors were 6 under lower-level management, 14 under middle-level management and 3 respondents from the top-level management. For consulting firms, the respondents' positions were 10 under lower-level management, 22 under middle-level management and 2 respondents from the top-level management. This is illustrated in Figure 4.1 (a) and (b).



(a). Responses from Contractors on Position in the Organization/Construction Firm



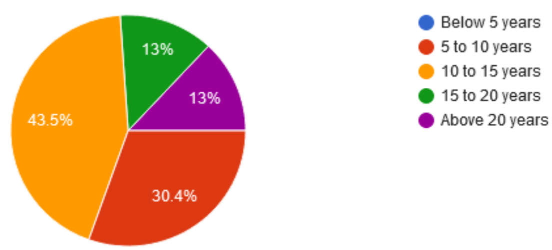
(b). Responses from Consultants on Position in the Organization/Construction Firm

Figure 4.1 (a) & (b): Responses from Contractors and Consultants on Position in the Organization/Construction Firm

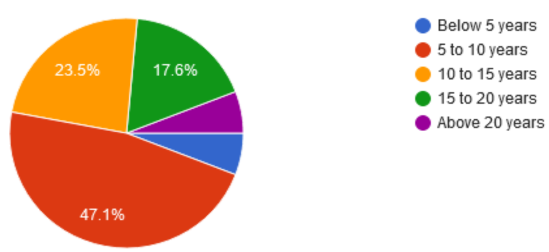
Source: Data Survey, 2021

4.4 Experience of respondents in the organization/construction firm

In order to determine the credibility of the data acquired, it is critical to examine the respondents' experiences. As a result, it is assumed that if the respondents have sufficient experience, their responses will be more reliable. Out of 57 questionnaires returned, 43.5% had experience between 10 to 15 years followed by respondents with experience between 5 to 10 years who scored 30.4% while those with experience between 15 to 20 years and above 20 years each scored 13% for contractors whereas for consultants, 47.1% had experience between 5 to 10 years followed by respondents with experience between 10 to 15 years who scored 23.5% while those with experience between 15 to 20 years scored 17.6% and those above 20 years scored 5.9%. This implies that the majority of the respondents had sufficient expertise in the construction industry, making their responses reliable and lending credibility to the survey results. The response rate illustrating experience of respondents is shown in Figure 4.2 (a) and (b).



(a). Responses from Contractors on Experience in the Organization/Construction Firm



(b). Responses from Contractors on Experience in the Organization/Construction Firm

Figure 4.2 (a) & (b): Responses from Contractors and Consultants on Experience in the Organization/Construction Firm

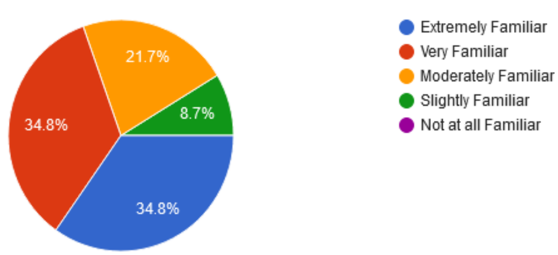
Source: Data Survey, 2021

4.5 Results and Discussion on the use of HDPE (Weholite) in Construction Projects in Tanzania

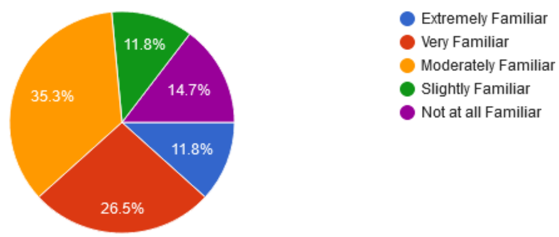
In responding to the first objective of this research which aimed at evaluating the use of high-density polyethylene, HDPE (Weholite) technology in construction projects, six questions were structured in the questionnaires to establish respondents familiarity with the technology; awareness of the technology; to determine the number of projects that the respondent has utilized/specified the technology for use; the type of project that utilized the technology; to evaluate user experience in terms of 'effectiveness' of the technology and to determine the likelihood of utilizing/adopting or specifying the technology for future projects. The results for these questions are discussed hereunder.

4.5.1 Familiarity with HDPE (Weholite) Technology

Respondents were asked to rank their familiarity with HDPE (Weholite) technology in order to establish the level of knowledge of the technology amongst construction professionals in the construction industry. This was paramount because it assisted in establishing technology reception in the construction industry. For contractors, a score of 34.8% was obtained for both very and extreme familiarity with the technology, with 21.7% moderately familiar and 8.7% of respondents scored being slightly familiar with the technology. Consultants on the other hand recorded a score of 35.3% for being moderately familiar altogether with a 26.5% for being very familiar with the technology, 11.8% for slightly familiarity and 14.7% were not familiar with the technology at all. These results show that for both contractors and consultants, familiarity with the technology is well above average. This is illustrated in Figure 4.3 (a) and (b).



(a). Responses from Contractors on Familiarity with HDPE (Weholite) Technology



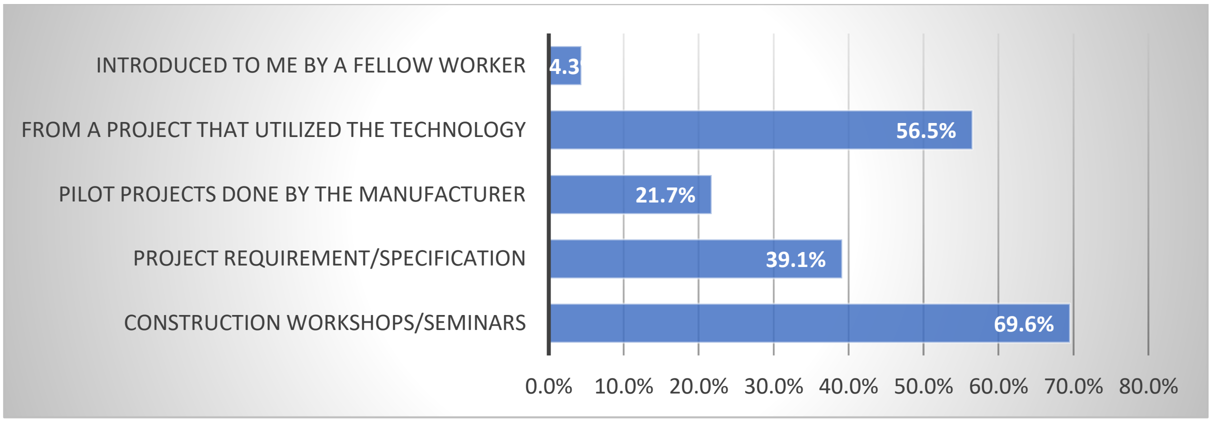
(b). Responses from Consultants on Familiarity with HDPE (Weholite) Technology

Figure 4.3 (a) & (b): Responses from Contractors and Consultants on Familiarity with HDPE (Weholite) Technology

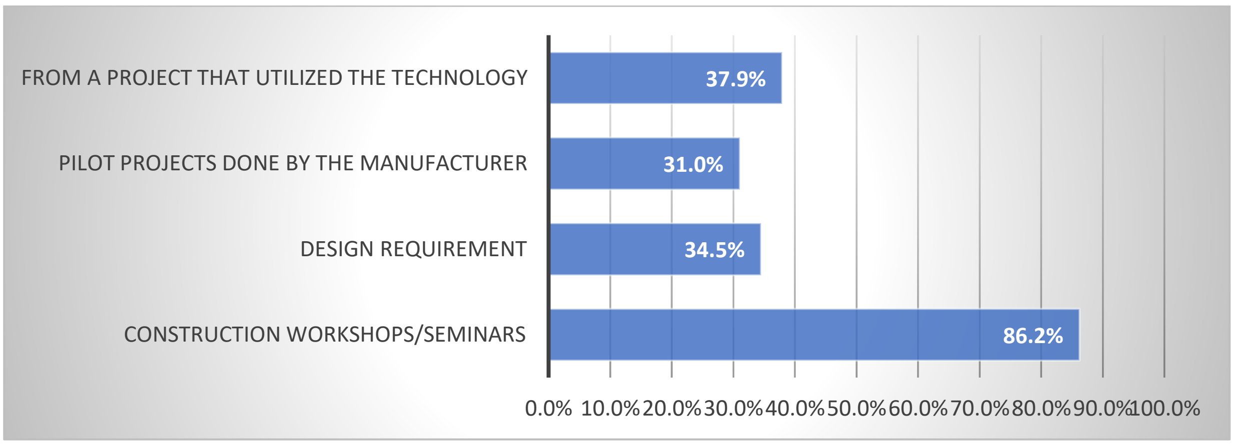
Source: Data Survey, 2021

4.5.2 Awareness of HDPE (Weholite) Technology

In this question, respondents were asked on how they first became aware of the technology. It is notable that the technology was first introduced in Tanzania in 2018. This question was aimed at determining the media through which a construction professional is influenced in adopting a technology which foremost starts with being made aware in order to facilitate ease of integration and implementation in design or construction works. Construction workshops/seminars scored 69.6%; awareness through a project that had utilized a similar technology followed at 56.5% with project requirement/specification at 39.1%, pilot projects 21.7% and introduction from a fellow colleague captured one response thereby recording a score of 4.3% for contractors whereas consultants recorded scores were: 86.2% for construction workshops/seminars, 37.9% for projects that utilized similar technology, 34.5% for design requirements and 31% for pilot projects. Higher scores for construction workshops and similar projects that had utilized the technology show that there is a relative high awareness of the technology. Moreover, pilot projects have also proven to be create positive impact in creating awareness. This is illustrated in Figure 4.4 (a) and (b).



(a). Responses from Contractors on Initial Awareness of HDPE (Weholite) Technology



(b). Responses from Consultants on Initial Awareness of HDPE (Weholite) Technology

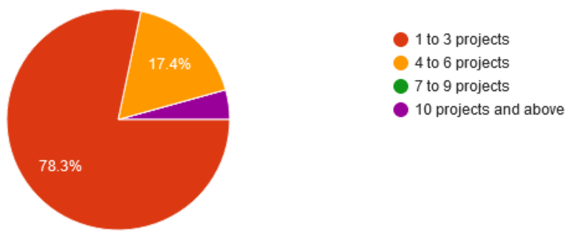
Figure 4.4 (a) & (b): Responses from Contractors and Consultants on Initial Awareness of HDPE (Weholite) Technology

Source: Data Survey, 2021

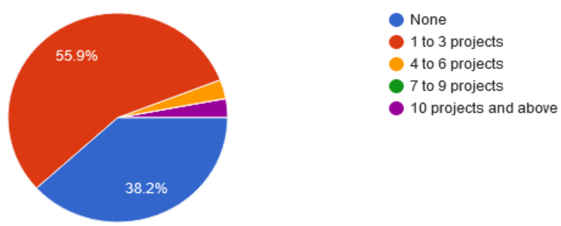
4.5.3 Number of projects utilizing/specified the Use of HDPE (Weholite) Technology

Respondents were asked to indicate the number projects in which they have utilized the technology (for contractors) and designed/specified the use of the technology for consultants. This was necessary in determining the extent of integration of HDPE (Weholite) in construction projects in Tanzania. Contractors scored 78.3% for 1 to 3 projects, 17.4% for 4 to 6 projects whereas consultants scored 55.9% for 1 to 3 projects, 2.9% each for 4 to 6 projects and above. However, a 38.2% was recorded for ‘none’ indicating that the specification for the use of the technology in construction projects in still below average. Overall responses suggest a good knowledge on the technology for the contractors that have utilized it as well as a well above average for consultants with a greater need in integration of the technology in design aspects.

Figure 4.5 below show the summary of results.



(a). Responses from Contractors on the Number of Projects for which they have used HDPE (Weholite) Technology



(b). Responses from Consultants on the Number of Projects for which they have specified the Use of HDPE (Weholite) Technology

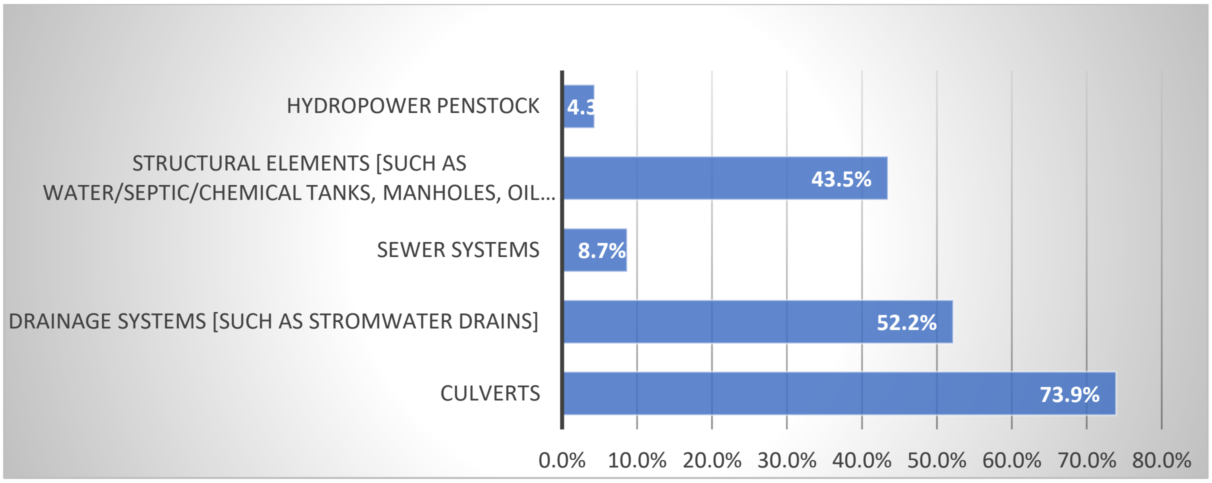
Figure 4.5 (a) & (b): Number of Projects Utilizing/Specified the Use of HDPE (Weholite) Technology

Source: Data Survey, 2021

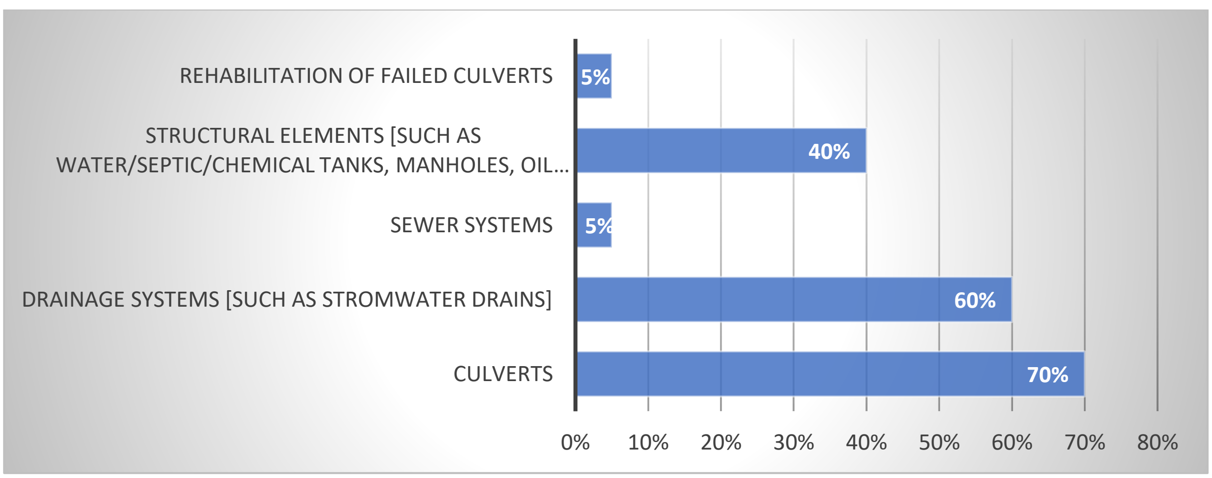
4.5.4 Type of Application for the Use of HDPE (Weholite) Technology

Respondents were asked to evaluate the type of projects for which they have utilized/specified the design of the technology to determine the nature of projects and overall technology reception with regard to type of project and application. Overall ranking for contractors recorded 73.9% for culverts, 52.5% for drainage systems and 43.5% for structural components; consultants scored culverts at 70% followed by 60% for drainage systems with 40% for structural components. Notably other applications for which the technology has been used for were identified by respondents as: sewer systems, hydropower penstock and rehabilitation of failed culverts.

Responses indicate a greater usage of the technology in drainage systems and culverts for construction. With HDPE (Weholite) technology, the applications are limitless and with applications focused greatly on two types of projects as indicated from responses (i.e., culverts and drainage systems), there is a greater need for adoption of the technology in other types of projects. This is illustrated in Figure 4.6 (a) and (b).



(a). Responses from Contractors on Project Applications for which they have used HDPE (Weholite) Technology



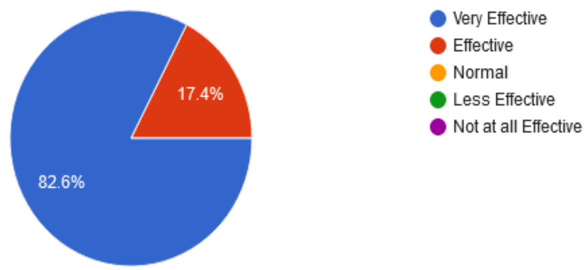
(b). Responses from Contractors on Project Applications for which they have specified HDPE (Weholite) Technology

Figure 4.6 (a) & (b): Responses from Contractors and Consultants on Project Applications using HDPE (Weholite) Technology

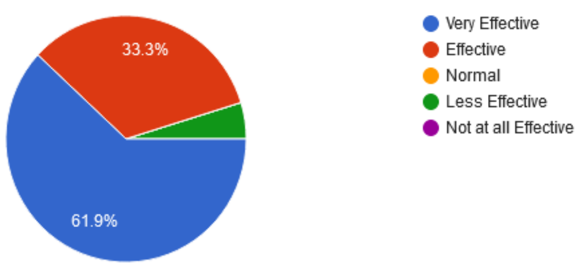
Source: Data Survey, 2021

4.5.5 Effectiveness of HDPE (Weholite) Technology as reported by Respondents

In evaluating the use of high-density polyethylene, HDPE (Weholite) technology in construction projects, respondents were asked to rate the overall effectiveness of the technology in relation to their experiences in projects that the technology has been used/specified by them. Contractors reported an 86% very effective and 17.4% effective whereas consultants recorded 61.9% very effective, 33.3% effective and 4.8% less effective. Evaluation of responses indicate that the technology is indeed effective. This is illustrated in Figure 4.7 (a) and (b).



(a). Responses from Contractors on the Effectiveness of HDPE (Weholite) Technology



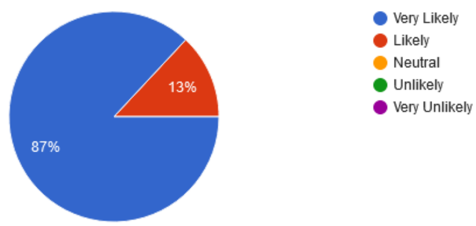
(b). Responses from Consultants on the Effectiveness of HDPE (Weholite) Technology

Figure 4.7 (a) & (b): Effectiveness of HDPE (Weholite) Technology as experienced by respondents

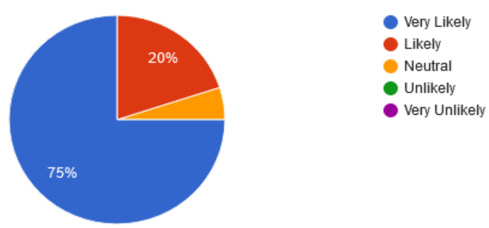
Source: Data Survey, 2021

4.5.6 Adoption/Use of HDPE (Weholite) Technology for Future Construction Projects

Technology adoption goes hand in hand with the possibility for future usage of the same provided the technology has met and/or exceeded user needs. Hence respondents were assessed to determine the likelihood of utilizing or specifying the technology for future projects based on the experiences obtained from their knowledge and implementation of the technology in construction projects. The likelihood of adoption the technology for future projects foremost provides feedback that the technology was successful and the possibility for continued usage of the same. Respondents from contractor's indicated an 87% likelihood of using the technology whereas consultants indicated a 75% likelihood. This shows that the integration of the technology has steered construction professionals towards the possibility of adoption of HDPE (Weholite) technology for future construction projects. Responses are illustrated in Figure 4.8.



(a). Responses from Contractors on the Likelihood of Adopting HDPE (Weholite) Technology for Future Construction Projects



(b). Responses from Consultants on the Likelihood of Adopting HDPE (Weholite) Technology for Future Construction Projects

Figure 4.8: Projections on the Use of HDPE (Weholite) Technology for Future Construction Projects

Source: Survey Data (2021)

4.6 Results and Discussion on the Influence of Performance Characteristics in Adoption of Use and Benefits Derived from the Use of HDPE (Weholite) Technology in Construction Projects in Tanzania

In responding to the second objective of this research which aimed at examining the influence of performance characteristics of HDPE (Weholite) technology in construction projects, two questions were structured in tabular form. The first question aimed at evaluating the influence of the performance characteristics of the technology in construction projects in order to ascertain what properties were most important in the decision to use the technology. The second question aimed at evaluating benefits achieved using the technology in construction by requiring respondents to indicate the impact level of such benefits in projects that they opted to adopt the technology or for the design/specification of the technology. Both questions were evaluated on a five-point Likert scale (1 – Very Low/Not at All to 5 – Very High/Very Much) in order to gauge respondents' views with respect to using/specifying the technology in construction projects. The data was extracted through online questionnaire and opened by using spreadsheet which helped in shifting the data to SPSS for analysis and summarization of the findings obtained.

4.6.1 Influence of Performance Characteristics of HDPE (Weholite) Technology

Respondents were given a list of performance characteristics of HDPE (Weholite) technology and asked to rank them to establish the major characteristics that influenced their decisions to opt using/specifying the technology in construction projects. The summary of findings from contractors' perspective is indicated in Table 4.2 whereas Table 4.3 represents consultants' perspective. From the contractor perspective, characteristics such as durability, light weight, superior quality, flexibility and reliability are seen as major characteristics that influenced utilizing the technology with mean scores 4.96, 4.83, 4.78, 4.70 and 4.70 respectively whereas consultants ranked durability, material service life, superior hydraulic properties, abrasion resistance and superior quality with mean scores 4.76, 4.56, 4.50, 4.41 and 4.41 respectively. Generally, it is seen that the quality, durability, hydraulic properties and material service life are the similar factors recorded by both contractors and consultants as the most influencing performance characteristics of the technology for use in construction projects. Other factors which had little/minimal influence on the adoption of the technology by both contractors and consultants are micro-organisms resistance, wide temperature range, UV resistant which were ranked low in both cases.

Table 4.2: Responses from Contractors' Perspective on the Influence of Performance Characteristics of HDPE (Weholite) Technology in Construction Projects

S/N	Performance Characteristics of HDPE (Weholite) Technology		Contractors' Response on Influence Level						
			VM 5	SW 4	N 3	SN 2	NA 1		
		TR	%	%	%	%	%	MS	Rank
1	Light Weight	23	82.6	17.4	0	0	0	4.83	2
2	Durability	23	95.7	4.3	0	0	0	4.96	1
3	Reliability	23	69.6	30.4	0	0	0	4.70	4
4	Superior Hydraulic Properties	23	82.6	17.4	0	0	0	4.83	2
5	Flexibility	23	69.6	30.4	0	0	0	4.70	4
6	Watertight Mechanical Joints	23	34.8	34.8	30.4	0	0	4.04	10
7	Fusion Welded Joints	23	43.5	30.4	26.1	0	0	4.17	8
8	Lower Carbon Footprint	23	39.1	34.8	26.1	0	0	4.13	9
9	Material Service Life	23	82.6	17.4	0	0	0	4.83	2
10	Chemical Resistance	23	47.8	43.5	8.7	0	0	4.39	6
11	Abrasion Resistance	23	43.5	56.5	0	0	0	4.43	5
12	Impact Resistance	23	34.8	65.2	0	0	0	4.35	7
13	Corrosion Resistance	23	43.5	47.8	8.7	0	0	4.35	7
14	Superior Quality	23	78.3	21.7	0	0	0	4.78	3
15	Non-Toxic	23	30.4	43.5	26.1	0	0	4.04	10
16	Environmental Deterioration Resistant	23	39.1	26.1	34.8	0	0	4.04	10
17	UV Resistant	23	34.8	21.7	43.5	0	0	3.91	11
18	Physiologically Safe	23	39.1	60.9	0	0	0	4.39	6
19	Micro-organisms Resistance	23	21.7	30.4	47.8	0	0	3.74	12
20	Wide temperature range sustainability (-40°C to 45°C for long term use; 80°C for short term use)	23	8.7	47.8	43.5	0	0	3.65	13

Source: Data Survey, 2021

Table 4.3: Responses form Consultants' Perspective on the Influence of Performance Characteristics of HDPE (Weholite) Technology in Construction Projects

S/N	Performance Characteristics of HDPE (Weholite) Technology		Consultants' Response on Influence Level						
			VM 5	SW 4	N 3	SN 2	NA 1		
		TR	%	%	%	%	%	MS	Rank
1	Light Weight	34	35.3	50.0	14.7	0	0	4.21	5
2	Durability	34	76.5	23.5	0	0	0	4.76	1
3	Reliability	34	20.6	61.8	17.6	0	0	4.03	7
4	Superior Hydraulic Properties	34	55.9	38.2	5.9	0	0	4.50	3
5	Flexibility	34	11.8	44.1	44.1	0	0	3.68	11
6	Watertight Mechanical Joints	34	5.9	44.1	44.1	5.9	0	3.50	15
7	Fusion Welded Joints	34	2.9	61.8	29.4	5.9	0	3.62	13
8	Lower Carbon Footprint	34	14.7	32.4	50.0	2.9	0	3.59	14
9	Material Service Life	34	61.8	35.3	0	2.9	0	4.56	2
10	Chemical Resistance	34	17.6	52.9	23.5	5.9	0	3.82	10
11	Abrasion Resistance	34	41.2	58.8	0	0	0	4.41	4
12	Impact Resistance	34	35.3	50.0	14.7	0	0	4.21	5
13	Corrosion Resistance	34	35.3	47.1	17.6	0	0	4.18	6
14	Superior Quality	34	44.1	52.9	2.9	0	0	4.41	4
15	Non-Toxic	34	14.7	67.6	17.6	0	0	3.97	8
16	Environmental Deterioration Resistant	34	5.9	52.9	41.2	0	0	3.65	12
17	UV Resistant	34	2.9	44.1	50.0	2.9	0	3.47	16
18	Physiologically Safe	34	2.9	79.4	17.6	0	0	3.85	9
19	Micro-organisms Resistance	34	0	41.2	55.9	2.9	0	3.38	18
20	Wide temperature range sustainability (-40°C to 45°C for long term use; 80°C for short term use)	34	0	47.1	50.0	2.9	0	3.44	17

Source: Data Survey, 2021

4.6.2 Benefits Achieved from the use of HDPE (Weholite) Technology

Contractors were asked to assess the impact of benefits resulting from the use of technology in construction projects they had completed, whilst consultants were asked to assess how such benefits are important when choosing materials for construction. This was done to see how such benefits would affect project performance and goals. The summary of findings from contractors' perspective is indicated in Table 4.4 whereas Table 4.5 represents consultants' perspective. Contractors ranked reduction in installation time, overall reduction in project labour costs, reduction in work program, availability of customized pipe lengths and eliminates regular system maintenance with mean scores 4.83, 4.78, 4.74, 4.74 and 4.70; consultants on the other hand ranked reduction in installation time, very low maintenance costs (after project completion), overall reduction in project labour costs, increases project efficiency and easiness of transport and handling with mean scores 4.68, 4.62, 4.59, 4.59 and 4.56. Factors such as cost savings achieved during project rehabilitation through product recycling, wide selection of fittings meeting standard or challenging needs, eliminates system infiltration and availability and easiness of repair were found have less impact on the adoption of the technology in construction projects for both contractors and consultants. Furthermore, most benefits were ranked higher for both consultants and contractors indicating that the use of the technology has a 'high' impact on project performance.

Table 4.4: Responses from Contractors' Perspective on the impact of benefits achieved by using HDPE (Weholite) Technology in Construction Projects

S/N	Benefits Achieve by using HDPE (Weholite) Technology in Construction Projects		Contractors' Response on Impact Level						
			VH 5	HI 4	M 3	LO 2	VL 1		
		TR	%	%	%	%	%	MS	Rank
1	Easiness of transport and handling	23	65.2	30.4	4.3	0	0	4.61	6
2	Reduction in installation time	23	87.0	8.7	4.3	0	0	4.83	1
3	Overall reduction in project labour costs	23	87.0	4.3	8.7	0	0	4.78	2
4	Availability of large diameters (up to 3 meters)	23	30.4	43.5	21.7	0	0	3.96	15
5	Availability of customized pipe lengths	23	73.9	26.1	0	0	0	4.74	3
6	Tailored designs based on project requirements	23	65.2	34.8	0	0	0	4.65	5
7	Product versatility	23	52.2	47.8	0	0	0	4.52	7
8	Availability and easiness of repair	23	21.7	47.8	21.7	8.7	0	3.83	16
9	Project value engineering is achieved using Weholite	23	52.2	34.8	13.0	0	0	4.39	10
10	Very low maintenance costs (after project completion)	23	69.6	4.3	17.4	8.7	0	4.35	11
11	Reliable joints (welded)	23	47.8	21.7	30.4	0	0	4.17	12
12	Cost savings achieved during project rehabilitation through product recycling	23	30.4	4.3	26.1	26.1	13.0	3.13	18
13	Wide selection of fittings meeting standard or challenging needs	23	26.1	13.0	43.5	17.4	0	3.48	17
14	Ability to withstand ground movements	23	39.1	60.9	0	0	0	4.39	10

15	Excellent quality of workmanship	23	47.8	47.8	4.3	0	0	4.43	9
16	Ability to fabricate custom-made structural elements (such as manholes, valve chambers, storage tanks)	23	43.5	52.2	0	4.3	0	4.35	11
17	Optimized flow rates due to smooth internal surface	23	65.2	26.1	8.7	0	0	4.57	6
18	Materials saving in installation (backfill)	23	47.8	26.1	13.0	13.0	0	4.09	13
19	Eliminates system infiltration	23	26.1	56.5	13.0	4.3	0	4.04	14
20	Eliminates regular system maintenance	23	73.7	21.7	4.3	0	0	4.70	4
21	Availability of various pipe stiffness classes (2, 4 and 8Kn/m²)	23	60.9	39.1	0	0	0	4.61	6
22	Reduction in work program and facilitating ease of construction	23	73.9	26.1	0	0	0	4.74	3
23	Expected longevity of product technology [100 years buried; 60 years above ground]	23	43.5	56.5	0	0	0	4.43	9
24	Promotes off-site fabrication	23	52.2	43.5	4.3	0	0	4.48	8
25	Reduces waster hence value generation	23	69.6	26.1	4.3	0	0	4.65	5
26	Increases project efficiency	23	60.9	39.1	0	0	0	4.61	6

Source: Data Survey, 2021

Table 4.5: Responses from Consultants' Perspective on the impact of benefits achieved by using HDPE (Weholite) Technology in Construction Projects

S/N	Benefits Achieve by using HDPE (Weholite) Technology in Construction Projects		Consultants' Response on Impact Level						
			VH 5	HI 4	M 3	LO 2	VL 1		
		TR	%	%	%	%	%	MS	Rank
1	Easiness of transport and handling	34	64.7	26.5	8.8	0	0	4.56	4
2	Reduction in installation time	34	70.6	26.5	2.9	0	0	4.68	1
3	Overall reduction in project labour costs	34	61.8	35.3	2.9	0	0	4.59	3
4	Availability of large diameters (up to 3 meters)	34	26.5	44.1	26.5	2.9	0	3.94	17
5	Availability of customized pipe lengths	34	32.4	55.9	8.8	2.9	0	4.18	13
6	Tailored designs based on project requirements	34	29.4	67.6	2.9	0	0	4.26	11
7	Product versatility	34	8.8	70.6	20.6	0	0	3.88	18
8	Availability and easiness of repair	34	17.6	50.0	32.4	0	0	3.85	19

9	Project value engineering is achieved using Weholite	34	29.4	67.6	2.9	0	0	4.26	11
10	Very low maintenance costs (after project completion)	34	64.7	32.4	2.9	0	0	4.62	2
11	Reliable joints (welded)	34	17.6	52.9	29.4	0	0	3.88	18
12	Cost savings achieved during project rehabilitation through product recycling	34	2.9	8.8	38.2	47.1	2.9	2.62	22
13	Wide selection of fittings meeting standard or challenging needs	34	0	35.3	58.8	5.9	0	3.29	21
14	Ability to withstand ground movements	34	14.7	85.3	0	0	0	4.15	14
15	Excellent quality of workmanship	34	20.6	58.8	20.6	0	0	4.00	15
16	Ability to fabricate custom-made structural elements (such as manholes, valve chambers, storage tanks)	34	50.0	50.0	0	0	0	4.50	6
17	Optimized flow rates due to smooth internal surface	34	44.1	52.9	2.9	0	0	4.41	7
18	Materials saving in installation (backfill)	34	14.7	67.6	17.6	0	0	3.97	16
19	Eliminates system infiltration	34	5.9	64.7	29.4	0	0	3.76	20
20	Eliminates regular system maintenance	34	38.2	47.1	14.7	0	0	4.24	12
21	Availability of various pipe stiffness classes (2, 4 and 8Kn/m^2)	34	11.8	73.5	14.7	0	0	3.97	16
22	Reduction in work program and facilitating ease of construction	34	35.3	64.7	0	0	0	4.35	8
23	Expected longevity of product technology [100 years buried; 60 years above ground]	34	52.9	47.1	0	0	0	4.53	5
24	Promotes off-site fabrication	34	35.3	58.8	5.9	0	0	4.29	10
25	Reduces waster hence value generation	34	32.4	67.6	0	0	0	4.32	9
26	Increases project efficiency	34	58.8	41.2	0	0	0	4.59	3

Source: Data Survey, 2021

4.7 Results and Discussion on the Barriers Towards the Adoption of HDPE (Weholite) Technology in Construction Projects in Tanzania

Respondents were asked to assess the barriers towards adoption of the technology in Tanzania with a view to investigate the reasons and causes that hinder/slow adoption in the construction industry. Responses from contractors indicate major barriers such as insufficient incentives for adoption of emerging technologies in the construction industry, insufficient knowledge on Weholite as a construction material, little awareness of the technology and its applications, current construction industry culture inherently slows adoption of the technology, lack of R&D in the construction industry, inadequate knowledge on the design aspects of Weholite and resistance to the adoption of the technology with mean scores 4.35, 4.35, 4.17, 4.17, 4.17, 4.13 and 4.00 respectively. Responses from consultants indicated insufficient incentives for adoption of emerging technologies in the construction industry, insufficient knowledge on Weholite as a construction material, inadequate technology training to construction industry professionals and inadequate knowledge on the design aspects of Weholite with mean scores 4.56, 4.53, 4.44 and 4.38 respectively. This summary of findings is presented in Table 4.6 and 4.7 for contractors and consultants respectively.

Table 4.6: Responses from Contractors' Perspective on the Barriers towards adoption of HDPE (Weholite) Technology in Construction Projects

S/N	Barriers towards adoption of HDPE (Weholite) Technology in Construction Projects		Contractors' Response on Degree of Acceptance						
			SA 5	AG 4	N 3	DA 2	SD 1		
		TR	%	%	%	%	%	MS	Rank
1	There is little awareness of Weholite and its applications in Tanzania	23	47.8	34.8	4.3	13	0	4.17	2
2	The technology is relatively new	23	26.1	43.5	8.7	21.7	0	3.74	7
3	Insufficient performance characteristics data to draw from implemented projects	23	0	43.5	26.1	30.4	0	3.13	12
4	Insufficient knowledge on Weholite as a construction material	23	56.5	30.4	4.3	8.7	0	4.35	1
5	Insufficient support for emerging technologies in the construction industry	23	21.7	47.8	0	30.4	0	3.61	8
6	Insufficient financial investment/budget by potential users	23	4.3	52.2	26.1	17.4	0	3.43	10
7	Management hesitancy to adopt the technology	23	43.5	39.1	4.3	13.0	0	4.13	3
8	Current construction industry culture inherently slows adoption of Weholite	23	34.8	56.5	0	8.7	0	4.17	2
9	Inadequate technology training to construction industry professionals	23	8.7	78.3	0	13	0	3.83	6

10	Lack of R&D (research and development) in the construction industry	23	52.2	17.4	26.1	4.3	0	4.17	2
11	Unsatisfactory/bad experience in the use of emerging technologies in construction	23	0	26.1	39.1	34.8	0	2.91	13
12	Insufficient incentives for adoption of emerging technologies in the construction industry	23	43.5	47.8	8.7	0	0	4.35	1
13	Low access to latest technology in the construction industry	23	0	8.7	21.7	60.9	8.7	2.30	15
14	Fear of risks associated with adopting a new technology	23	0	69.6	26.1	4.3	0	3.65	9
15	Adaptability of Weholite to various constraining site conditions	23	0	26.1	30.4	39.1	4.3	2.78	14
16	Inadequate knowledge on the design aspects of Weholite	23	26.1	65.2	4.3	4.3	0	4.13	3
17	Resistance to the adoption of Weholite in the construction industry	23	13.0	78.3	4.3	4.3	0	4.00	4
18	Competitiveness against other products in the market	23	26.1	17.4	4.3	52.2	0	3.17	11
19	High cost of acquiring technical equipment	23	30.4	47.8	8.7	13.0	0	3.96	5
20	Insufficient demand of Weholite in the construction industry	23	0	0	4.3	60.9	34.8	1.70	17
21	Current technology is enough	23	0	0	4.3	34.8	60.9	1.43	18
22	Unclear benefits	23	0	21.7	8.7	26.1	43.5	2.09	16
23	Lack of technical Experts	23	0	21.7	8.7	47.8	21.7	2.30	15
24	Insufficient technology infrastructure	23	4.3	56.5	17.4	21.7	0	3.43	10
25	Time and cost of training	23	8.7	60.9	13.0	17.4	0	3.61	8

Source: Data Survey, 2021

Table 4.7: Responses from Consultants' Perspective on the Barriers towards adoption of HDPE (Weholite) Technology in Construction Projects

S/N	Barriers towards adoption of HDPE (Weholite) Technology in Construction Projects		Consultants' Response on Degree of Acceptance						
			SA 5	AG 4	N 3	DA 2	SD 1		
		TR	%	%	%	%	%	MS	Rank
1	There is little awareness of Weholite and its applications in Tanzania	34	47.1	41.2	5.9	5.9	0	4.29	6
2	The technology is relatively new	34	8.8	67.6	14.7	8.8	0	3.76	12
3	Insufficient performance characteristics data to draw from implemented projects	34	5.9	32.4	44.1	11.8	5.9	3.21	15
4	Insufficient knowledge on Weholite as a construction material	34	58.8	35.3	5.9	0	0	4.53	2
5	Insufficient support for emerging technologies in the construction industry	34	11.8	76.5	2.9	8.8	0	3.91	8
6	Insufficient financial investment/budget by potential users	34	8.8	61.8	23.5	5.9	0	3.74	13
7	Management hesitancy to adopt the technology	34	23.5	67.6	5.9	2.9	0	4.12	6
8	Current construction industry culture inherently slows adoption of Weholite	34	35.3	61.8	2.9	0	0	4.32	5
9	Inadequate technology training to construction industry professionals	34	47.1	50.0	2.9	0	0	4.44	3
10	Lack of R&D (research and development) in the construction industry	34	17.6	70.6	8.8	2.9	0	4.03	7
11	Unsatisfactory/bad experience in the use of emerging technologies in construction	34	0	32.4	55.9	8.8	2.9	3.18	16
12	Insufficient incentives for adoption of emerging technologies in the construction industry	34	64.7	26.5	8.8	0	0	4.56	1
13	Low access to latest technology in the construction industry	34	5.9	2.9	5.9	70.6	14.7	2.15	21
14	Fear of risks associated with adopting a new technology	34	2.9	58.8	32.4	5.9	0	3.59	14
15	Adaptability of Weholite to various constraining site conditions	34	0	14.7	38.2	44.1	2.9	2.65	19

16	Inadequate knowledge on the design aspects of Weholite	34	41.2	55.9	2.9	0	0	4.38	4
17	Resistance to the adoption of Weholite in the construction industry	34	2.9	88.2	2.9	5.9	0	3.88	9
18	Competitiveness against other products in the market	34	8.8	29.4	17.6	29.4	14.7	2.88	17
19	High cost of acquiring technical equipment	34	2.9	79.4	14.7	2.9	0	3.82	11
20	Insufficient demand of Weholite in the construction industry	34	0	2.9	11.8	47.1	38.2	1.79	23
21	Current technology is enough	34	0	2.9	38.2	58.8	0	2.44	20
22	Unclear benefits	34	0	8.8	47.1	44.1	0	2.65	19
23	Lack of technical Experts	34	0	2.9	11.8	52.9	32.4	1.85	22
24	Insufficient technology infrastructure	34	26.5	41.2	23.5	8.8	0	3.85	10
25	Time and cost of training	34	0	20.6	35.3	35.3	9	2.68	18

Source: Data Survey, 2021

4.8 Results and Discussion on the Strategies Toward increased Adoption of HDPE (Weholite) Technology in Construction Projects in Tanzania

The research aimed at assessing strategies that can be used to influence the adoption of the technology in construction and hence respondents were asked to evaluate the same. From contractors' perspective – the use and application of Weholite technology should be taught and illustrated to construction industry professionals using various platforms, project consultants to specify Weholite as a material option where applicable, developing training approach prior to introduction of new technology, project concept design to factor in the usability/applicability of Weholite with mean scores 4.87, 4.83, 4.70 and 4.52 respectively. Consultants indicated the use and application of Weholite technology should be taught and illustrated to construction industry professionals using various platforms, developing training prior approach prior to introduction of new technology, project consultants to specify Weholite as a material option where applicable, project concept design to factor in the usability/applicability of Weholite and integrating technology deployment with change management with mean scores 4.82, 4.79, 4.74, 4.74 and 4.65 respectively. An overall response indicates that both contractors and consultants agree to most strategies with the aim to further increase the adoption in construction.

Table 4.8: Responses from Contractors' Perspective on strategies towards increased adoption of HDPE (Weholite) Technology in Construction Projects

S/N	Strategies towards increased adoption of HDPE (Weholite) Technology in Construction Projects		Contractors' Response on Degree of Acceptance						
			SA 5	AG 4	N 3	DA 2	SD 1		
		TR	%	%	%	%	%	MS	Rank
1	The use and application of Weholite technology should be taught and illustrated to construction industry professionals using various platforms	23	87.0	13.0	0	0	0	4.87	1
2	Project consultants to specify Weholite as a material option where applicable	23	82.6	17.4	0	0	0	4.83	2
3	Project concept design to factor in the usability/applicability of Weholite	23	56.5	39.1	4.3	0	0	4.52	4
4	Overcoming existing habits of resistance to adopt new technologies	23	21.7	73.9	4.3	0	0	4.17	9
5	Construction companies to design implementation strategies to new technologies	23	17.4	69.6	13.0	0	0	4.04	12
6	Incorporate R&D (research and development) for evaluating material properties for construction works	23	26.1	43.5	30.4	0	0	3.96	14
7	Develop performance metrics on the adoption of emerging technologies in the Tanzanian construction industry	23	34.8	65.2	0	0	0	4.35	7
8	Evaluation of challenges faced by users	23	8.7	82.6	8.7	0	0	4.00	13
9	Develop training approach prior to introduction of new technology	23	69.6	30.4	0	0	0	4.70	3
10	Integrate technology deployment with change management	23	47.8	47.8	4.3	0	0	4.43	5
11	Develop measurable success factors for monitoring technology adoption	23	47.8	43.5	8.7	0	0	4.39	6
12	Engage construction stakeholders to create awareness and readiness to adopt emerging technologies	23	30.4	65.2	4.3	0	0	4.26	8
13	Trainings and learnings	23	17.4	73.9	8.7	0	0	4.09	11
14	Evaluate product inefficiencies	23	8.7	30.4	21.7	39.1	0	3.09	15

15	Government support in the implementation of emerging technologies	23	39.1	34.8	26.1	0	0	4.13	10
16	Increasing capacity to provide whole-life value to client	23	30.4	65.2	4.3	0	0	4.26	8

Source: Data Survey, 2021

Table 4.9: Responses from Consultants' Perspective on strategies towards increased adoption of HDPE (Weholite) Technology in Construction Projects

S/N	Strategies towards increased adoption of HDPE (Weholite) Technology in Construction Projects		Consultants' Response on Degree of Acceptance						
			SA 5	AG 4	N 3	DA 2	SD 1		
		TR	%	%	%	%	%	MS	Rank
1	The use and application of Weholite technology should be taught and illustrated to construction industry professionals using various platforms	34	82.4	17.6	0	0	0	4.82	1
2	Project consultants to specify Weholite as a material option where applicable	34	76.5	20.6	2.9	0	0	4.74	3
3	Project concept design to factor in the usability/applicability of Weholite	34	73.5	26.5	0	0	0	4.74	3
4	Overcoming existing habits of resistance to adopt new technologies	34	17.6	70.6	11.8	0	0	4.06	13
5	Construction companies to design implementation strategies to new technologies	34	20.6	73.5	5.9	0	0	4.15	11
6	Incorporate R&D (research and development) for evaluating material properties for construction works	34	32.4	47.1	20.6	0	0	4.12	12
7	Develop performance metrics on the adoption of emerging technologies in the Tanzanian construction industry	34	38.2	61.8	0	0	0	4.38	8
8	Evaluation of challenges faced by users	34	23.5	70.6	5.9	0	0	4.18	10
9	Develop training approach prior to introduction of new technology	34	79.4	20.6	0	0	0	4.79	2
10	Integrate technology deployment with change management	34	67.6	29.4	2.9	0	0	4.65	4
11	Develop measurable success factors for monitoring technology adoption	34	35.3	64.7	0	0	0	4.35	9
12	Engage construction stakeholders to create awareness and readiness to adopt emerging technologies	34	44.1	55.9	0	0	0	4.44	7

13	Trainings and learnings	34	52.9	47.1	0	0	0	4.53	6
14	Evaluate product inefficiencies	34	20.6	58.8	17.6	2.9	0	3.97	14
15	Government support in the implementation of emerging technologies	34	17.6	61.8	20.6	0	0	3.97	14
16	Increasing capacity to provide whole-life value to client	34	61.8	35.3	2.9	0	0	4.59	5

Source: Data Survey, 2021

4.9 General Response

Further to evaluation respondents' data, the researcher sought to investigate the relationship between the responses obtained from the two groups under study i.e., contractors and consultants. This was done to ascertain the correlation between responses as well as determine the general response between the two groups with regard to research questions. Spearman's correlation coefficient was also determined using the rankings from responses.

4.9.1 Combined Response on the Influence of Performance Characteristics in Use of HDPE (Weholite) Technology in Construction Projects in Tanzania

Generally, results from contractors indicate that the influencing factors for opting to use the technology were greatly centered on product 'usability' (such as flexibility, light weight) implying that such properties influence their work program and execution of activities. Consultants on the other hand indicated greater influence on the 'material properties' (such as material service life, durability, abrasion resistance) of the technology implying that the design and specification in the intent to adopt the technology will rely on the performance characteristics of the material. Combined responses from both groups ranked durability, material service life, superior hydraulic properties, superior quality and light weight with higher mean scores 4.86, 4.69, 4.66, 4.60 and 4.52 respectively. According to results, 65% of the performance characteristics were ranked with high mean scores while 35% fell under medium/moderate scores showing that the performance characteristics of HDPE (Weholite) greatly influences its adoption in construction. Responses were further evaluated to determine correlation of ranking of performance characteristics between contractors and consultants using Spearman's rank correlation coefficient yielding a value of 0.80 indicating a significant correlation and that sound conclusions can be drawn from them. This shows a positive correlation of findings indicating that both groups agree that the performance characteristics of the technology greatly influences the adoption of the technology in construction projects. Results for combined responses from both contractors and consultants are presented in Table 4.10 below.

Table 4.10: Combined Response on the Influence of Performance Characteristics in Use of HDPE (Weholite) Technology in Construction Projects in Tanzania

S/N	Performance Characteristics of HDPE (Weholite) Technology	TR	Contractor's Response		Consultants' Response		Combined Response	
			MS	Rank	MS	Rank	MS	Rank
1	Light Weight	57	4.83	2	4.21	5	4.52	5
2	Durability	57	4.96	1	4.76	1	4.86	1
3	Reliability	57	4.70	4	4.03	7	4.36	7
4	Superior Hydraulic Properties	57	4.83	2	4.50	3	4.66	3
5	Flexibility	57	4.70	4	3.68	11	4.19	10
6	Watertight Mechanical Joints	57	4.04	10	3.50	15	3.77	17
7	Fusion Welded Joints	57	4.17	8	3.62	13	3.90	14
8	Lower Carbon Footprint	57	4.13	9	3.59	14	3.86	15
9	Material Service Life	57	4.83	2	4.56	2	4.69	2
10	Chemical Resistance	57	4.39	6	3.82	10	4.11	12
11	Abrasion Resistance	57	4.43	5	4.41	4	4.42	6
12	Impact Resistance	57	4.35	7	4.21	5	4.28	8
13	Corrosion Resistance	57	4.35	7	4.18	6	4.26	9
14	Superior Quality	57	4.78	3	4.41	4	4.60	4
15	Non-Toxic	57	4.04	10	3.97	8	4.01	13
16	Environmental Deterioration Resistant	57	4.04	10	3.65	12	3.85	16
17	UV Resistant	57	3.91	11	3.47	16	3.69	18
18	Physiologically Safe	57	4.39	6	3.85	9	4.12	11
19	Micro-organisms Resistance	57	3.74	12	3.38	18	3.56	19
20	Wide temperature range sustainability (-40°C to 45°C for long term use; 80°C for short term use)	57	3.65	13	3.44	17	3.55	20

Spearman rank correlation coefficient (Contractors versus Consultants) = 0.80

Critical rho = 0.38

Result: SC = Significantly Correlated at 5% alpha

Source: Data Survey, 2021

4.9.2 Combined Response on the Impact of Benefits Derived from the Use of HDPE (Weholite) Technology in Construction Projects in Tanzania

It is generally seen that both contractors and consultants scored similar benefits that aim at increasing project performance and meeting project goals – such as reduction in installation time and work program, overall reduction in labor costs and easiness of transport and handling. It is thus evident that the benefits derived from the use of HDPE (Weholite) technology greatly impact the project goals and integration of the technology in construction will ensure positive outcomes. This has been derived from the combined response of both groups in ranking of benefits derived from the use of the technology which shows similar ranking and agreement in factors. Responses from both groups indicate 77% impact of benefits ranked with high mean score, 15% ranked with moderate mean score and 8% ranked with low mean score. Responses were further evaluated to determine correlation of ranking of impact of benefits between contractors and consultants using Spearman's rank correlation coefficient yielding a value of 0.70 indicating a significant correlation. A value of 0.70 shows a positive correlation between the groups further signifying that both groups agree that the myriad of benefits derived from the use of the technology positively impact project objectives/goals. Results for combined responses from both contractors and consultants are shown in Table 4.11 below.

Table 4.11: Combined Response on the Impact of Benefits Derived from the Use of HDPE (Weholite) Technology in Construction Projects in Tanzania

S/N	Benefits Achieve by using HDPE (Weholite) Technology in Construction Projects	TR	Contractors' Response		Consultants' Response		Combined Response	
			MS	Rank	MS	Rank	MS	Rank
1	Easiness of transport and handling	57	4.61	6	4.56	4	4.58	4
2	Reduction in installation time	57	4.83	1	4.68	1	4.75	1
3	Overall reduction in project labour costs	57	4.78	2	4.59	3	4.69	2
4	Availability of large diameters (up to 3 meters)	57	3.96	15	3.94	17	3.95	18
5	Availability of customized pipe lengths	57	4.74	3	4.18	13	4.46	8
6	Tailored designs based on project requirements	57	4.65	5	4.26	11	4.46	8
7	Product versatility	57	4.52	7	3.88	18	4.20	16
8	Availability and easiness of repair	57	3.83	16	3.85	19	3.84	20
9	Project value engineering is achieved using Weholite	57	4.39	10	4.26	11	4.33	12

10	Very low maintenance costs (after project completion)	57	4.35	11	4.62	2	4.48	7
11	Reliable joints (welded)	57	4.17	12	3.88	18	4.03	17
12	Cost savings achieved during project rehabilitation through product recycling	57	3.13	18	2.62	22	2.87	22
13	Wide selection of fittings meeting standard or challenging needs	57	3.48	17	3.29	21	3.39	21
14	Ability to withstand ground movements	57	4.39	10	4.15	14	4.27	14
15	Excellent quality of workmanship	57	4.43	9	4.00	15	4.22	15
16	Ability to fabricate custom-made structural elements (such as manholes, valve chambers, storage tanks)	57	4.35	11	4.50	6	4.42	10
17	Optimized flow rates due to smooth internal surface	57	4.57	6	4.41	7	4.49	6
18	Materials saving in installation (backfill)	57	4.09	13	3.97	16	4.03	17
19	Eliminates system infiltration	57	4.04	14	3.76	20	3.90	19
20	Eliminates regular system maintenance	57	4.70	4	4.24	12	4.47	9
21	Availability of various pipe stiffness classes (2, 4 and 8Kn/m²)	57	4.61	6	3.97	16	4.29	13
22	Reduction in work program and facilitating ease of construction	57	4.74	3	4.35	8	4.55	5
23	Expected longevity of product technology [100 years buried; 60 years above ground]	57	4.43	9	4.53	5	4.48	7
24	Promotes off-site fabrication	57	4.48	8	4.29	10	4.39	11
25	Reduces waster hence value generation	57	4.65	5	4.32	9	4.49	6
26	Increases project efficiency	57	4.61	6	4.59	3	4.60	3

Spearman rank correlation coefficient (Contractors versus Consultants) for frequencies = 0.70

Critical rho = 0.331

Result: SC = Significantly Correlated at 5% alpha

Source: Data Survey,2021

4.9.3 Combined Response on the Barriers Towards the Adoption of HDPE (Weholite) Technology in Construction Projects in Tanzania

Overall responses indicate that apart from insufficient awareness and knowledge on the technology, other barriers such as construction industry culture, insufficient support for emerging technologies, lack of research and development and resistance to adoption are among the contributing factors that hinder adoption. Moreover, both sides have indicated that the benefits of the technology are clear; that the is indeed access to latest technology in the construction industry and sufficient technology infrastructure; that there is sufficient technical experts and clear benefits in adopting the technology and that the demand and competitiveness of Weholite are minor barriers to adoption of the technology in the Tanzanian construction industry. This shows an agreement in adopting the technology for construction with main focus in overcoming resistance to adoption of emerging technologies and trainings and learning to impart knowledge. Responses were further evaluated to determine correlation of ranking of barriers between contractors and consultants using Spearman's rank correlation coefficient yielding a value of 0.81 indicating a significant correlation. Results for combined responses from both contractors and consultants are shown in Table 4.12 below.

Table 4.12: Combined Response on the Barriers Towards the Adoption of HDPE (Weholite) Technology in Construction Projects in Tanzania

S/N	Barriers towards adoption of HDPE (Weholite) Technology in Construction Projects	TR	Contractors' Response		Consultants' Response		Combined Response	
			MS	Rank	MS	Rank	MS	Rank
1	There is little awareness of Weholite and its applications in Tanzania	57	4.17	2	4.29	6	4.23	5
2	The technology is relatively new	57	3.74	7	3.76	12	3.75	12
3	Insufficient performance characteristics data to draw from implemented projects	57	3.13	12	3.21	15	3.17	16
4	Insufficient knowledge on Weholite as a construction material	57	4.35	1	4.53	2	4.44	2
5	Insufficient support for emerging technologies in the construction industry	57	3.61	8	3.91	8	3.76	11
6	Insufficient financial investment/budget by potential users	57	3.43	10	3.74	13	3.59	15

7	Management hesitancy to adopt the technology	57	4.13	3	4.12	6	4.12	7
8	Current construction industry culture inherently slows adoption of Weholite	57	4.17	2	4.32	5	4.25	4
9	Inadequate technology training to construction industry professionals	57	3.83	6	4.44	3	4.13	6
10	Lack of R&D (research and development) in the construction industry	57	4.17	2	4.03	7	4.10	8
11	Unsatisfactory/bad experience in the use of emerging technologies in construction	57	2.91	13	3.18	16	3.04	8
12	Insufficient incentives for adoption of emerging technologies in the construction industry	57	4.35	1	4.56	1	4.45	1
13	Low access to latest technology in the construction industry	57	2.30	15	2.15	21	2.23	22
14	Fear of risks associated with adopting a new technology	57	3.65	9	3.59	14	3.62	14
15	Adaptability of Weholite to various constraining site conditions	57	2.78	14	2.65	19	2.71	20
16	Inadequate knowledge on the design aspects of Weholite	57	4.13	3	4.38	4	4.26	3
17	Resistance to the adoption of Weholite in the construction industry	57	4.00	4	3.88	9	3.94	9
18	Competitiveness against other products in the market	57	3.17	11	2.88	17	3.03	19
19	High cost of acquiring technical equipment	57	3.96	5	3.82	11	3.89	10
20	Insufficient demand of Weholite in the construction industry	57	1.70	17	1.79	23	1.74	25
21	Current technology is enough	57	1.43	18	2.44	20	1.94	24
22	Unclear benefits	57	2.09	16	2.65	19	2.37	21
23	Lack of technical Experts	57	2.30	15	1.85	22	2.08	23
24	Insufficient technology infrastructure	57	3.43	10	3.85	10	3.64	13
25	Time and cost of training	57	3.61	8	2.68	18	3.14	17

Spearman rank correlation coefficient (Contractors versus Consultants) for frequencies = 0.81

Critical rho = 0.337

Result: SC = Significantly Correlated at 5% alpha

Source: Data Survey, 2021

4.9.4 Combined Response on the Strategies Toward increased Adoption of HDPE (Weholite) Technology in Construction Projects in Tanzania

Combined response from both groups shows a need to develop methods that can be used to foster emerging technologies integration in the construction industry by developing training approach prior to introduction of new technology as well as providing trainings when implementing the technology in construction. Furthermore, change management, increasing capacity to provide whole-life value to clients and developing performance metrics on the adoption of emerging technologies in the construction industry have also been identified as a crucial strategies. It is notable that 94% of suggested strategies were ranked with high mean scores whereas only 6% was ranked with a moderate score. Responses were further evaluated to determine correlation of ranking of strategies toward increased adoption of the technology between contractors and consultants using Spearman's rank correlation coefficient yielding a value of 0.86 indicating a significant correlation. Results for combined responses from both contractors and consultants are shown in Table 4.13 below.

Table 4.13: Combined Response on the Strategies Toward increased Adoption of HDPE (Weholite) Technology in Construction Projects in Tanzania

S/N	Strategies towards increased adoption of HDPE (Weholite) Technology in Construction Projects	TR	Contractors' Response		Consultants' Response		Combined Response	
			MS	Rank	MS	Rank	MS	Rank
1	The use and application of Weholite technology should be taught and illustrated to construction industry professionals using various platforms	23	4.87	1	4.82	1	4.85	1
2	Project consultants to specify Weholite as a material option where applicable	23	4.83	2	4.74	3	4.78	2
3	Project concept design to factor in the usability/applicability of Weholite	23	4.52	4	4.74	3	4.63	4
4	Overcoming existing habits of resistance to adopt new technologies	23	4.17	9	4.06	13	4.12	10
5	Construction companies to design implementation strategies to new technologies	23	4.04	12	4.15	11	4.10	11
6	Incorporate R&D (research and development) for evaluating	23	3.96	14	4.12	12	4.04	14

	material properties for construction works							
7	Develop performance metrics on the adoption of emerging technologies in the Tanzanian construction industry	23	4.35	7	4.38	8	4.37	7
8	Evaluation of challenges faced by users	23	4.00	13	4.18	10	4.09	12
9	Develop training approach prior to introduction of new technology	23	4.70	3	4.79	2	4.74	3
10	Integrate technology deployment with change management	23	4.43	5	4.65	4	4.54	5
11	Develop measurable success factors for monitoring technology adoption	23	4.39	6	4.35	9	4.37	7
12	Engage construction stakeholders to create awareness and readiness to adopt emerging technologies	23	4.26	8	4.44	7	4.35	8
13	Trainings and learnings	23	4.09	11	4.53	6	4.31	9
14	Evaluate product inefficiencies	23	3.09	15	3.97	14	3.53	15
15	Government support in the implementation of emerging technologies	23	4.13	10	3.97	14	4.05	13
16	Increasing capacity to provide whole-life value to client	23	4.26	8	4.59	5	4.42	6

Spearman rank correlation coefficient (Contractors versus Consultants) for frequencies = 0.86

Critical rho = 0.429

Result: SC = Significantly Correlated at 5% alpha

Source: Data Survey,2021

4.10 Rank Correlation Results

The study also computed Spearman's Rank Correlation Coefficient rho (ρ) for Contractors' vs Consultants' ranking for performance characteristics of HDPE (Weholite) Technology and results are presented hereunder.

Table 4.14: Rank Correlation Results

S/N	Performance Characteristics of HDPE (Weholite) Technology	Contractors' Ranking	Consultants' Ranking	di	di^2
1	Light Weight	2	5	-3	9
2	Durability	1	1	0	0
3	Reliability	4	7	-3	9
4	Superior Hydraulic Properties	2	3	-1	1
5	Flexibility	4	11	-7	49

6	Watertight Mechanical Joints	10	15	-5	25
7	Fusion Welded Joints	8	13	-5	25
8	Lower Carbon Footprint	9	14	-5	25
9	Material Service Life	2	2	0	0
10	Chemical Resistance	6	10	-4	16
11	Abrasion Resistance	5	4	1	1
12	Impact Resistance	7	5	2	4
13	Corrosion Resistance	7	6	1	1
14	Superior Quality	3	4	-1	1
15	Non-Toxic	10	8	2	4
16	Environmental Deterioration Resistant	10	12	-2	4
17	UV Resistant	11	16	-5	25
18	Physiologically Safe	6	9	-3	9
19	Micro-organisms Resistance	12	18	-6	36
20	Wide temperature range sustainability (-40°C to 45°C for long term use; 80°C for short term use)	13	17	-4	16
				Total di^2	260

Note: N = 20 (number of factors/observations)

From: $Rho = 1 - \frac{6 * \text{sum of } di^2}{N(N^2-1)}$ where: di = the difference in ranking between each pair of factors

Therefore: $Rho = 1 - \frac{(6*260)}{20(20^2-1)} = 0.80$

The computed Spearman rank correlation coefficient (rho) value of 0.80 against the value N=20 is greater than the critical value rho(Pα) of 0.38 from the table at 5% level of significance for one-tailed test. This means that there is a considerable and positive correlation between the two categories of ranks when it comes to the influence of HDPE (Weholite) technology performance features on consultant and contractor rankings. (**Note**: For contractors vs consultants, all Spearman rank correlation coefficients are computed in the same way as indicated above).

4.11 Development of Framework for HDPE (Weholite) Technology Adoption in Construction Projects in Tanzania

Several technology adoption models and frameworks, such as the Technology Adoption Model, TAM2 (Venkatesh & Davis, 2000), the Unified Theory of Acceptance and Use of Technology Model, UTAUT (Venkatesh et al., 2000), and the Construction Safety Technology Adoption Framework, C-STAF (Venkatesh et al., 2000), have been developed and studied (Nnaji et al., 2018). Such technological models and frameworks can help lead technology adoption in various construction firms and enterprises, build implementation roadmaps and strategies, and transform the construction industry to promote project success. The perceived usefulness, ease of use and innovation assessment of technology were the subject of these investigations. The framework was developed using a flow chart which provided procedures to be followed for adoption of the technology in a construction project. The flow chart was developed considering the various stages of a construction project – project planning, implementation, monitoring and closure. Each step of the project was used in the framework to depict technology integration process in construction.

Based on research findings, the proposed framework for HDPE (Weholite) technology adoption draws from the C-STAF model and modifies it whilst focusing on application of the technology with regard to a construction project undertaking by identifying key activities/areas for technology integration and pertinent outputs that could influence adoption decisions. Findings from the research and framework validation by experts show that for ease of integration/ adoption of the technology in construction, evaluation of benefits for adoption the technology are to be determined; project appraisal is to be done with focus on the economic, financial and technical aspects of the project as well as introducing the technology as part of the design (and specification) during a project undertaking. The features of the proposed framework model are explained hereunder.

4.11.1 Technology Dissemination and Diffusion

This is the first step for the framework and is basically centered on the vendor of the technology who may also be considered as part of the adoption process (Sepasgozar & Davis, 2018). It refers to the process of promoting the technology. Foremost, the technology is suggested. This can be achieved through demonstrations, trainings and pilot projects aimed at establishing precedence for various applications of the technology. Technology dissemination and diffusion is essential in creating awareness amongst construction professionals. Further to this, manufacturers can develop incentives to foster technology adoption. This has been indicated in research findings as a major determinant towards increased adoption of the technology in construction. Another strategy reported by both contractors and consultants was engaging construction stakeholders to create awareness and readiness to adopt emerging technologies.

4.11.2 Feasibility Evaluation

Before introducing a new technology in construction, a feasibility check is conducted to determine the usefulness of the technology. This is incorporated in the project concept design which also constitutes a project brief. This step is key in ascertaining the need for adopting a technology as well as identifying feasible options that can use the technology in the project. This is crucial in establishing the project areas in which the technology can be adopted. This establishes the foundation for integrating technologies in construction projects by establishing the demand to meet project needs and objectives.

4.11.3 Technology Assessment

The researcher has defined this step through project appraisal, project planning and technology assessment. Project appraisal is a methodical process of evaluating the viability of a project or proposal that includes comparing numerous choices and evaluating economic, financial, and technical appraisal. The economic and financial appraisal will determine the monetary effects of adopting the technology whereas the technical appraisal provides the assessment of the status of the technical know-how and design as envisaged in the project. All this is done to help with the decision making to adopt the technology. Project planning involves the design, analysis and material specification in which a thorough analysis of the technology is conducted to determine the design requirements for use and application. Finally, technology assessment is done to evaluate the effectiveness, usability, reliability and material properties of a technology with regard to the nature of use for construction. Although the major goal of a technology assessment is to identify its effectiveness, previous studies have also looked at the technology's reliability and complexity (Gambatese et al., 2017).

End-users are unlikely to adopt technology that is ineffective, unreliable, or complicated to use, regardless of how financially viable it is or whether it has the right features. To increase the rate of technology adoption, a thorough review study underpinned by academic rigor is required (Nnaji et al., 2018). A technology is expected to satisfy specified objectives after a successful feasibility evaluation. For instance, results from the survey questionnaire indicate that participants expect the technology to be durable, light weight, reliable and with adequate material service life. This step is conducted to establish that the technology meets the expectation of the end-user in terms of functionality and usefulness.

4.11.4 Adoption of Technology

After an assessment of the technology has been conducted and the technology has met expectations/ requirement, it is recommended for adoption. This step involves the integration of the technology in construction altogether with monitoring the implementation of the technology. Technology adoption is after a final decision has been issued to adopt the technology. Evidence-based technology adoption decision-making is becoming more essential (Moja et al., 2016). Given the normative and traditional nature of the construction sector, evidence-based decision making is critical for driving innovation acceptance. This is fostered through trainings and learnings as well as devising implementation strategies to new technologies which were ranked with high mean scores by both respondents). Implementation strategies to new technologies are aimed at creating a road map for technology adoption. It involves developing an implementation plan for the technology and offering support while implementing the technology. This is followed by technology monitoring implementation which is done by skilled construction professionals altogether manufacturer supervision to ensure proper installation and use is adhered to. Sometimes technology adoption leads to changes in the original design and specification and such changes are to be managed to avoid project delays and disruption hence it is essential to integrate technology deployment with change management. This was a strategy for increased adoption of the technology in construction and was also ranked with a high mean score (4.54). This is generally summarized as commencement of operation, maintenance setup and assessment. These stages are supported by vendors through delivery and trainings, repair support and feedback mechanisms.

After technology implementation, the project is commissioned, and this is done through offering support for transition and handover process and detailed efficiency reports on the technology. Vendor support is essential in ensuring technology effectiveness and ease of use with a view to increase capacity to provide whole-life value to clients.

4.11.5 Technology Appraisal

Following results from questionnaires, participants indicated the need for strategies towards increased adoption of HDPE (Weholite) technology that the researcher has used to develop an integral part of the framework. This includes development of performance metrics for technology adoption, incorporation of research and development (R&D) for evaluating material properties in construction, evaluating challenges faced by users of technology and developing measurable success factors for monitoring technology adoption.

4.11.6 Framework Validation

This section provides the validation process's results, as a final stage of the study and an important process aimed at addressing the final portion of the final goal by confirming the quality and validity of the proposed framework model. To validate the suggested framework, the study used "expert validation". An expert review is a procedure in which experts are asked for their ideas, suggestions, feedback, or remarks. This method has also been used by various authors for framework validation (Ng'etich et al., 2021; Kavishe, N. & Chileshe, N., 2019; Torrecilla-Salinas et al., 2019; Tigelaar et al., 2004; Angkananon et al., 2013,). The validation process presented an opportunity to ascertain the accuracy of information underpinning the draft framework and identified key points for framework refinement. The process allowed participants to comment freely on the framework components in an open forum, which allowed for extensive discussions and drew out diverse stakeholder and expert opinions.

Purposive sampling was used to select the survey respondents for the validation process in order to obtain valid and relevant information needed for it is considered most effective when a researcher wants to study a sample of population with certain knowledge. A total of six (6) experts – four (4) from the construction industry (2 contractors and 2 consultants) were invited to participate in framework validation for the study. The respondents from contractors and consultants were obtained from the study sample based on their experience in the construction industry, knowledge and familiarity with Weholite technology. The remaining two (2) respondents were sought from the manufacturer of the technology in Tanzania – PLASCO LTD. These had adequate knowledge on the technology as well as its use in construction. Respondents were called and asked to participate in a follow-up interview to validate the suggested framework of adoption of HDPE (Weholite) technology; consent forms were sought and subsequently signed by the experts and the interview was carried out for respective respondents. Table 4.15 below further indicates that the respondents had sufficient knowledge and expertise to aid in validation the framework for integration into construction.

4.11.6.1 Demographic information of the respondents

Table 4.15 demonstrates that all respondents have sufficient construction project knowledge and experience. Furthermore, respondents were obtained from contractors, consultants and manufacturer.

Table 4.15: Profile of population for validation process

S/N	Firm/Organization	Experience	Professional Background	Response Status
1	Contractor 1	5 – 10 years	Engineer	Accepted & Interviewed
2	Contractor 2	10 – 15 years	Engineer	Accepted & Interviewed
3	Consultant 1	5 – 10 years	Engineer	Accepted & Interviewed
4	Consultant 2	> 15 years	Engineer	Accepted & Interviewed
5	Weholite Expert 1	> 15 years	Quality Management	Accepted & Interviewed
6	Weholite Expert 2	> 20 years	Engineer	Accepted & Interviewed

4.11.6.2 Discussion of framework findings

During discussion in the interview process, after taking the respondents thorough the proposed framework, room was set for discussion on the steps shown in the framework. All respondents agreed on the initial step – technology dissemination and diffusion emphasizing that it a necessary step toward introduction of technologies in the construction industry to set a basis and engage construction stakeholders. For the technology assessment step, all respondents agreed on the fact that it is necessary for construction professional to assess the need for integrating Weholite technology by evaluating the technologies attributes and suitability with respect to construction.

Further to this, the interview revealed that incentives are required to foster the technology adoption in construction as well as trainings and devising implementation strategies for technology adoption in construction. During project commissioning, respondents pointed out that it would be beneficial for transition support to be provided by the manufacturer and technology appraisal to be conducted by both parties to evaluate performance. Responses from experts were used to map project concepts and refine the framework. A key point that emerged for refining the proposed framework was technology appraisal. This was recommended by the consultant and contractor who took part in the interviews for which they suggested that the manufacturer as well as construction projects that have decided to adopt the technology should set parameters to monitor technology performance also saying that this will set a benchmark for other stakeholders to adopt the technology. Another suggestions that emanated from the discussion was the evaluation of challenges faced during adoption of the technology so as to figure a way to overcome them in future projects.

Responses from experts were triangulated based on existing models and technology adoption frameworks, literature review and user evaluation. This was done to ensure credibility of the results (Cohen & Manion, 2000; Altrichter et al., 2008). By presenting the framework to industry professionals, the framework was discussed and the participants' opinions on the established framework were solicited throughout the interviews. The industry experts' findings were also used for validity purposes and to provide additional information about the implementation process. This validity technique has already been applied in construction in many forms (Yang et al., 2010; Sepasgozar & Davis, 2018). Furthermore, interviews with industry experts, according to Lucko and Rojas (2009), provide deeper feedback because the researcher can clarify and extend individual elements ad hoc in a semi-structured manner.

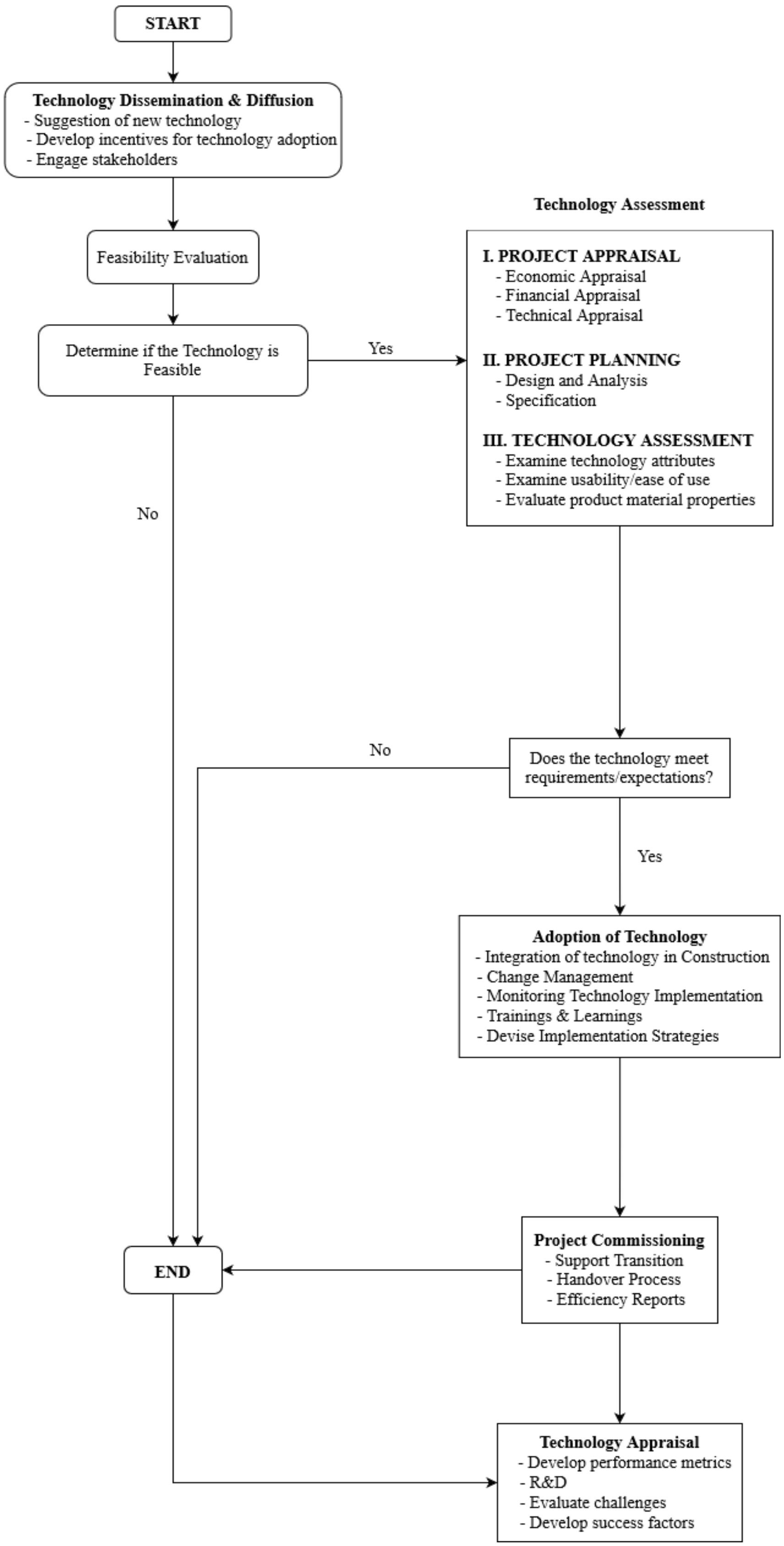


Figure 4.9: Proposed Framework for HDPE (Weholite) Technology Adoption

4.12 Chapter Summary

This chapter has discussed on data collection and analysis. The response rate has been discussed followed by demographic data for respondents. Results and discussion on the use, influence of performance characteristics and benefits of HDPE (Weholite) technology are further discussed herein. Moreover, results and discussion on barriers toward adoption of the technology are presented followed by strategies towards increased adoption of the technology in construction. Finally, combined responses from contractors and consultants are evaluated and a framework for the adoption of HDPE (Weholite) is established.

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter summarizes the findings of this study whose objectives were to evaluate the use of HDPE (Weholite) technology; to examine the influence of performance characteristics of HDPE (Weholite) technology; to assess the barriers and evaluate strategies towards adoption of HDPE (Weholite) and to develop a framework for the adoption of HDPE (Weholite) in construction projects in Tanzania. Furthermore, recommendations and areas for further studies are provided.

5.2 Conclusions

The researcher sought to assess the adoption of HDPE (Weholite) technology in construction projects in Tanzania with specific objectives – to evaluate the use of the technology in construction projects; to examine the influence of performance characteristics and the adoption of the technology in construction projects; to assess the barriers towards the adoption of the technology and evaluate strategies for mitigation and to develop a framework for the adoption of the technology in construction projects in Tanzania. All objectives were key in devising research questionnaire which was used for data collection. The following are the conclusions based on each specific objective for the research.

5.2.1 To evaluate the use of HDPE (Weholite) technology in construction projects in Tanzania

The study revealed that there is sufficient knowledge and awareness of HDPE (Weholite) technology in the construction industry in Tanzania with the technology regarded as ‘very effective’ in its use/adoption in construction projects. It is also seen that there is great familiarity with the technology amongst construction professionals. Furthermore, findings indicate an overall application of the technology of 1 to 3 projects for most users with the topmost application of the technology being culverts followed by drainage lines and sewer applications. Also, both contractors and consultants show a higher chance of using the technology for future projects. Further to this, both groups of respondents indicate that the technology is very effective, and with such findings, the study concludes that the use of the technology in construction projects will indeed foster project performance.

5.2.2 To examine the influence of performance characteristics and the adoption of HDPE (Weholite) technology in construction projects in Tanzania

The study also revealed that the performance characteristics of the technology are ranked with high mean scores indicating a myriad of merits achieved in adoption of the technology towards project performance. Various performance characteristics of the technology have been established to influence adoption with the topmost being durability followed by material service life, light weight, superior quality and hydraulic properties, flexibility and abrasion and the least one being wide temperature range sustainability, UV resistance and microorganisms resistance. It is from such performance characteristics that the benefits of the technology can be reflected in a construction project as indicated by both contractors and consultants. Such benefits include reduction in installation time, overall reduction in project labour costs, reduction in work program, easiness of transport and handling, increase in project efficiency and eliminating regular system maintenance. With these and many other merits ranked with high mean scores by both groups of respondents, it is evident the technology is beneficial in meeting project objectives when adopted. Moreover, analysis of combined responses from both contractors and consultants show a correlation of results that both groups are in agreement with ranking showing a greater number of factors ranked with higher mean scores indicating that the performance characteristics of the technology have greatly influenced the use of the technology in construction projects in Tanzania.

5.2.3 To assess the barriers towards the adoption of HDPE (Weholite) technology and evaluate strategies for mitigation in construction projects in Tanzania

The study identified the following major barriers to adoption of the technology listed chronologically – insufficient incentives for adoption of emerging technologies in the construction industry, insufficient knowledge on Weholite as a construction material, inadequate knowledge on the design aspects of Weholite, current construction industry culture inherently slows adoption of the technology and little awareness of the technology and its applications. Least barriers were identified by both contractors and consultants as follows: low access to latest technology in the construction industry, insufficient demand of Weholite in the construction industry, lack of technical experts and unclear benefits. It is evident the design knowledge on aspects of the technology is lacking in the Tanzanian construction industry altogether with hesitancy to adopt the technology being major determinants for adoption. Moreover, both consultants and contractors have indicated a lack of incentives for adoption of emerging technologies in the construction industry showing a need for manufacturers, construction stakeholders and the government in supporting and motivating the use of emerging technologies in the construction industry. In line with this objective, the study evaluated strategies towards increased adoption of HDPE (Weholite) technology in construction and findings revealed major strategies listed chronologically as the use and application of the technology should be taught and illustrated to construction industry professionals using various platforms, project consultants to specify Weholite technology as a material option where applicable, developing a training approach prior to introduction of a new technology and project concept design to factor the use of Weholite in construction with both groups ranking over 94% of the strategies with high mean scores.

5.2.4 To develop a framework for adoption of HDPE (Weholite) technology in construction projects in Tanzania.

Finally, the study facilitated the development of a framework for adoption of HDPE (Weholite) technology in construction projects based on previous works on adoption of technology concepts, and modification of the C-STAF model altogether with research findings. The framework was established based with regard to vendor and end-user (consultant and contractor) relations in a construction project undertaking from project feasibility study to project commissioning. The framework indicated as foremost the need to establish the areas for which the technology can be better integrated in the construction process. This has been identified in the framework beginning with the feasibility study which is aimed at identifying possible application of the technology in the project. This is followed by technology assessment which aims at evaluating the technology through project appraisal to determine the cost benefits associated with adopting the technology then project planning integrates the technology through design and specification of the technology for areas identified in the feasibility study. Further to this, the technology is evaluated in terms of attributes, usability and product material properties to determine its suitability with the project in hand. Once the technology is deemed to have met all project requirements, it is adopted. This is the implementation stage of the technology which centres on integration of the technology into construction. This is achieved through monitoring technology implementation, trainings and learnings, devising technology implementation strategies and change management for construction. Thereafter, the framework proposes supporting the transition in the handover process whilst generating technology efficiency reports to determine the working on the implemented technology. Finally, the framework also proposes 'technology appraisal'. This was evaluated in the study through participants responses on the strategies for increased adoption of the technology and is achieved though developing performance metrics for monitoring technology adoption, evaluating challenges faced by users of the technology, incorporation of R&D for evaluating material properties for construction and developing measurable success factors for monitoring technology adoption.

5.3 Recommendations

Based on the findings obtained from the research, the study makes the following recommendations:

i. **Technology Appraisal**: Technology appraisal is a critical technique for building and construction management, and it can have a substantial impact on an organization's or project's overall performance. This can be achieved by evaluating construction technology assessment criteria i.e., quality, time and cost. Appraisal is done to ensure that the adopted fully meets the requirements of use in terms of quality, time and cost. Appraisal by the contractor after project completion will assess the benefits of adopting the technology in terms of quality, time and cost for delivery of the project whereas vendor appraisal will be done to evaluate the 'product performance' under use in the project to ensure that it fully meets the warranty period and more.

ii. There is a need for construction stakeholders to facilitate the adoption of emerging technologies in the construction industry through incentives and support towards increasing project efficiency and performance. As both consultants and contractors have stated, HDPE (Weholite) technology has proven to be a dependable and cost-effective solution, and thus there is a need for integration of the technology into construction in order to achieve project objectives and sustainability. For instance, a respondent in the research questionnaires suggested incentives such site support, discounted rate on certain volumes, provide tools of trade where needed may bring appetite on adopting the technology.

iii. **Adopting the proposed framework in construction projects in Tanzania**: the proposed framework for technology adoption is geared towards integrating the technology by defining steps for integration of the technology during a project undertaking – from planning to commissioning. The use of the framework will help to develop numerous components that may be used for future researches as well as aid in improving this framework to boost technology adoption in the construction industry.

iv. **Overcoming habits of resistance to adoption of emerging technologies in construction**: The study's findings suggested that this is a key obstacle to technology adoption in Tanzania's construction industry, with a higher mean score from respondent (4.12). Previous researches (Ern et al., 2017; Lines et al., 2015; Olaniyan, 2019) also found this to be a significant obstacle to technology adoption in the construction industry. Technology in the construction business is continually evolving, and it is critical for construction professionals to conduct research and investigations into technical breakthroughs aimed at enhancing construction performance and overcoming the fear of trying something new.

v. **Monitoring Technology Implementation and Use**: once the technology has been adopted, it is essential that the technology is monitored to ensure it meets requirements for use. Monitoring of technology also establishes the precedence for use in other projects. Moreover, it sets ground for evaluating the performance of the technology. This is a key element towards ensuring that the technology has been properly installed and is used accordingly.

vi. **Trainings and Learnings**: training is essential for technology deployment. Provision of trainings and learnings will help impart knowledge and understating of the technology to construction shareholders thereby fostering ease of adoption.

5.4 Areas for further studies

The following areas for further research have been identified by the researcher:

i. Development of a framework for technology adoption by examining drivers of technology in both contractors and consultants.

ii. Investigation on how change management facilitates technology adoption in the construction industry.

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APPENDICES

APPENDIX I: RESEARCH QUESTIONNAIRE

The following is a sample of research questionnaire for the study which was distributed to contractors.

INTRODUCTION LETTER

Dear Respondent,

My name is **Dominic Justin Hando**, a postgraduate student at Ardhi University – Dar es Salaam. I am conducting a research titled: "***An Assessment of the Adoption of HDPE (Weholite) Technology in Construction Projects in Tanzania***". This questionnaire is meant to aid in data collection for my study. I trust that you will take the time to read through the questionnaire and answer all the questions contained herein by either choosing the correct answer from the options provided or writing a brief statement where appropriate.

The information provided will be treated with strict confidentiality and be used for academic purposes only.

Thank you.

Dominic Justin Hando,

Master of Science in Construction Economics and Management,

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QUESTIONNAIRE

This questionnaire is made up of four sections – section I, II, III & IV. When filling the questionnaire, please tick (√) as appropriate or write in the space provided.

SECTION I: General Information

1.1 Name of the Company/Organization: ………………………………………………………

1.2 What is your position in the construction company/organization that you are working with?

( ) Top Level Management [such as: Director, Owner]

( ) Middle Level Management [such as: Project Engineer, Head of Department]

( ) Low Level Management [such as: Site/Office Engineer, Site Inspector]

1.3 What are your years of experience in the construction industry?

( ) Below 5 years

( ) 5 to 10 years

( ) 10 to 15 years

( ) 15 to 20 years

( ) Above 20 years

SECTION II: Objective 1 – To evaluate the use of HDPE (Weholite) technology in Construction Projects in Tanzania.

2.1 Are you familiar with high-density polyethylene, HDPE (Weholite) technology that is used in construction?

( ) Extremely Familiar

( ) Very Familiar

( ) Moderately Familiar

( ) Slightly Familiar

( ) Not at all Familiar

2.2 The manufacturing of high-density polyethylene, HDPE (Weholite) was first introduced in Tanzania in 2018. How did you become aware of this technology? [Please tick (√) as many as applicable].

( ) Construction Workshops/Seminars

( ) Project Requirement/Specification

( ) Pilot Projects done by the manufacturer

( ) From a project that utilized the technology

( ) Other (please indicate):…………………………………………………………

2.3. In your own account, how many projects have you utilized high-density polyethylene, HDPE (Weholite) over the past 4 years in construction projects in Tanzania?

( ) None

( ) 1 to 3 projects

( ) 4 to 6 projects

( ) 7 to 9 projects

( ) 10 projects and above

2.4 High-density polyethylene, HDPE (Weholite) technology has numerous applications in construction works. In your experience, what type of application have you utilized the technology for? [Please tick (√) as many as applicable]

( ) Culverts

( ) Drainage Systems [such as stormwater drains]

( ) Sewer Systems

( ) Structural Elements [such as; water/septic/chemical tanks, manholes, oil separators]

( ) Other (please indicate): ……………………………….…………………………………

2.5 How do you rank your experience towards utilizing high-density polyethylene, HDPE (Weholite) technology in construction projects that you have undertaken?

( ) Very Effective

( ) Effective

( ) Normal

( ) Less Effective

( ) Not at all Effective

2.6 Are you likely to suggest the use of high-density polyethylene, HDPE (Weholite) technology in other construction projects in Tanzania where applicable?

( ) Very Likely

( ) Likely

( ) Neutral

( ) Unlikely

( ) Very Unlikely

SECTION III: Objective 2 – To evaluate the influence of the Performance Characteristics of high-density polyethylene, HDPE (Weholite) technology in construction projects in Tanzania.

3.1 The table below outlines the various performance characteristics derived from high-density polyethylene, HDPE (Weholite) technology. Please indicate the level of influence of each item towards utilizing the technology in various project(s) that you have undertaken by ticking in the appropriate box.

Given that: **5 – Very Much, 4 – Somewhat, 3 – Neutral, 2 – Somewhat Not** and **1 – Not at All**

S/N	PERFORMACE CHARACTERISTICS OF HIGH-DENSITY POLYETHYLENE, HDPE (WEHOLITE)	INFLUENCE LEVEL				
		5	4	3	2	1
1	Light Weight					
2	Durability					
3	Reliability					
4	Superior Hydraulic Properties					
5	Flexibility					
6	Watertight Mechanical Joints					
7	Fusion Welded Joints					
8	Lower Carbon Footprint					
9	Material Service Life					
10	Chemical Resistance					
11	Abrasion Resistance					
12	Impact Resistance					
13	Corrosion Resistance					
14	Superior Quality					
15	Non-Toxic					
16	Environmental Deterioration Resistant					
17	UV Resistant					
18	Physiologically Safe					
19	Micro-organisms Resistance					
20	Wide temperature range sustainability (-40°C to 45°C for long term use; 80°C for short term use)					

3.2 The following table lists the benefits derived from the use of high-density polyethylene, HDPE (Weholite) technology in construction projects. Such benefits have different impacts on the overall project performance and objectives. Please evaluate the level of impact that each merit has had on the project(s) that you have undertaken by ticking (√) in the space provided.

Given that: **5 – Very High, 4 – High, 3 – Moderate, 2 – Low** and **1 – Very Low**

S/N	**BENEFITS ACHIEVED BY USING HIGH-DENSITY POLYETHYLENE, HDPE (WEHOLITE) IN CONSTRUCTION PROJECTS**	**IMPACT LEVEL**				
		5	**4**	**3**	**2**	**1**
1	Easiness of transport and handling					
2	Reduction in installation time					
3	Overall reduction in project labour costs					
4	Availability of large diameters (up to 3m)					
5	Availability of customized pipe lengths					
6	Tailored designs based on project requirements					
7	Product Versatility					
8	Availability and easiness of repair					
9	Project Value Engineering is achieved using Weholite					
10	Very low maintenance costs (after project completion)					
11	Reliable Joints (welded)					
12	Cost savings achieved during project rehabilitation through product recycling					
13	Wide selection of fittings meeting standard or challenging needs					
14	Ability to withstand ground movements					
15	Excellent quality of workmanship					
16	Ability to fabricate custom-made structural elements (such as: manholes, valve chambers, storage tanks)					
17	Optimized flow rates due to smooth internal surface					
18	Material saving in installation (backfill)					
19	Eliminates system infiltration (such as root penetration)					
20	Eliminates regular system maintenance					
21	Availability of various pipe stiffness classes (2, 4 and 8Kn/m^2)					
22	Reduction in work program and facilitating ease of construction					
23	Expected longevity of product technology [100years buried; 60yrs above ground]					
25	Promotes off-site prefabrication					
25	Reduces waste hence value generation					
26	Increases project efficiency					

SECTION IV: Objective 3 – To assess the barriers towards the adoption of high-density polyethylene, HDPE (Weholite) technology in Construction Projects in Tanzania.

4.1 The table below outlines a list of barriers toward the adoption of high-density polyethylene, HDPE (Weholite) technology obtained from literature and personal experience. Please indicate your opinion on the degree of acceptance of each item by ticking (√) in the space provided.

Given that: **5 – Strongly Agree, 4 – Agree, 3 – Neutral, 2 – Disagree** and **1 – Strongly Disagree**

S/N	**BARRIERS TOWARD ADOPTION OF HIGH-DENSITY POLYETHYLENE HDPE (WEHOLITE) IN CONSTRUCTION PROJECTS**	**DEGREE OF ACCEPTANCE**				
		5	**4**	**3**	**2**	**1**
1	There is little awareness of Weholite and its applications in Tanzania					
2	The technology is relatively new					
3	Insufficient performance characteristics data to draw from implemented projects					
4	Insufficient knowledge on Weholite as a construction material					
5	Insufficient support for emerging technologies in the construction industry					
6	Insufficient financial investment/budget by potential users					
7	Management hesitancy to adopt the technology					
8	Current construction industry culture inherently slows adoption of Weholite					
9	Inadequate technology training to construction industry professionals					
10	Lack of R&D (research and development) in the construction industry					
11	Unsatisfactory/bad experience in the use of emerging technologies in construction					
12	Low access to latest technology in the construction industry					
13	Insufficient incentives for adoption of emerging technologies in the construction industry					
14	Fear of risks associated with adopting a new technology					
15	Adaptability of Weholite to various constraining site conditions					
16	Inadequate knowledge on the design aspects of Weholite					

17	Resistance to the adoption of Weholite by the construction industry					
18	Competitiveness against other products in the market					
19	High cost for acquiring technical equipment					
20	Insufficient demand of Weholite in the construction industry					
21	Current technology is enough					
22	Unclear benefits					
23	Lack of technical experts					
24	Insufficient technology infrastructure					
25	Time and cost of training					

4.2 The table below outlines a list of strategies that can be implemented towards increasing the adoption of high-density polyethylene, HDPE (Weholite) technology. Please indicate your opinion on the degree of acceptance of each item by ticking (√) in the space provided.

Given that: **5 – Strongly Agree, 4 – Agree, 3 – Neutral, 2 – Disagree** and **1 – Strongly Disagree**

S/N	**STRATEGIES TOWARDS INCREASED ADOPTION OF HIGH-DENSITY POLYETHYLENE, HDPE (WEHOLITE) IN CONSTRUCTION PROJECTS**	**DEGREE OF ACCEPTANCE**				
		5	**4**	**3**	**2**	**1**
1	The use and application of Weholite technology should be taught and illustrated to construction industry professionals using various platforms					
2	Project consultants to specify Weholite as a material option where applicable					
3	Project concept design to factor in the usability/applicability of Weholite					
4	Overcoming existing habits of resistance to adopt new technologies					
5	Construction companies to design implementation strategies to new technologies					
6	Incorporate R&D (research and development) for evaluating material properties for construction works					
7	Develop performance metrics on the adoption of emerging technologies in the Tanzanian construction industry					
8	Evaluation of challenges faced by users					
9	Develop training approach prior to introduction of new technology					

10	Integrate technology deployment with change management					
11	Develop measurable success factors for monitoring technology adoption					
12	Engage construction stakeholders to create awareness and readiness to adopt emerging technologies					
13	Trainings and learning					
14	Evaluate product inefficiencies					
15	Government support in the implementation of emerging technologies					
16	Increasing capacity to provide whole-life value to client					

4.3 Other than the strategies outlined above, what do you think is/are the best approach(es) or strategies that can be employed to facilitate the use of high-density polyethylene, HDPE (Weholite) technology in the Tanzanian construction industry?

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APPENDIX II: INTERVIEW FOR VALIDATION OF PROPOSED RESESARCH FRAMEWORK

INTRODUCTION:

Dear Participant,

My name is **Dominic Justin Hando**, a postgraduate student at Ardhi University – Dar es Salaam. I am conducting a research titled: "***An Assessment of the Adoption of HDPE (Weholite) Technology in Construction Projects in Tanzania***". This interview is meant to aid in validating a proposed framework for adoption of HDPE, (Weholite) technology in construction projects that I have developed from research findings and previous works on the adoption of technology in the construction industry. Please be informed that this interview will be strict confidential and be used for academic purposes only so feel free to voice your thoughts on the proposed framework and any other improvements you may think of.

Thank you.

SECTION A: Personal Information

1. Can you introduce yourself, please?..
2. What construction company/organization do you work for?...
3. Could you please state your years of experience in construction?..
4. What is your professional background?...

SECTION B: Framework Validation

Dear respondent, further to your participation in filling the questionnaire for my research, you have been selected to aid in validating a proposed framework for adoption of HDPE (Weholite) technology in construction projects in Tanzania. The framework is in a chart form and shows the various stages for integration of the technology in construction. I will explain all parts of the framework thoroughly followed by a discussion with you for each part. Please take your time to go through the framework and provide your opinions/insights.

(Please refer to Figure 4.9: Proposed Framework for HDPE (Weholite) Technology Adoption)

1. How would you explain technology dissemination and technology diffusion in a construction project?

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2. How do you evaluate the feasibility for technologies in construction projects?

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3. Once you have determined the technology is feasible, briefly explain how the technology assessment is done in various stages of the project.

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4. After deeming the technology to meet specifications for adoption in a project, briefly explain how this process is undertaken to integrate said technology in the construction project.

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5. How is technology adopted facilitated during project commissioning?

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6. Do you have any other comments regarding the proposed framework?

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