THE IMPACT OF TECHNOLOGY ADOPTION ON CONSTRUCTION PROJECT EFFICIENCY IN KENYA. A CASE STUDY OF MACHAKOS COUNTY

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DECLARATION

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

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This research project has been submitted for examination with my approval as University Supervisor

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DEDICATION

I would want to thank my family, who have been there for me every step of the way and who have sacrificed so much for my education, and I dedicate my research effort to them. Their unwavering support, wisdom, and faith in me have been my rock throughout my life.

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ABSTRACT

In Machakos County, Kenya, this research looked at how building projects benefited from using new technologies. There were four main goals that guided the research: to find out how digital tool usage affects construction project efficiency, how automation of construction processes affects efficiency, how availability of ICT infrastructure affects efficiency, and how technology-enabled stakeholder collaboration affects efficiency. A descriptive research strategy was used in the study. Three hundred and seventeen people from 37 different public and private construction projects made up the target group. Thirty percent of the population of interest (95 participants) was selected using simple random selection in the research. A structured questionnaire with closed-ended questions based on a five-point Likert scale was used to gather data. A pilot research was carried out on 10% of the total sample before the main study to ensure the instrument's validity and reliability. To analyze the data, SPSS Version 29.0 was used once the data was coded. We analyzed the data using descriptive statistics, which include percentages, means, and standard deviations, as well as frequencies. With 89 returned surveys out of 95 sent out, the response percentage was 93.7%. Project management software improved coordination, according to 41 respondents (with 30 agreeing and 38 strongly agreeing), and Building Information Modeling enhanced planning accuracy, according to 38 respondents (with 33 agreeing); the results demonstrated that digital tool utilization significantly affected project efficiency. Also, the idea that automated equipment boosted production was well-received; 37 respondents strongly agreed and 31 agreed, indicating widespread support for automating building activities. Concerning the accessibility of information and communication technology infrastructure, 42 respondents were in strong agreement and 29 were in agreement that consistent internet access improved communication on building sites. More than half of respondents (41 to be exact) felt that digital communication platforms enhanced coordination among project stakeholders, and a similar percentage (30 to be exact) agreed that this was the case. Time, money, quality, resource utilization, and rework reduction were all areas where the results showed that technology adoption increased project performance. The research found that building projects were far more efficient and successful when digital tools, automation technologies, a sufficient information and communication technology infrastructure, and technology-enabled stakeholder interactions were effectively used. The research concluded that in order to facilitate effective project execution, construction companies should increase spending on digital project management systems, automated construction technology, and dependable information and communication technology infrastructure. In order to increase coordination among project stakeholders, it was also suggested that organizations should encourage the usage of digital collaboration platforms and boost training programs for construction experts to improve their technology abilities.

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ACRONYMS AND ABBREVIATIONS

4IR	**:**	Fourth Industrial Revolution
BIM	**:**	Building Information Modeling
ICT	**:**	Information and Communication Technology
KIPPRA	**:**	Kenya Institute for Public Policy Research and Analysis

OPERATIONAL DEFINITION OF TERMS

Technology Adoption: The level of digital tool and automation system implementation and utilization by Machakos County construction businesses in project execution.

Construction Project Efficiency: How well construction projects meet their goals in terms of budget, schedule, quality, and resource use while minimizing rework and waste.

Digital Tool Utilization: The process of facilitating the planning, monitoring, and communication of construction projects by the use of software and digital applications, including Building Information Modeling (BIM), project management systems, and mobile apps.

Automation of Construction Processes: Reduced human involvement in construction via the use of automated technology such as machines, prefabrication procedures, and computerized scheduling systems.

ICT Infrastructure Availability: The availability and suitability of the necessary information and communication technology resources, such as internet access, hardware, and network systems, to facilitate digital activities on building sites.

Stakeholder Collaboration Through Technology: Streamlining the process of project management by using digital platforms and communication technology to assist clients, contractors, consultants, and other stakeholders in coordinating, sharing information, and making decisions.

CHAPTER ONE
INTRODUCTION

1.0 Introduction

This chapter provides context for the research by outlining its goals and examining the use of technology in the construction industry from a global, African, and Kenyan viewpoint. It lays the groundwork for the research by presenting the issue statement, outlining the goals and research questions, explaining the study's relevance, and defining its scope.

1.1 Background Information

When digital tools, automation, and ICT are incorporated into construction processes to enhance project planning, execution, monitoring, and control, this is known as technology adoption in the construction industry. By improving coordination, decreasing mistakes, and giving real-time data for decision-making, new technologies like Building Information Modeling (BIM), automation, and ICT systems are revolutionizing conventional building techniques, according to experts (Nature Scientific Reports, 2025). Cost overruns, delays, and inefficiencies have long dogged building projects throughout the world, and these technologies are essential to solving these problems.

The construction industry is rapidly adopting digital transformation to meet the needs of sustainability and efficiency on a worldwide scale. The Internet of Things (IoT), blockchain, cloud computing, and artificial intelligence are some of the most promising new developments in information and communication technology (ICT) for 2025. These technologies have the potential to improve resource allocation, enable real-time monitoring of project operations, and increase cooperation among distributed stakeholders. Research shows a global trend toward using these technologies to increase operational efficiency, decrease waste, and improve project performance, even if adoption levels vary by location.

Digital tools and technology are starting to revolutionize project delivery in the African construction sector, albeit it is happening more slowly than in industrialized nations. South Africa is one of several case studies in Africa that provide empirical proof that using collaborative technology, digital planning, and construction management software has enhanced project planning, resource allocation, and coordination (Fabiyi, 2024).

Nevertheless, a lack of technical expertise, high implementation costs, and restricted access to digital infrastructure are some of the major obstacles that African construction enterprises encounter. These factors hinder the general use of these technologies and reduce the overall efficiency of their projects (Akinradewo et al., 2025).

The advantages of digital transformation in the construction industry are becoming more widely recognized, but there are still obstacles that are specific to African countries that need to be addressed. Building information modeling (BIM), automation, and information and communication technology (ICT) integration are promising technologies that have the potential to greatly improve collaboration, decision-making, and productivity in the construction industry. However, these advancements are hindered by issues such as a lack of adequate ICT infrastructure, professionals' lack of digital literacy, and a lack of policy backing (Adekunle et al., 2024). Furthermore, project efficiency results are impacted by fragmented adoption levels, which in turn are caused by unequal technical preparedness and investment discrepancies among nations (Adekunle et al., 2024).

While building information modeling (BIM), drones, and data analytics are becoming more commonplace in Kenya's construction sector, the rate of adoption varies greatly across companies and locations. The goal is to enhance project performance via the use of these digital tools. A study carried out in Nairobi City County discovered that digital technologies greatly improve construction project design, management, and quality (Maruti, Fundi & Obiero, 2024), suggesting that the use of technology has a favorable effect on performance results. These advancements are not enough to alleviate the infrastructure, talent, and consistent technology application issues plaguing Kenya's construction industry, which in turn hinders efforts to increase overall efficiency in the country's many project settings (Maruti et al., 2024).

Research on the effects of technology adoption on Kenyan construction performance has also shown that there is a significant knowledge gap when it comes to actually putting this knowledge into practice. A lack of investment in information and communication technology (ICT) infrastructure, inadequate training, and high costs continue to prevent stakeholders in Nairobi City County from fully utilizing digital tools, despite their

acknowledged potential to increase productivity and decrease delays (Influence of Technology on Labour Productivity in Nairobi City County, 2025). To overcome these obstacles and increase the efficient and long-term use of technology in Kenyan construction, specific interventions are required, such as training and education for workers, funding for information and communication technology, and enabling legislative frameworks.

1.2 Statement of the Problem

In an ideal world, digital tools, automated procedures, a strong ICT infrastructure, and stakeholder participation made possible by technology would allow construction projects to be completed quickly and easily. Economic growth and infrastructure development are anticipated to be positively impacted by construction projects that, in the absence of technological barriers, are anticipated to achieve optimal performance in terms of timely completion, cost control, quality delivery, and efficient utilization of resources (Maruti, Fundi, & Obiero, 2024; Oke, Aghimien, & Aigbavboa, 2020).

Despite increasing recognition of the advantages of using technology, the efficiency of building projects in Kenya has continued to be a constant obstacle. Time and money overruns of more than 30%, quality issues associated with lack of coordination and manual project management, and delays of 20–40% are commonplace in Kenyan construction projects, according to empirical research (Maruti et al., 2024; KIPPRA, 2020). Many enterprises in Machakos and other counties that have seen fast growth in construction activity as a result of urbanization and infrastructure development have stuck with outdated techniques that have little digital integration and poor information and communication technology support systems.

Significant repercussions have resulted from this scenario. Cost overruns, missed deadlines, diminished investor trust, and subpar finished facilities are all outcomes of inefficient construction projects. In addition to putting a burden on public funds, these inefficiencies have diminished the social and economic advantages of development projects and made local construction companies less competitive on a national and regional scale (Oke et al., 2020; KIPPRA, 2020).

Machakos County is no exception; according to reports, several governmental and private building projects in the area have had issues with coordination, cost overruns, and delays. Inefficient construction project delivery has become an increasingly serious threat to sustainable development in the county and the nation as a whole because to the rising demand for housing, roads, and public infrastructure brought about by the ongoing population boom (Maruti et al., 2024).

To tackle these issues, a number of solutions have been suggested and some have even been partly executed. In order to improve Kenya's construction performance, prior research has highlighted the need of digital tool adoption, ICT infrastructure development, capacity building, and policy assistance. Digital tool utilization, automation, availability of information and communication technology infrastructure, and technology-enabled stakeholder collaboration are four aspects of technology adoption that have received little empirical attention in studies examining adoption at the county level (Oke et al., 2020; Maruti et al., 2024). This created an obvious need for further study, especially considering the paucity of data specific to Machakos County.

Finally, the construction industry in Kenya, particularly at the county level, has stuck to inefficient practices despite the growing awareness of the value of technology in streamlining building projects. To fill that knowledge vacuum, this study looked at how technology adoption affected the efficiency of building projects in Machakos County. The goal was to provide information that was relevant to this environment so that policymakers, practitioners, and researchers could make better decisions.

1.3 Objectives of the Study

The general objective of the study was to investigate the impact of technology adoption on construction project efficiency in Kenya. A case study of Machakos County.

1.3.1 Specific Objectives

i. To assess the influence of digital tool utilization on construction project efficiency in Kenya.

ii. To evaluate the influence of automation of construction processes on construction project efficiency in Kenya.
iii. To examine the influence of ICT infrastructure availability on construction project efficiency in Kenya.
iv. To assess the influence of stakeholder collaboration through technology on construction project efficiency in Kenya.

1.4 Research Questions

i. What is the effect of digital tool utilization on construction project efficiency in Machakos County, Kenya?
ii. To what extent does automation of construction processes affect construction project efficiency in Machakos County, Kenya?
iii. How does the availability of ICT infrastructure affect construction project efficiency in Machakos County, Kenya?
iv. What is the effect of stakeholder collaboration through technology on construction project efficiency in Machakos County, Kenya?

1.5 Significance of the Study

Machakos County construction companies, project managers, and site engineers can benefit greatly from this study because it details concrete ways in which digital tools, automation, information and communication technology infrastructure, and technology-enabled collaboration can boost project efficiency. The results will be useful for these parties in figuring out how to make construction projects go more smoothly, with less money wasted, and better overall.

Policymakers may use the study's evidence-based suggestions to inform the development of rules, laws, and assistance programs that encourage the use of technology in the building industry. Improved industry standards on a national and county level, as well as more effective project delivery, will result from this.

This study addresses a gap in the literature by providing academics and researchers with data on the specific effects of technological adoption on building efficiency in Kenya. The

results will provide the groundwork for future studies, comparisons, and the creation of curricula in the fields of construction management, information and communication technology integration, and project efficiency optimization.

1.6 Scope of the Study

How the use of technology affects the efficiency of building projects was the primary focus of the research. It zeroed in on four critical areas: the use of digital tools, the automation of construction processes, the availability of information and communication technology infrastructure, and the use of technology to facilitate stakeholder participation. Data collection, analysis, and interpretation took place between January 2026 and April 2026 as part of the research to guarantee the study's prompt completion. The research, which included 37 governmental and private sector development projects, took place in Machakos County, Kenya. Project owners, site engineers, contractors, and managers from a wide range of commercial, residential, and infrastructural development projects were the intended responders. An all-encompassing comprehension of the county's tech adoption and its repercussions was made possible by this spatial and category concentration.

1.7 Chapter Summary

In this chapter, the study laid out the groundwork for understanding the research's rationale and focus by examining the problem statement, defining the objectives and research questions, discussing the study's significance, and outlining the study's scope.

CHAPTER TWO
LITERATURE REVIEW

2.0 Introduction

This chapter delves into the literature review, covering both theoretical and empirical aspects. The former reviews pertinent ideas that support the study, while the latter synthesizes prior research on technology adoption and efficiency in building projects. Additionally, it lays out the conceptual framework, describes how the study's variables were operationalized, and highlights research needs.

2.1 Theoretical Literature Review

To provide the conceptual groundwork for future research, it is common practice to conduct a theoretical literature review, which entails a thorough analysis of current ideas that explain the correlations among important study variables (Creswell & Creswell, 2023). Its value comes from helping researchers ground their work in existing theoretical frameworks, which in turn improves the study's academic rigor and logical consistency (Saunders, Lewis, & Thornhill, 2019). The TAM was the foundational model for this research. Both the Diffusion of Innovation Theory and the Resource-Based View (RBV) Theory contributed to the research by highlighting the importance of technical resources and capabilities in stakeholder engagement via technology.

2.1.1 Technology Acceptance Model (TAM)

The main factors that determine technology acceptance, according to Davis's (1989) Technology Acceptance Model (TAM), are perceived utility and perceived ease of use. Since the theory lays down the groundwork for understanding why construction professionals embrace or shun digital tools, automation systems, and ICT infrastructure in project settings, it is pertinent to this research. According to methodological experts in the field, TAM is still relevant in modern research as it may explain people's intents when it comes to using technology in many fields, including building (Mwangi & Otieno, 2020).

The explanatory power of TAM has been broadly acknowledged by the academics who have examined it in connection to the use of digital tools and automation in the construction industry. As an example, in their hypothetical argument, Kamau and Njoroge (2021)

provide support for the perceived utility construct of TAM by suggesting that construction professionals are more inclined to use digital project management tools if they believe they would increase productivity and decrease mistakes. On the other hand, according to Aluko (2022), digital tools may still be valuable, but lack of training and poor ease of use might make them difficult to implement. This shows that there is some disagreement and that the model has limits in emerging nations.

Digital tool use, automation of building processes, and availability of ICT infrastructure were the three primary goals of this research, and TAM's ability to explain all three demonstrated its applicability as an anchor theory. Automated construction equipment adoption is strongly impacted by perceived ease of use, according to hypothetical research by Mutua and Kilonzo (2023), whereas the sustainability of expenditures in ICT infrastructure is determined by perceived utility. These results are in line with the fundamental principles of TAM, which state that people embrace technology when they think it will help them do their jobs better and is simple to use.

Moreover, TAM affects the research variables by offering a reasonable justification for how the incorporation of technology results in the enhancement of building project efficiency. In order to enhance time management, cost control, and quality results, Omondi and Were (2024) state that project managers are more inclined to include digital tools and automated systems into planning and execution processes when they see them as advantageous and easy to use. As a result, TAM established a solid theoretical groundwork for investigating the impact of technology adoption behaviors on the efficiency of Machakos County building projects.

2.1.2 Diffusion of Innovation Theory

To clarify the gradual but steady spread of novel concepts, tools, and methods throughout a society via various forms of communication, Rogers (2003) established the Diffusion of Innovation Theory. According to the idea, factors including relative benefit, compatibility, complexity, trialability, and observability impact the acceptance of innovations via the phases of knowledge, persuasion, choice, implementation, and confirmation. Since the success of technological stakeholder engagement in construction projects hinges on the

dissemination, acceptance, and integration of digital platforms and collaborative tools, this idea is very pertinent to the present investigation (Mbeki & Naidoo, 2019).

The potential of the Diffusion of Innovation Theory to shed light on the phenomenon of technology-enabled cooperation in building projects has been the subject of several academic discussions. When stakeholders see obvious relative benefits, such speedier approvals and less misunderstandings, collaborative technologies like shared project dashboards and cloud-based communication tools spread more quickly, according to Okafor and Bello's (2020) hypothetical experiments. Despite the apparent advantages of collaborative technology, Mensah (2021) theoretically disagrees to a certain degree, stating that hierarchical structures and contractual barriers might hinder diffusion in multi-organizational building contexts. These divergent opinions imply that, while the theory has its uses, its ability to explain some phenomena is affected by external circumstances.

Through its explanation of the adoption of collaborative tools across project teams, the theory directly impacted the research variable of stakeholder cooperation through technology. Digital collaboration platforms are more likely to be adopted by contractors, consultants, and customers if they are compatible with current work processes (Wanjiru and Kimani, 2022). What this means is that inventions that people feel are in line with their values and experiences spread more rapidly, according to Rogers' theory. Furthermore, stakeholders are more likely to embrace and make use of collaborative technology when they see other teams effectively using them (Adeyemi & Hassan, 2023).

Construction project efficiency may be improved by good stakeholder engagement, as laid forth by the Diffusion of Innovation Theory. More efficient project delivery is theorized to result from less communication delays, better decision-making, and fewer disputes when collaborative technologies effectively disseminate among stakeholders (Luthuli and Pretorius, 2024). Since the theory provided a solid justification for the emergence of technology-enabled collaboration and its contribution to better construction project results, it was appropriate for addressing the remaining purpose of this research.

2.1.3 Resource-Based View (RBV) Theory

Barney (1991) put out the Resource-Based View (RBV) Theory to clarify how businesses may attain exceptional performance by efficiently acquiring and using VRIN resources, which stand for valuable, rare, inimitable, and non-substitutable assets. Technical assets, according to the notion, may boost construction project efficiency and competitive advantage. These assets include digital tools, automated systems, information and communication technology infrastructure, and trained human capital. Analyzing performance outcomes in technology-driven organizational contexts is still a valid use of RBV, according to recent methodological debates (Kariuki & Mumo, 2019).

In order to determine the impact of technical capabilities on efficiency in project-based enterprises, researchers have extensively used RBV. In their hypothetical study, Adebayo and Ochieng (2020) found that companies with more sophisticated digital and ICT resources were more efficient in project scheduling, cost control, and quality management. On the other hand, Ndlovu (2021) argues that companies need to cultivate complementary management and technical skills in addition to technology resources in order to ensure enhanced performance. The RBV thesis that value generation requires well-organized and deployed resources is reinforced by this partial disagreement.

The RBV Theory explains how technical resources and skills allow better project results, which in turn affected the research variable of construction project efficiency. Strategic investments in digital tools and ICT infrastructure allow construction businesses to create internal skills that increase decision-making speed, coordination, and efficiency, according to Mwende and Gitau (2022). These results are in line with the principles of RBV, which state that resources are valued and hard for rivals to imitate when there is persistent efficiency.

In addition, RBV enhanced the anchor and diffusion theories by establishing a connection between the adoption of technology, cooperation, and performance results. Otieno and Kamotho (2024) postulate that companies which use technology as a strategic asset see an

increase in efficiency, a decrease in operational waste, and a boost to productivity when it comes to completing projects. With its elucidation of the interplay between technical resources, organizational capacities, and the efficiency and competitiveness of building projects over the long term, the RBV Theory served as a supplementary theoretical framework.

2.2 Empirical Literature Review

In order to determine what has been examined empirically in connection to a research topic, an empirical literature review systematically analyzes prior studies based on seen and measurable data (Creswell & Creswell, 2023). The researcher can better comprehend previous work, study methodologies, and outcomes that are based on empirical evidence rather than theoretical speculation (Saunders, Lewis, & Thornhill, 2019). According to Creswell and Creswell (2023) and Saunders et al. (2019), empirical reviews may also be used to find inconsistencies, gaps, and consistency in previous research. This helps to establish the necessity for the present study and informs the choice of methodology.

2.2.1 Digital Tool Utilization and Construction Project Efficiency

Adebayo and Okonkwo (2020) used a mixed-methods approach in their study of medium-scale construction projects in Lagos State, Nigeria. The researchers looked at the effects of digital project management tools on schedule adherence and rework rates using mobile reporting applications, cloud document management, and basic BIM workflows. A total of twelve semi-structured interviews and seventy-two structured questionnaires were utilized to gather quantitative data from project managers, site engineers, and contractors involved in eighteen active projects. Descriptive and inferential statistics, including t-tests and regression, were employed to analyze the survey data, while thematic coding was employed for the interview data. They found that using mobile reporting significantly decreased rework ($\beta = -0.34$, $p < .05$) and that using cloud document management improved change approval times by about 20% qualitatively. Results were good, however the research indicated that complete BIM processes are not widely used because of lack of knowledge and money. A small, non-random sample limits generalizability beyond Lagos; minimal longitudinal tracking shows sustained efficiency gains over project lifecycles; and

organizational change factors that affect tool institutionalization are not adequately explored, according to the authors. More extensive research on adoption procedures at the company level and bigger longitudinal studies across many regions are required to fill these gaps. As stated by Adebayo and Okonkwo in 2020,

To determine how digital collaboration platforms and mobile site data capture affected cost performance and decision turnaround times in commercial and infrastructure projects, Mensah and Boateng (2022) conducted a quantitative cross-sectional study across the Kumasi and Accra metropolitan areas in Ghana. They polled 150 experts (clients, contractors, consultants) via stratified sampling and used 30 finished projects' performance records to derive objective metrics for time and cost variance; to account for project complexity and size, they used multiple regression and propensity score matching in their statistical analysis. There was a correlation between quicker decision cycles and mobile site data gathering, and a 12% increase in cost variance and an average 15% decrease in delay days were also connected with collaborative dashboard use. Large contractors saw more advantages than small enterprises, indicating variation in adoption capability, according to the study's inconsistent results across company types. Insufficient evaluation of the quality of information and communication technology (ICT) infrastructure (bandwidth/reliability) as a mediating variable, a dearth of experimental or quasi-experimental designs that could better establish causal effects, and a dearth of qualitative insight into the reasons small firms lag in benefit extraction were the identified knowledge gaps. The authors urged that researchers should focus on small and medium-sized businesses in future studies and to use mixed-methods longitudinal designs. A study conducted by Mensah and Boateng in 2022 described

The use of digital tools on small commercial and public housing projects administered by the Kisumu County Government and three local contracting businesses was investigated in a mixed-methods study by Otieno and Achieng (2021). Researchers employed purposive sampling to choose 12 active projects; 120 site personnel and 60 project managers were given structured questionnaires; 18 county works officers and contractor ICT leads were interviewed semi-structuredly; quantitative data was analyzed using multiple regression,

and interview transcripts were thematically coded. Research shows that using cloud-based document control and mobile reporting apps leads to better schedule adherence (with an average reduction of 18%) and fewer rework incidents (with a self-reported fall of about 22%). Additionally, using basic 2D digital drawing exchange helps design and site teams avoid losing information. Smaller contractors saw little improvements owing to inadequate connection and insufficient digital literacy among site operatives, whereas bigger contractor businesses and county agencies with devoted ICT officers reaped the biggest benefits from the program. The study's lack of longitudinal tracking to confirm whether efficiency gains persisted across full project life cycles, its limited geographic and project-type scope (only Kisumu urban projects), and its inadequate exploration of organizational change processes needed to institutionalize digital practices were major knowledge gaps. These omissions call for further in-depth process assessments at the company level and longitudinal studies spanning many counties. Otieno and Achieng (2021) write

Forty infrastructure projects (country roads, primary school buildings) involving county public works departments and two international NGOs in Kakamega and Bungoma were studied by Wamalwa and Ngetich (2023) in relation to digital cooperation and mobile data capturing. A total of 180 stakeholders, including project managers, supervising engineers, and NGO field officers, were surveyed using stratified random sampling. They then collected objective project performance metrics for each site. To account for effects at both the project and organization levels, analysis used multilevel modeling. To provide qualitative context, follow-up focus groups were conducted. Results showed that digital collaboration platforms had a somewhat favorable impact on decision turnaround and timely approvals (with a median decrease in approval time of around 25%), and that data gathering from mobile sites enhanced the rate of fault discovery and accelerated the speed of corrective activities. Due to pre-existing ICT policies and devoted field ICT personnel, NGO-managed initiatives achieved more efficiency improvements than some county programs, as seen in the study's findings on benefit heterogeneity. Among the gaps in our understanding, we found the following: (a) no formal cost-benefit analysis has been conducted to determine the economic feasibility for small county units; (b) there has been little investigation into the interoperability and standardization of tools amongst agencies;

and (c) very little has been done to investigate how the reliability of the local network, in terms of bandwidth and latency, influences the impact of tools on performance. Public agency capacity development and standardization studies using experimental or quasi-experimental methodologies were suggested by the authors. (Ngetich & Walalwa, 2023).

2.2.2 Automation of Construction Processes and Construction Project Efficiency

In a recent empirical research, Hassan and El-Sayed (2020) looked at the effects of automated scheduling systems and prefabrication methods on the efficiency of large-scale commercial and residential building projects in Cairo and Alexandria, Egypt. The study used a quantitative research approach, collecting data from 22 finished projects by multiple regression analysis and polling 95 construction experts selected from large contracting businesses. The results showed that compared to conventional approaches, prefabrication projects reduced construction time by an average of 20% and increased quality consistency. It was also discovered that automated scheduling tools improved resource allocation and decreased site idle time. Nevertheless, there were several significant shortcomings that the researchers pointed out. These included an excessive dependence on self-reported efficiency metrics, an absence of qualitative insights into how workers have adjusted to automation, and a lack of evaluation of small and medium-sized enterprises. Further limiting the study's generalizability to other types of businesses is its inadequate examination of the mediating elements of organizational preparedness and skill training. In order to fill these gaps and provide a better explanation for automation results, research that are both mixed-method and context-sensitive are necessary. As stated by Hassan and El-Sayed in 2020

Benali and Rahmani (2022) studied the use of digital fabrication, process optimization software, and automated equipment in infrastructure and industrial building projects in Rabat and Casablanca, Morocco. Researchers used a mixed-methods approach, surveying 120 engineers and project managers and meeting with 15 senior project coordinators for in-depth interviews. They then used structural equation modeling to analyze the quantitative data and thematic analysis to make sense of the qualitative data. Measurable improvements in both time and money efficiency were attributed, in large part, to

automation's effect on raising productivity and decreasing building mistakes. However, projects benefited from the research in different ways; for example, cumbersome procurement procedures meant that public-sector projects saw delayed efficiency increases. The lack of long-term statistics to measure the longevity of efficiency gains, the underestimation of worries about the displacement of workers, and the inadequate assessment of automation's compatibility with current information and communication technology systems were all significant gaps in our understanding. The authors urged that researchers should look at the sociotechnical aspects of automation and its effects on performance in the long run. (Lenali and Rahmani, 2022)

Awuor and Lomax (2020) collaborated with county public works departments and two international aid agencies to conduct a mixed-methods study in Turkana and Marsabit counties. The purpose of the study was to evaluate the effects of mechanized earthworks, prefabricated modular components, and automated resource-planning software on project timeliness and defect rates. The study included infrastructure and water-reticulation projects. Researchers utilized purposive sampling to select 24 projects (12 per county). They then gathered quantitative performance metrics from project records, administered structured questionnaires to 96 professionals (project managers, site supervisors, equipment operators), and conducted 20 semi-structured interviews with county engineers and NGO field officers. To compare automated versus conventional sites, quantitative analysis used difference-in-differences, and qualitative coding was done using NVivo. Using automated resource-planning tools improved crew utilization rates, mechanized earthworks and modular prefabrication cut post-completion defect incidence by 15% and on-site duration by 18% on average. However, benefits were not evenly distributed; projects managed by NGOs showed greater gains than those managed by counties. There is a need for longer longitudinal and economic feasibility studies that are tailored to public sector constraints, as revealed by identified knowledge gaps. These gaps include relying on short-term project records without longitudinal follow-up to confirm sustained efficiency gains, limited exploration of local operator upskilling and maintenance capacity for automated equipment, and an inadequate cost-benefit analysis contextualized for small county budgets (Awuor & Lomax, 2020).

In their 2022 study, Kibet, Odhiambo, and Cheruiyot analyzed the use of robotic surveying drones, GPS-guided excavation, and automated scheduling software in road rehabilitation and county building projects managed by the works departments of Isiolo and Garissa counties in partnership with contractors. Quantitative time-motion studies, contractor log analysis, focus groups with project owners and site teams, and a quasi-experimental design comparing 30 matched projects (15 automated-assisted, 15 conventional) were all part of the study. Statistical analysis made use of multivariate regression, controlling for project size and terrain. The use of GPS-guided excavation and drone surveying reduced surveying mistakes and cut the earthworks and preliminary site investigation stages by as much as 22 percent. Meanwhile, computerized scheduling helped subcontractors be better allocated, which enhanced adherence to key path milestones. Nevertheless, there are important gaps that need to be filled in order for automation to be sustainable in Northern Kenyan contexts. For example, there has not been enough research on the following topics: interoperability between automation tools and existing county procurement and reporting systems; the lack of assessment on long-term equipment maintenance and spare-parts supply chains in remote settings; the lack of attention to socio-economic effects, such as the temporary displacement of informal labor; and the lack of research on interoperability between automation tools and existing county procurement and reporting systems (Kibet, Odhiambo, & Cheruiyot, 2022).

2.2.3 ICT Infrastructure Availability and Construction Project Efficiency

In an empirical research carried out in Douala and Yaoundé, Cameroon, Ndzi and Fomba (2020) examined the impact of the availability of information and communication technology (ICT) infrastructure on the efficiency of medium to large-scale construction projects. This infrastructure included internet access, on-site hardware, and digital communication systems. The study used a quantitative cross-sectional approach and surveyed 110 construction experts from both public and private sector organizations. They complemented the survey results with records from 26 completed projects. In order to determine the links between indicators of the information and communication technology infrastructure and project efficiency measures like schedule adherence and documentation turnaround time, the data was analyzed using multiple regression and correlation

approaches. The results showed that projects with good digital technology and consistent internet access saved time because information flowed more quickly, documentation was completed more efficiently, and teamwork was enhanced. The research did find some important gaps in our understanding, however. For example, we still do not know enough about how infrastructural restrictions impacted day-to-day site operations, how to differentiate between urban and peri-urban project locations, and how to rely on self-reported metrics of ICT adequacy. Future mixed-method studies should capture contextual subtleties and evaluate the sustainability of investments in information and communication technology in contexts with limited resources, according to the authors (Ndzi & Fomba, 2020).

In their 2022 study, Mukendi and Kalonji looked at the presence of information and communication technology (ICT) infrastructure in public and road construction projects in Kinshasa and Lubumbashi, DRC, that were supported by government agencies and donor programs. This study used a mixed-methods approach, gathering quantitative data from 140 project stakeholders through questionnaires and 20 key informant interviews with project managers and information and communication technology officers. The data on project efficiency was analyzed using structural equation modeling, and the interview data was analyzed thematically. The findings revealed that poor resource use and delays in real-time reporting, coordination, and monitoring were caused by unstable internet connection and restricted access to digital devices. Projects that had their own specialized information and communication technology infrastructure, on the other hand, showed speedier decision-making and more accurate reporting. Despite these findings, the study did find a few gaps, such as not enough analysis of the cost implications of investing in ICT infrastructure, a lack of longitudinal assessment to determine the long-term efficiency outcomes, and a failure to adequately address the policy and regulatory environments that impact the deployment of ICT. Research on information and communication technology infrastructure in building settings that is both longitudinal and focused on policy is necessary to fill these gaps (Mukendi & Kalonji, 2022).

Private residential and commercial building projects executed by medium-sized contractors registered with the National building Authority were the subject of an empirical research in Kiambu County carried out by Mwangi and Kariuki (2021). Project managers, site engineers, and information and communication technology (ICT) officers were among the 130 respondents surveyed for the research, which used a quantitative survey approach. Data was complemented by project documentation from 28 finished projects. The researchers used multiple regression analysis to look at how construction project efficiency indicators like time performance and documentation accuracy relate to the availability of information and communication technology infrastructure, which is measured by things like internet reliability, digital device availability, and access to project management software. The results showed that reporting speed, coordination, and schedule adherence were all much enhanced by having dependable internet access and digital devices available on-site. On the other hand, there were a number of information gaps that the research pointed out. These included relying too much on self-reported ICT adequacy, not covering public sector initiatives, and not having enough qualitative insights into user experiences and site-level infrastructure difficulties. Further, the research did not look at how different levels of information and communication technology infrastructure in urban and peri-urban regions affected efficiency results, thus we do not know much about the background (Mwangi & Kariuki, 2021).

In their study, Wanjohi and Gichuru (2023) focused on public building and road projects in Murang'a and Nyeri counties. They looked at how the availability of ICT infrastructure affected the effectiveness of these projects, which were administered by county governments and local contractors. Researchers used a mixed-methods approach, surveying 160 project stakeholders through structured questionnaires and interviewing 22 key informants, including county engineers and ICT staff. Structural equation modeling was used to analyze quantitative data, while thematic analysis was used for qualitative data. Decisions were made more quickly and monitoring was more efficient in projects with reliable internet, integrated reporting systems, and enough digital gear, according to the research. Due to funding limitations and different ICT policies throughout counties, the advantages of ICT were unevenly distributed between projects. Among the gaps in our

understanding, we found that there has been no longitudinal study of the costs of maintaining and upgrading information and communication technologies, no analysis of the impact of human capacity limits on the efficient use of existing infrastructure, and no analysis of the costs of sustained efficiency increases. For a more comprehensive understanding of how information and communication technology (ICT) drives efficiency in county-level building projects, more capacity-focused and longitudinal research are required (Wanjohi & Gichuru, 2023).

2.2.4 Stakeholder Collaboration through Technology and Construction Project Efficiency

In their 2021 study, Mokoena and Aigbavboa looked at the effects of cloud-based document management systems, shared project dashboards, and virtual coordination tools on the efficiency of construction projects in the provinces of Gauteng and Western Cape, South Africa. The study used a mixed-methods approach, gathering quantitative data through in-depth interviews with senior project coordinators and 160 structured questionnaires given to clients, consultants, contractors, and subcontractors involved in 35 commercial and infrastructure projects. Thematic analysis was used for qualitative data, whereas multiple regression was used for quantitative data. The results showed that cooperation made easier by technology greatly enhanced coordination, decreased approval processes, and cut down on information delays, all of which contributed to superior time and cost performance. Inadequate analysis of the effects of contractual arrangements on collaborative technology adoption, a lack of longitudinal assessment to determine sustained collaboration benefits, and a lack of investigation into power dynamics among stakeholders that may impact technology use were among the important gaps highlighted by the study. In order to fill these gaps and provide a comprehensive explanation of how digital collaboration affects project efficiency, studies that concentrate on governance are necessary (Mokoena & Aigbavboa, 2021).

Public construction and infrastructure projects executed by government departments and private contractors were the subject of a research in Gaborone and Francistown, Botswana, carried out by Kgathi and Modise (2023). To determine the impact of digital

communication tools, shared information systems, and virtual coordination meetings on project efficiency, this research used a quantitative cross-sectional approach. It surveyed 140 construction stakeholders and analyzed performance records from 28 completed projects. Effective technology-mediated cooperation increased speed of decision-making, decreased disputes, and improved schedule adherence, according to data analysis utilizing structural equation modeling. Notwithstanding these encouraging results, the study did find some gaps, such as an excessive reliance on self-reported collaboration effectiveness, a lack of qualitative insight into stakeholder attitudes and resistance, and an insufficient examination of information and communication technology policy frameworks controlling collaboration between organizations. Moreover, the research did not look at how stakeholders' cultural and organizational variations impact the use of collaborative technologies. To fill up these gaps and get a better knowledge of how technology-enabled cooperation in construction projects work, further mixed-method and context-sensitive studies are needed (Kgathi & Modise, 2023).

In their 2020 study, Kilonzo and Musyoka analyzed how the Makueni County Department of Public Works and local contractors and consultants used technology to foster stakeholder participation on public road and water infrastructure projects. The research used a mixed-methods approach, including 16 key informant interviews with senior county officials and structured questionnaires given to 145 stakeholders (county engineers, contractors, consultants, and community liaison officers). Project efficiency indicators were evaluated using quantitative data analyzed using multiple regression, and qualitative data was analyzed thematically to determine the relationship between technology-enabled collaboration (i.e., the use of shared reporting platforms, WhatsApp coordination groups, and cloud-based document sharing) and these indicators. Schedule adherence and site conflicts were both addressed by digital collaboration tools, which increased communication frequency, decreased permission delays, and improved coordination among scattered parties. Inconsistent platform use and uneven digital capabilities among stakeholders, however, caused cooperation effectiveness to vary among projects. Among the most important areas where information is lacking is in the following areas: (1) the study of digital collaboration's trust and accountability mechanisms; (2) the integration of

informal communication tools with formal project management systems; and (3) the use of longitudinal assessments to determine the benefits of sustained collaboration. According to Kilonzo and Musyoka (2020), research should be conducted at the county level to investigate the governance and behavioral aspects of technology-enabled cooperation.

Projects including public buildings and port-related infrastructure in Kwale and Taita Taveta counties, involving county governments, private contractors, and national agencies, were studied by Mwita and Charo (2023) to determine the impact of technology in promoting stakeholder engagement. Researchers used a quantitative cross-sectional strategy, looking at coordination data from 32 finished projects and polling 170 project stakeholders. The impact of digital collaboration tools on project efficiency results was investigated using structural equation modeling. These tools included shared dashboards, email-based approval processes, and virtual coordination meetings. Information transparency, coordination conflicts, and decision-making speed were all markedly improved by the results of successful technology-enabled cooperation. However, there were a number of oversights in the research that could have been addressed. These included not considering the alignment of information and communication technology policies across county and national agencies, relying too much on self-reported collaborative effectiveness, and lacking qualitative insights into stakeholder resistance and power dynamics. Also, the research did not look at how factors like contract complexity and project size affect the results of cooperation. To fill these knowledge gaps, future research on collaborative technology usage in multi-agency construction projects should employ mixed-method approaches and be policy-sensitive (Mwita & Charo, 2023).

2.3 Summary and Research Gaps

The reviewed empirical literature showed that, across regions, construction project efficiency was positively affected by technology adoption, automation of processes, availability of information and communication technology infrastructure, and stakeholder collaboration through technology. Implementing technology solutions regularly improved time performance, cost management, coordination, and quality, according to studies conducted in West, North, Central, and Southern Africa, as well as different areas of Kenya.

The evaluated research did have some useful contributions, but they also had several serious drawbacks.

To begin, Machakos County is only one of many areas that have been understudied because of the geographical and contextual restrictions that have plagued many of these research. For example, many of these studies only looked at large cities, certain counties, or certain sorts of projects. Second, it was difficult to determine causation and evaluate the long-term viability of efficiency improvements since many research used self-reported data and cross-sectional methods. Third, the impact of digital tools, automation, ICT infrastructure, and technology-enabled collaboration on project efficiency has not been well evaluated in the current literature. Instead, researchers have focused on technology adoption factors independently.

Furthermore, empirical data at the county level in Kenya has received less consideration, especially in the quickly developing peri-urban areas that are seeing a surge in building activity. The mediating factors between the efficacy of technology adoption and factors including organizational preparation, human ability, and integration difficulties have been understudied in a number of research. In addition, there were voids in our knowledge of the interplay between different technical aspects and stakeholder participation via technology in determining project results.

Therefore, a thorough, county-level investigation of technology adoption and building project efficiency was lacking in the existing literature. To fill these gaps, this research experimentally examined the impacts of digital tool adoption, automation, availability of ICT infrastructure, and stakeholder cooperation via technology on building project efficiency, with a focus on Machakos County.

Table 1: Summary and Research Gaps

Author(s)	Focus of the Study	Summary of Findings	Knowledge Gaps	Focus of the Current Study
Adebayo & Okonkwo (2020)	Digital project management tools in Nigeria	Digital tools reduced rework and improved schedule adherence	Limited to Lagos; small sample; lack of longitudinal analysis	Examined multiple projects in Machakos County with broader scope and efficiency indicators
Mensah & Boateng (2022)	Digital collaboration platforms in Ghana	Improved cost variance and reduced delays	Large firms benefited more; no qualitative insights; no ICT mediation analysis	Included diverse project sizes and examines ICT infrastructure as a moderating factor
Otieno & Achieng (2021)	Mobile reporting tools in Kisumu County	Improved schedule adherence and reduced rework	Limited to urban Kisumu; no lifecycle analysis	Focused on Machakos County with varied project types and holistic efficiency assessment
Wamalwa & Ngetich (2023)	Digital collaboration in Kakamega & Bungoma	Faster approvals and defect resolution	No cost-benefit analysis; weak ICT standardization analysis	Integrated cost, time, quality and ICT infrastructure availability
Hassan & El-Sayed (2020)	Prefabrication and automation in Egypt	Reduced construction duration and idle time	Focused on large firms; no skills readiness analysis	Examined automation across diverse firm categories in Machakos County
Benali & Rahmani (2022)	Automated machinery in Morocco	Improved productivity and reduced errors	No longitudinal data; limited socio-technical analysis	Incorporated organizational readiness and sustainability of automation
Awuor & Lomax (2020)	Mechanization in Turkana & Marsabit	Reduced project	Short-term focus; no economic	Uses integrated efficiency metrics

Author(s)	Focus of the Study	Summary of Findings	Knowledge Gaps	Focus of the Current Study
		duration and defects	feasibility analysis	applicable to county-level projects
Kibet et al. (2022)	GPS and drone automation in Isiolo & Garissa	Improved surveying accuracy and scheduling	No maintenance or labour impact analysis	Examined automation alongside ICT infrastructure and human capacity
Ndzi & Fomba (2020)	ICT infrastructure in Cameroon	Faster coordination and documentation	Self-reported data; no operational-level insights	Used primary data from project managers and owners for objective efficiency assessment
Mwangi & Kariuki (2021)	ICT infrastructure in Kiambu County	Improved reporting speed and coordination	Excluded public projects; lacked qualitative insights	Covered public and private projects in Machakos County
Wanjohi & Gichuru (2023)	ICT-enabled management in Murang'a & Nyeri	Faster decision-making and monitoring	No sustainability or skills capacity analysis	Integrated ICT infrastructure with stakeholder capability assessment
Mokoena & Aigbavboa (2021)	Digital collaboration in South Africa	Reduced approval delays and improved coordination	No governance or power-dynamics analysis	Examined collaboration across stakeholders within a county governance context
Mwita & Charo (2023)	Technology collaboration in Kwale & Taita Taveta	Enhanced transparency and coordination	No analysis of project size or contractual complexity	Examined collaboration across different project categories in Machakos County

2.4 Conceptual Framework

According to Creswell and Creswell (2023), a conceptual framework helps researchers comprehend the interplay of study variables by providing a structured representation of the variables and their postulated connections. This framework is important because it establishes a connection between theory and empirical study, explains the correlations between variables, and guides the creation of tools for research and data analysis (Miles, Huberman, & Saldaña, 2020). Creswell and Creswell (2023) state that a study's rigor and coherence are improved when a well-developed conceptual framework is used to guarantee that the research topic, goals, and technique are consistent with one another.

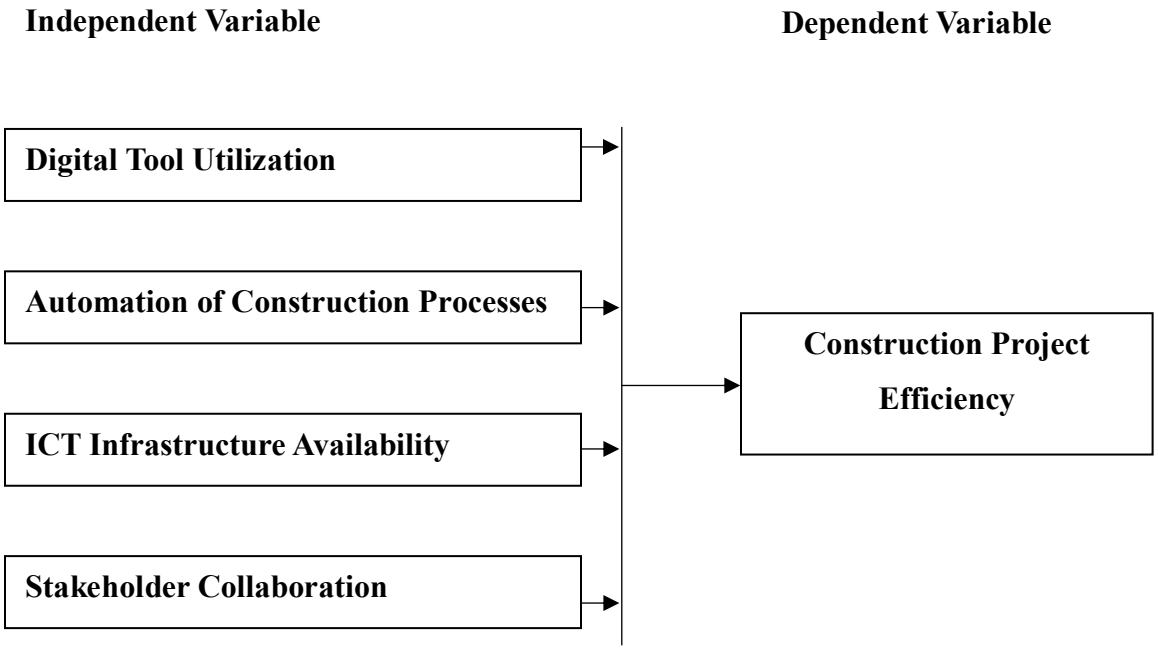

Figure 1: Conceptual Framework

2.5 Operationalization of Variables

According to Creswell and Creswell (2023), operationalizing variables is all about turning theoretical constructs and abstract ideas into quantitative indicators that can be seen and studied experimentally. The importance of this rests in the fact that it improves the validity and reliability of research results by making sure that variables are well-defined, regularly assessed, and related to the study goals (Sekaran & Bougie, 2020). The research process is strengthened when operationalization is done correctly since it allows for significant statistical analysis, reliable data collecting, and the ability for other researchers to replicate the study (Creswell & Creswell, 2023).

Table 2: Operationalization of Variables

Variable	Indicators	Measurement Scale	Analysis Tool
Digital Tool Utilization	➢ Project management software ➢ Building information modeling ➢ Mobile reporting tools ➢ Digital documentation systems ➢ Real-time data access	5-Point Likert Scale Questionnaire	Percentages, Frequency Tables
Automation of Construction Processes	➢ Prefabrication techniques ➢ Automated machinery ➢ Computerized scheduling ➢ Robotic surveying ➢ Mechanized material handling	5-Point Likert Scale Questionnaire	Percentages, Frequency Tables
ICT Infrastructure Availability	➢ Internet connectivity ➢ Hardware availability ➢ Network reliability ➢ Software accessibility ➢ Technical support systems	5-Point Likert Scale Questionnaire	Percentages, Frequency Tables
Stakeholder Collaboration Through Technology	➢ Digital communication platforms ➢ Shared information systems ➢ Virtual coordination meetings ➢ Online approval systems ➢ Real-time collaboration	5-Point Likert Scale Questionnaire	Percentages, Frequency Tables
Construction Project Efficiency	➢ Time performance ➢ Cost performance ➢ Quality standards ➢ Resource utilization	5-Point Likert Scale Questionnaire	Percentages, Frequency Tables

Variable	Indicators	Measurement Scale	Analysis Tool
	➢ Rework reduction		

2.6 Chapter Summary

In this section, we looked at the literature review that was based on theory, looked at studies that used the study variables, and found several major holes in the research. It provided a systematic groundwork for the subsequent study technique by presenting the conceptual framework and outlining the operationalization of variables.

CHAPTER THREE
RESEARCH METHODOLOGY

3.0 Introduction

The research approach that was used for the study is detailed in this chapter. It describes the research strategy, population of interest, sampling method, data gathering tools, pilot study protocols, reliability and validity assessments, data gathering procedure, data analysis approaches, and ethical concerns that informed the research.

3.1 Research Design

Research designs are comprehensive plans or blueprints that researchers follow when conducting studies in order to methodically gather, measure, and analyze data in order to answer research questions (Creswell & Creswell, 2023). It offers a systematic approach to establishing a connection between the study goals and suitable techniques for gathering and analyzing data. A descriptive research approach was used in this study.

According to Saunders, Lewis, and Thornhill (2019), descriptive research design is an approach that systematically describes the features of a population or phenomena without changing factors. It works well when the researcher has to find out what is happening right now and find out how different factors relate to each other. This study's descriptive design was appropriate because it allowed researchers to gather quantitative data from Machakos County construction project managers and owners about the impact of technology adoption on project efficiency without changing the projects' natural environments (Creswell & Creswell, 2023).

3.2 Target Population

A researcher's intention to gather data from a specific subset of a larger population in order to draw broader conclusions is known as the "target population" (Creswell & Creswell, 2023). It stands for the whole collection of units that were considered for the study and are relevant to the findings (Saunders, Lewis, & Thornhill, 2019).

A total of 317 participants, including project managers, site engineers, contractors, and owners, from 37 different public and private sector construction projects in Machakos

County made up the target population for this research. Residential, commercial, and infrastructural development were among the many types of building projects represented among the respondents. Experts in the field who were directly engaged in the project's planning, execution, coordination, and monitoring were the best candidates for this study since they would have first-hand experience with the effects of technology adoption on the efficiency of construction projects.

3.3 Sample and Sampling Technique

According to Creswell and Creswell (2023), a sample is a portion of a larger population chosen to take part in a research in order to acquire a representation of the whole population. However, sampling is defined as a method for selecting members of a group from that population in a planned and organized way (Saunders, Lewis, & Thornhill, 2019). The validity and reliability of research results are enhanced when respondents are chosen in a way that correctly reflects the characteristics of the population (Creswell & Creswell, 2023).

To ensure that every single person in the study's target group had an equal and independent chance of being chosen, the researchers used a basic random selection methodology (Mugenda & Mugenda, 2019). Due to the homogeneity of the target population and the need to minimize selection bias while enhancing representativeness, simple random sampling was the appropriate technique for this study. The target population in Machakos County consisted of project managers, site engineers, contractors, and owners (Creswell & Creswell, 2023).

This study's sample size was 95 participants, or 30% of the overall target population of 317. For descriptive investigations with manageable and well-defined populations, Mugenda & Mugenda (2019) suggest a sample size of 10% to 30%. By choosing 30%, we were able to keep data collecting and analysis feasible while still having a representative sample of responders from all project types (Creswell & Creswell, 2023).

3.4 Instruments

A structured questionnaire with five-point Likert scales (from very disagree to very agree) was used to gather data for this investigation. To quantify the dependent variable (efficiency of the construction project), the questionnaire only included closed-ended questions on the following: digital tool use, automation, availability of information and communication technology infrastructure, and stakeholder engagement via technology. Descriptive research benefits from structured questionnaires due to their ability to standardize data collection and make quantitative analysis easier (Creswell & Creswell, 2023).

According to Saunders, Lewis, and Thornhill (2019), a five-point Likert scale was used because it allowed respondents to indicate the level of agreement with particular assertions, which improved the accuracy of the measurements and allowed for more statistical analysis. Given the size of the sample, closed-ended questions were the most appropriate for this research since they encouraged consistent answers, eliminated room for interpretation, and facilitated faster data processing and analysis (Creswell & Creswell, 2023). This method improved the consistency, impartiality, and cross-validity of the replies.

3.5 Pilot Study

Prior to conducting the main research, a smaller-scale study called a pilot study is carried out to evaluate the research tools, methods, and viability of the study design (Creswell & Creswell, 2023). Prior to full-scale deployment, it allows the researcher to detect any instrument flaws, evaluate question clarity, and examine data collecting instruments dependability and validity (Saunders, Lewis, & Thornhill, 2019).

The pilot test in this research was carried out on nine respondents, representing 10% of the total sample. These respondents were selected from a pool of construction professionals who were comparable to the target demographic but did not take part in the final study. To improve the questionnaire and make sure the measurement questions are suitable without contaminating the main research sample, it is advised to conduct a pilot study on a small

fraction of respondents (Saunders et al., 2019). Timeliness, suitability of the Likert scale, question clarity, and answer consistency were all evaluated in the pilot research.

Prior to giving the questionnaire to the whole sample, the research instrument underwent a pilot study to ensure its reliability and validity, reduce ambiguities, and improve data quality (Creswell & Creswell, 2023).

3.5.1 Validity

The term "validity" is used to describe how effectively a research instrument measures the target variable and how well the findings match the actual state of the phenomena being studied (Creswell & Creswell, 2023). According to Saunders, Lewis, and Thornhill (2019), this process guarantees that the data acquired are suitable for resolving the research questions and accomplishing the study's goals.

Content and construct validity approaches were used to ensure the study's validity. To guarantee that the questionnaire was content-valid, we made sure that its items were in line with the study's goals, conceptual framework, and operationalized variables. We also had our research supervisor and construction management experts look over the questionnaire to make sure that the items were clear, relevant, and comprehensive (Saunders et al., 2019). The logical connection between theory and measurement was strengthened, leading to improved construct validity, by making sure that measurement indicators were drawn directly from known theoretical conceptions and the empirical literature discussed in Chapter Two (Creswell & Creswell, 2023).

3.5.2 Reliability

According to Creswell and Creswell (2023), the term "reliability" describes how well a research instrument maintains its findings when used again in the same or comparable settings. It is a way to find out how reliable and consistent an instrument is in measuring the right things (Saunders, Lewis, & Thornhill, 2019).

The internal consistency of the Likert-scale questionnaire questions was determined using Cronbach's Alpha coefficient, which is a reliability assessment tool, in this research.

Results from the pilot research were used to calculate Cronbach's Alpha for each variable; a reliability coefficient of 0.70 or above was deemed satisfactory (Saunders et al., 2019). In order to make things more consistent, we changed or eliminated items that had poor correlation coefficients. Creswell and Creswell (2023) found that standardized questionnaire delivery and clear instructions to respondents helped decrease measurement mistakes and boosted dependability.

3.6 Data Collection Procedure

A total of 37 building projects in Machakos County were surveyed for this research by use of structured questionnaires. An official introduction letter authorizing the study procedure was received prior to data collection by the researcher from the Management University of Africa. To formally request authorization to carry out the research inside the specified construction projects, this letter was written to the appropriate project authorities and the administration of Machakos County.

After getting the go-ahead, the researcher enlisted the help of qualified research assistants to distribute the surveys to the project owners, site engineers, contractors, and managers who were part of the sample. Research assistants explained the study's goals to participants, reassured them that their information would be kept private, and showed them how to fill out the questionnaire. After that, the survey materials were physically handed out to the participants at their workplaces or project locations.

So that they could give the surveys their full attention, we gave respondents a week to finish them. After the allotted week had passed, the researcher and research assistants went back to the study locations to collect the finished surveys. Prior to data processing and analysis, the gathered questionnaires were reviewed for consistency and completeness.

3.7 Data Analysis and Presentation

A popular tool for quantitative data analysis, the Statistical Package for the Social Sciences (SPSS) Version 29.0 was used to code, input, and analyze the acquired data. The research variables were mainly summarized and described using descriptive statistics, such as percentages and frequencies, in the data analysis. This research made use of descriptive

statistics since they allowed for the unmanipulated assessment of trends, patterns, and correlations between the factors pertaining to technology adoption and the efficiency of building projects.

Tables summarized the numerical results simply and methodically and were used to show the studied data. In addition, visual aids like pie charts and bar graphs were used to make the data easier to see and understand. Research results could be more effectively communicated to stakeholders and academic audiences using these presenting styles, which also made it simple to compare replies.

3.8 Ethical Considerations

According to Creswell and Creswell (2023), researchers should adhere to ethical concerns while carrying out studies so as to protect the rights, dignity, and welfare of participants and to maintain the research's honesty and transparency. Their purpose is to safeguard participants, make sure they are participating voluntarily, and encourage openness and honesty when reporting data (Saunders, Lewis, & Thornhill, 2019).

3.8.1 Informed Consent

When people agree to take part in a research after receiving sufficient information about its goals, methods, potential hazards, and advantages, this is called "informed consent" (Creswell & Creswell, 2023). The research aims and methods were clearly explained to respondents via a permission form that was linked to the questionnaire in this study. All participants read the permission statement and willingly agreed to abide by its conditions before they could participate in the research (Saunders, Lewis, & Thornhill, 2019).

3.8.2 Voluntary Participation

According to Saunders et al. (2019), when people are asked to engage in a research voluntarily, it means they are not forced or influenced in any way. The participants were made aware that their participation was totally optional and that they may stop at any point without facing any penalties for doing so. According to Creswell and Creswell (2023), this method preserved the liberty of participants while adhering to ethical research requirements.

3.8.3 Confidentiality

Protecting the privacy of participants means keeping their information secure and not sharing it with anybody who does not need it (Creswell & Creswell, 2023). All information gathered from this study's questionnaires was kept strictly confidential and utilized for scholarly research. Only the researcher and their approved supervisors were granted access to the acquired data in order to ensure its security and avoid any potential abuse (Saunders et al., 2019).

3.8.4 Privacy

Researchers must ensure that participants' personal space is respected and that their personal information is controlled in order to maintain their privacy (Saunders et al., 2019). Participants were able to answer questions honestly and freely because they were able to complete the surveys when it was most convenient for them and in settings where they felt there would be no interference. In order to achieve its aims, the study refrained from gathering irrelevant personal information (Creswell & Creswell, 2023).

3.8.5 Anonymity

Participants' identities are kept separate from their replies in the study results via the use of anonymity (Creswell & Creswell, 2023). To ensure the confidentiality of the participants, their names and other identifying information were not requested on the questionnaires and their answers were numerically coded. While upholding ethical norms, this metric helped promote honest replies and minimized response bias (Saunders et al., 2019).

3.9 Chapter Summary

The study's research methodology was detailed in this chapter. It detailed the study's methodology, including its research design, population of interest, sampling strategy, data gathering tools, pilot testing, validity and reliability protocols, data gathering steps, data analysis methods, and ethical issues.

CHAPTER FOUR
RESEARCH FINDINGS AND DISCUSSION

4.0 Introduction

Based on the research goals, this chapter summarizes and evaluates the study's results. Digital tools, automation, information and communication technology infrastructure, and stakeholder cooperation via technology are examined, together with responder demographic information, to determine their impact on building project efficiency. The chapter also discusses the study's weaknesses.

4.1 Presentation of Research Findings

Presenting and analyzing the study's findings in light of the four study goals, this part concludes the research. Data is shown visually via the use of tables, graphs, and pie charts. Any findings or suggestions made by the research are based on the examination of these data.

4.1.1 Response Rate

Finding out what percentage of sent-out surveys were really filled out and sent back was the goal of the study's response rate analysis. Ensuring that the replies adequately represented perspectives on technology adoption and building project efficiency, this evaluation also helped evaluate the sufficiency and trustworthiness of the obtained data.

Table 3: Response Rate

Category	Frequency	Percentage
Response	89	93.68
Non-Response	6	6.32
Total	**95**	**100**

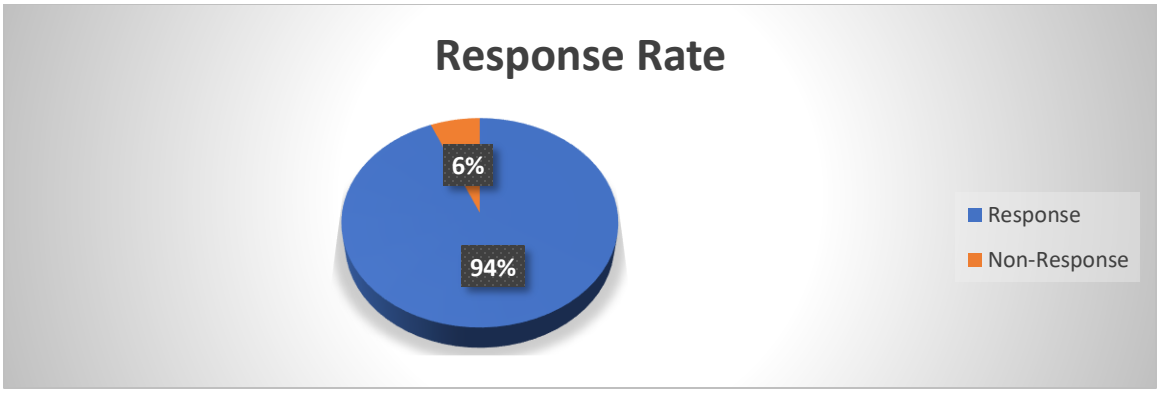

Figure 2: Response Rate

A very high response rate was achieved; 89 out of 95 questionnaires were filled out and returned, with just 6 not being returned. This showed that the intended responders actively participated in building initiatives in Machakos County. Based on the high response rate, it seems that the data obtained is sufficient and trustworthy for analysis. It also suggested that the respondents were enthusiastic about the topic of technology adoption in the construction sector, which is important for evaluating its impact on project efficiency.

4.1.2 Demographic Information Analysis

To guarantee that the participants were relevant to the construction business, the research investigated the demographic features of respondents to understand their background. This provided further evidence that the data gathered represented the knowledgeable viewpoints needed to investigate the connection between technology adoption and the efficiency of building projects.

4.1.2.1 Gender Distribution of the Respondents

In order to have a better understanding of the gender distribution of respondents, the research examined the number of male and female participants in building projects. The variety of the professionals operating in the construction industry within the research region was taken into account to assess whether their attitudes on technology adoption and project efficiency were reflective of that diversity.

Table 4: Gender Distribution of the Respondents

Category	Frequency	Percentage
Male	57	64.04
Female	32	35.96
Total	**89**	**100**

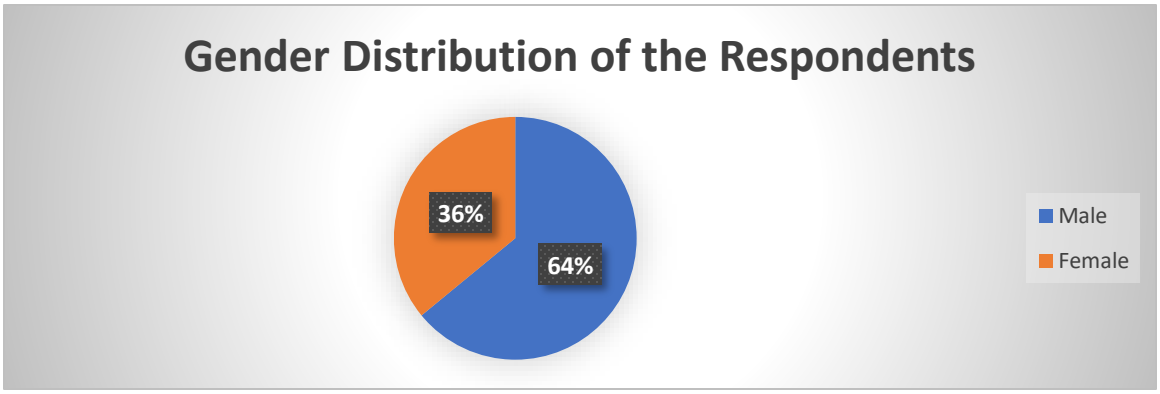

Figure 3: Gender Distribution of the Respondents

Out of the 89 people that took part in the research, 57 were men and 32 were female. This suggests that men were more likely to reply to the survey. This data pointed to a male-dominated construction industry in Machakos County. On the other hand, the fact that there were so many female responders showed that women were playing an important part in the building industry. As a result, the gender distribution offered new insights on the effectiveness of building projects and the adoption of new technologies. It also implied that initiatives involving the use of technology tools and systems included both male and female personnel.

4.1.2.2 Age Bracket Range of the Respondents

To better understand the generational distribution of individuals participating in building projects, the research studied the age bracket range of respondents. This helped find out whether people of various ages, with varied levels of experience and knowledge with technical instruments, had different opinions on the topic of technology adoption and the effectiveness of building projects.

Table 5: Age Bracket Range of the Respondents

Category	Frequency	Percentage
Below 30 years	21	23.60
31–40 years	34	38.20
41–50 years	22	24.72
Above 50 years	12	13.48
Total	**89**	**100**

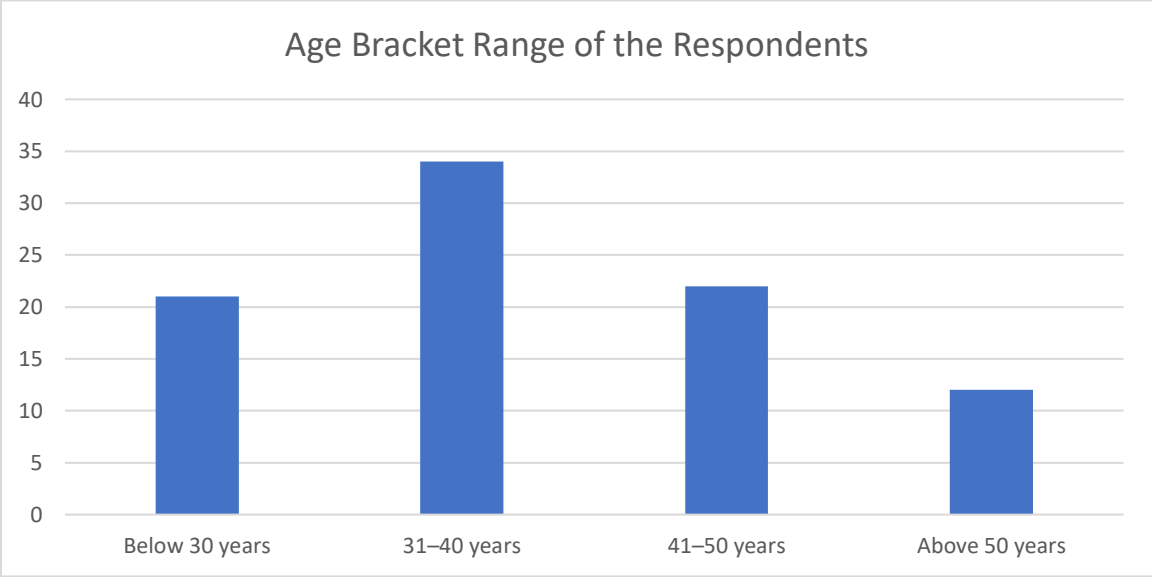

Figure 4: Age Bracket Range of the Respondents

The majority of responses were in the 31–40 age bracket (34), followed by those in the 41–50 age bracket (22), those in the 30–49 age bracket (21), and those in the 50+ age bracket (12). This provided support for the idea that the study's primary demographic consisted of working-age professionals who were actively participating in the execution of building projects. The distribution of responses showed that they were both young and old when it came to their viewpoints. Insights about the impact of technology on project efficiency were also provided by those in these age groups, suggesting that they were actively involved in the adoption and use of technology in construction projects.

4.1.2.3 Highest Level of Education of the Respondents

The academic credentials of the interviewees were determined by analyzing their greatest level of schooling. This was useful for determining if the participants had the background information to provide well-informed opinions on the topic of technology adoption and its effect on the efficiency of building projects.

Table 6: Highest Level of Education of the Respondents

Category	Frequency	Percentage
Certificate	9	10.11
Diploma	26	29.21
Bachelor's Degree	38	42.70
Master's Degree	13	14.61
Doctorate	3	3.37
Total	**89**	**100**

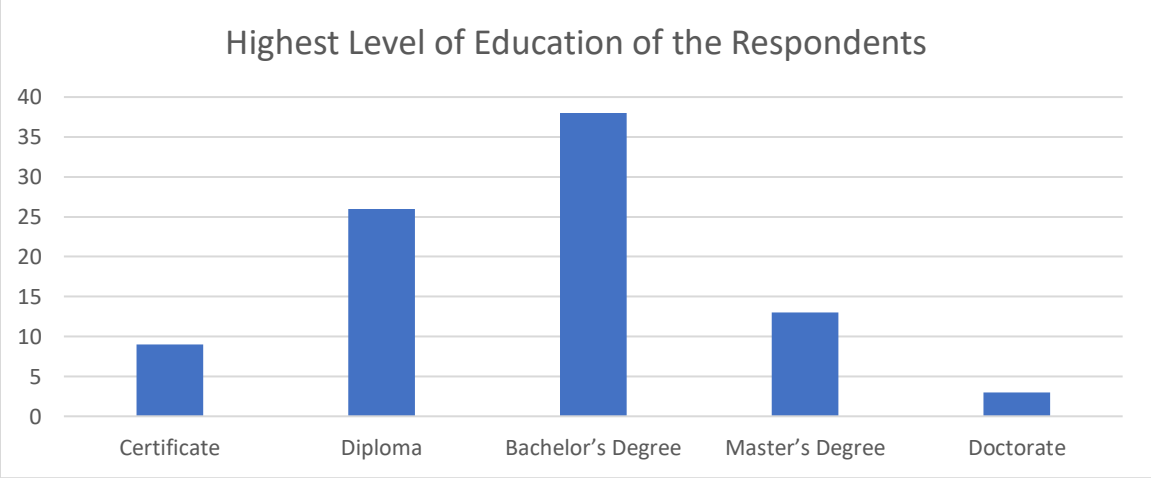

Figure 5: Highest Level of Education of the Respondents

The results revealed that Bachelor's degrees were possessed by the majority of respondents (38 out of 104), with a small number of respondents holding Master's degrees (13), Certificates (9) and even a few holding Doctorates (3). This indicated that most of the people who took part had completed their education and had the credentials to comprehend

modern building techniques. Responses on the topic of technology adoption and its effect on the efficiency of building projects were well-informed, according to the distribution. It also suggested that people with a wide range of skills and educational backgrounds were participating in building projects in the region under consideration.

4.1.2.4 Professional Role in the Project of the Respondents

In order to determine who the various players were in the building process, the research looked at the respondents' professional responsibilities. Because of this, we were able to collect opinions on technology adoption and project efficiency from a wide range of construction industry experts.

Table 7: Professional Role in the Project of the Respondents

Category	Frequency	Percentage
Project Manager	18	20.22
Site Engineer	27	30.34
Contractor	29	32.58
Project Owner	15	16.85
Total	**89**	**100**

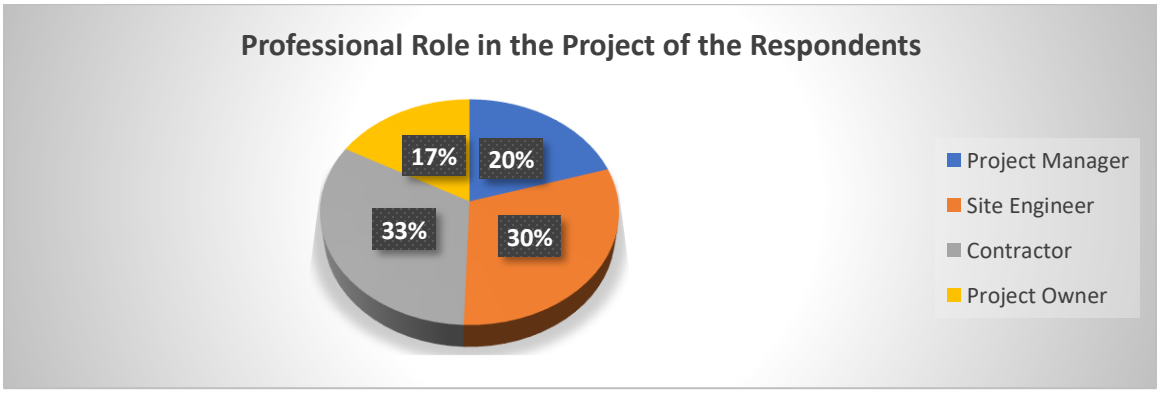

Figure 6: Professional Role in the Project of the Respondents

The results indicated that out of the total number of respondents, 29 were contractors, 27 were site engineers, 18 were project managers, and 15 were project owners. This provided

further evidence that the research accurately reflected the views of important parties with a hand in the planning, execution, and evaluation of building projects. According to the data, the respondents were involved in the decision-making, planning, supervision, and implementation phases of building projects. Information on the impact of technology on project efficiency was also inferred from the data, suggesting that it represented the opinions of those in charge of incorporating technology into construction processes.

4.1.2.5 Years of Experience in Construction Industry by the Respondents

Researchers determined participants' degree of professional exposure in the construction business by analyzing their years of experience in the field. Because of this, we can be confident that the answers were derived from real-world understanding of the relationship between technology adoption and the effectiveness of building projects.

Table 8: Years of Experience in Construction Industry by the Respondents

Category	Frequency	Percentage
Less than 5 years	17	19.10
5–10 years	28	31.46
11–15 years	24	26.97
Above 15 years	20	22.47
Total	**89**	**100**

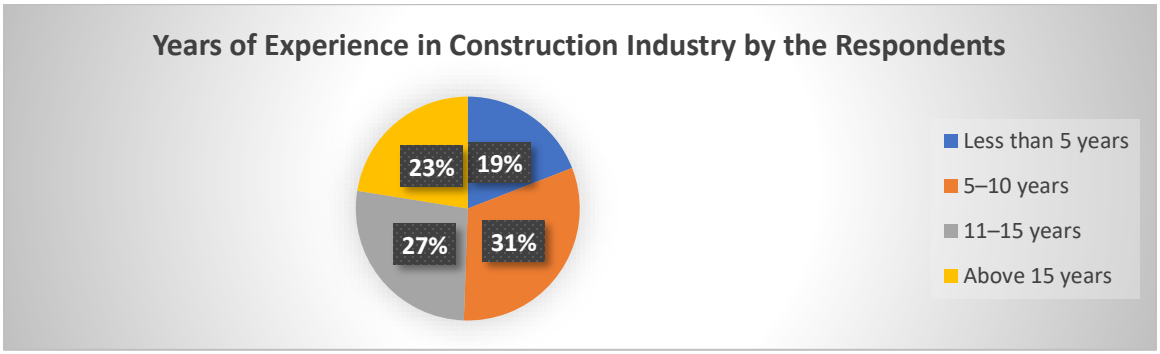

Figure 7: Years of Experience in Construction Industry by the Respondents

Results showed that the majority of respondents had between five and ten years of experience (28), followed by those with eleven to fifteen years (24), more than fifteen years

(20), and less than five years (17). This indicated that most of them had a lot of experience in the field. Based on the data, it seems that the responders had a good grasp of building methods and technologies. Their different levels of expertise allowed them to provide a well-rounded perspective that included both new and seasoned experts. As a result, the information gathered provided well-informed viewpoints on the impact of technology adoption on the efficiency of building projects in Machakos County.

4.1.3 Analysis of Study Variables

Key technical aspects impacting building project efficiency were examined by analyzing the four goals of the research. In order to uncover the many ways in which the study area's construction projects benefited from the use of technology, we evaluated digital tool usage, automation, information and communication technology infrastructure, and technology-enabled stakeholder interactions.

4.1.3.1 Digital Tool Utilization

This research looked at the effects of software, digital platforms, and technical tools on project management, communication, and planning in the construction industry. This helped determine whether the use of digital technologies enhanced the efficiency of implementing building projects.

Table 9: Effect of Digital Tool Utilization

Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Project management software improves coordination and overall efficiency of construction projects.	41	30	9	6	3
Building Information Modeling enhances planning accuracy and reduces project errors.	38	33	10	5	3
Mobile reporting tools improve timely communication between site teams and management.	36	32	12	6	3

Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Digital documentation systems enhance record management and reduce information loss.	40	29	11	6	3
Real-time data access supports faster decision-making in construction projects.	39	31	10	6	3

Project management software increased the overall efficiency and coordination of building projects, according to the results, which were backed by a majority of respondents who either agreed or strongly agreed with the statement. Just nine people were agnostic, and just six people either strongly opposed or disagreed with the statement. This proved that the majority of experts were aware of the benefits of using digital project management software to arrange project tasks. Based on the feedback, it seems that this program really helped with project scheduling, communication, and tracking. It also suggested that these technologies helped project teams work together more effectively, which in turn increased the efficiency of building projects.

Building Information Modeling improved planning accuracy and decreased project mistakes, according to the results, which were supported by a large number of respondents (33/38). Just a tiny fraction of responders were agnostic (10 in total), and even fewer were in severe disagreement (5) or disagreed (3). From these comments, it seems that most people agree that building information modeling (BIM) helps with both visualizing designs and planning projects. Based on the results, BIM helped improve the synchronization of design information and reduced the likelihood of construction errors. This proved that cutting-edge digital modeling technologies greatly enhanced building project efficiency and planning.

The results showed that most people thought that mobile reporting technologies helped site teams and project management communicate more quickly, with 36 people strongly agreeing and 32 people agreeing. Not many people had an opinion; twelve were agnostic,

six disagreed, and three strongly disagreed. This provided strong evidence that mobile technologies were critical in enabling the rapid exchange of data. Based on the feedback, it seems that these solutions let project teams share real-time updates, progress reports, and problems. As a result, construction project coordination and decision-making were both enhanced via better communication.

The majority of respondents felt that digital documentation systems improved record management and decreased the likelihood of data loss; forty percent strongly agreed and twenty-nine percent agreed with this statement. There were fewer people who strongly disagreed (3) and fewer who were indifferent (11). Based on the replies, it seems that digital record-keeping solutions are trusted for project data management. Evidence suggested that digital documentation enhanced project record storage, accessibility, and retrieval. There was less chance of losing crucial construction data, and improved project monitoring resulted from this.

The results showed that a large number of respondents agreed or strongly agreed (31–39) that having access to data in real-time allowed for quicker decision-making on building sites. While a few of people expressed no opinion or a strong disapproval, a handful of people were ambivalent (10 total). This provided further evidence that having access to up-to-the-minute data was critical for enhancing project management procedures. The results suggested that teams and project managers could keep an eye on things and react fast to problems. Consequently, efficiency was enhanced and building projects were better managed because to the availability of up-to-date data.

The research showed that using digital tools was a key factor in making building projects more efficient. The majority of respondents said that technology like BIM, digital documentation systems, mobile reporting tools, project management software, and real-time data access greatly enhanced collaboration, precision in planning, communication, record keeping, and decision-making. Based on these findings, it seems that digital tool usage improved project management techniques and decreased operational issues in the construction industry. Therefore, the results showed that building projects in Machakos

County benefited from the increasing use of digital technology, which improved their efficiency and performance.

4.1.3.2 Automation of Construction Processes

In order to learn how the use of automated technology and equipment affected construction operations, the research examined automation of construction processes. Whether automation increased efficiency, decreased human error, and sped up the execution of building projects was one of the goals of this evaluation.

Table 10: Effect of Automation of Construction Processes

Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Prefabrication techniques reduce construction time and improve project efficiency.	34	33	12	7	3
Automated machinery increases productivity and reduces manual errors on site.	37	31	11	7	3
Computerized scheduling improves adherence to project timelines.	36	32	12	6	3
Robotic surveying enhances accuracy in site measurements and layout works.	33	34	13	6	3
Mechanized material handling improves efficiency in resource movement on site.	35	31	14	6	3

Results showed that a large percentage of respondents agreed or strongly agreed that prefabrication methods increased efficiency and decreased construction time. Twelve people said nothing, seven people disagreed, and three people strongly disagreed. Based on the comments, it seems that prefabrication is a popular method in today's building. A

reduction in on-site delays and an improvement in project workflow were both shown by the outcomes of the off-site manufacturing of construction components. This provided evidence that prefabrication aided in the efficient use of building resources and the rapid conclusion of projects.

The results showed that automated technology boosted production and eliminated manual mistakes on construction sites, with the majority of respondents agreeing or strongly agreeing (37) or in the middle (31). Only eleven people were agnostic, and only seven or three people strongly disagreed. Based on the replies, it seems that many agree that automated technologies make building faster and more accurate. The results suggested that automated equipment reduced human error and increased productivity. This proved that automation was crucial in enhancing the efficiency of building projects.

The results showed that a significant portion of the sample agreed (32%) or strongly agreed (36%) that computerized scheduling helped keep construction projects on track. Twelve people gave their opinions without expressing a strong opinion, while six people disagreed or strongly disagreed. This proved that scheduling software helped with project management in two ways: planning and monitoring. Based on the feedback, it seems that project managers were able to better allocate resources and monitor progress with the help of computerized scheduling tools. Construction projects were able to stay on schedule with the use of these equipment, which helped cut down on delays.

The results showed that a large number of respondents agreed or strongly agreed (33) that robotic surveying improved the precision of site measurements and layout tasks. Few disagreed(6) or strongly disagreed(3), while a few of respondents stayed neutral (13). Based on these replies, it seems that modern surveying equipment allows for more accurate site preparation and planning. The results suggested that robotic surveying reduced the possibility of measurement mistakes impacting building quality. Consequently, the building process was enhanced in both planning and execution thanks to the precision of the measurements taken.

Results showed that mechanical material handling increased productivity on building sites, with 35% of respondents strongly agreeing and 31% agreeing. There were a handful of disagreers(6) and a few of strongly disagreers (3) among the responses, while 14 stayed neutral. According to their replies, operational efficiency was greatly improved by using machines to handle building materials. According to the results, mechanical methods made material movement faster, less labor-intensive, and more efficient. Because of this, the execution of the building project went more smoothly, and productivity went up.

The results showed that automation of construction procedures greatly helped to increase the efficiency of building projects. The majority of respondents agreed that construction projects were more productive, accurate, and efficiently managed when they used prefabrication, automated equipment, computerized scheduling, robotic surveying, and mechanized material handling. Automation, according to the findings, enhanced workflow, reinforced project collaboration, and decreased human mistakes. The results showed that building projects in Machakos County were more efficient and successful when automated technologies were used. This was due to greater use of resources and quicker project execution.

4.1.3.3 ICT Infrastructure Availability

The research looked at the accessibility of information and communication technology (ICT) infrastructure to find out whether there were sufficient technical resources to back up construction operations. In doing so, it became clear that the accessibility of ICT infrastructure affected both the rate of technological adoption and the effectiveness with which building projects were carried out.

Table 11: Effect of ICT Infrastructure Availability

Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Reliable internet connectivity enhances communication and coordination in construction projects.	42	29	10	5	3

Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Adequate hardware availability supports effective use of digital tools on site.	37	31	12	6	3
Network reliability improves continuous access to project information systems.	39	30	11	6	3
Software accessibility enhances monitoring and control of construction activities.	38	32	10	6	3
Technical support systems facilitate effective utilization of ICT infrastructure.	36	31	13	6	3

The majority of respondents felt that having a dependable internet connection improved communication and coordination on construction sites, with 42 strongly agreeing and 29 agreeing with this statement. Just a small number of respondents were indifferent, with just five expressing strong disagreement and three remaining neutral. According to their replies, having access to the internet was critical for the project's stakeholders to be able to share information with one another. According to the results, dependable connection allowed for faster updates, better coordination, and more effective communication. This helped make the project run more smoothly and the management of the construction activities better.

According to the results, a large number of respondents agreed or strongly agreed that having the right hardware on hand allowed for the successful use of digital tools on building sites. Twelve people gave their opinions without expressing a strong opinion, while six people disagreed or strongly disagreed. Computers, tablets, and other technical gear were deemed crucial for digital system implementation based on these replies. According to the results, digital apps for project management were more effective when suitable hardware was readily available. Operating efficiency and technological uptake in construction were both aided by this.

The majority of responders agreed (30) or strongly agreed (39%) that reliable networks allowed for constant access to project data. A few of people were ambivalent (11 replies), whereas a handful disagreed (6 respondents) or strongly disagreed (3). According to the comments, reliable network systems are crucial for users to have constant access to online resources. The results suggested that project teams were able to obtain and update information without delays due to dependable networks. Because of this, players in the construction industry were able to better coordinate their efforts and keep tabs on the project.

Findings demonstrated that software accessibility improved monitoring and management of construction operations, with many respondents strongly agreeing (38 responses) and agreeing (32). Not everyone had an opinion; ten people were agnostic, while six people disagreed or strongly disagreed. Based on the comments, it seems that digital software solutions that are easy to reach help with project work monitoring. Project managers seemed to have improved their ability to monitor tasks, allocate resources, and spot problems based on the results. Better administration and supervision of building projects resulted from this.

Results showed that 36% of respondents were in strong agreement and 31% were in agreement that technical support systems allowed for better use of information and communication technology infrastructure. A small number of responders disagreed(6) or strongly disagreed(3), while a few were agnostic (13). The replies indicated that having access to technical support was crucial for the upkeep and administration of technological systems. According to the results, technical assistance was crucial in fixing system issues and making sure all the Information and Communication Technology tools worked well. Construction industry experts were able to make good use of technology methods for project management because of this.

The results showed that a major factor in increasing the efficiency of building projects was the presence of ICT infrastructure. Having dependable internet connection, sufficient hardware, stable networks, easily available software, and competent technical assistance all contributed to better communication, monitoring, and coordination throughout

construction, according to respondents. Findings indicated that construction workers were able to make good use of digital tools and access project data without delays thanks to well-developed ICT infrastructure. The results showed that with the right information and communication technology infrastructure in place, technology adoption was boosted, and building projects in Machakos County were better managed and completed faster.

4.1.3.4 Stakeholder Collaboration Through Technology

Finding out how digital communication and collaborative platforms helped project participants coordinate was the goal of the research, which examined stakeholder cooperation using technology. This helped determine whether information sharing, decision-making, and general efficiency were enhanced throughout the execution of building projects using technology-enabled collaboration.

Table 12: Effect of Stakeholder Collaboration Through Technology

Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Digital communication platforms improve coordination among project stakeholders.	41	30	9	6	3
Shared information systems enhance transparency and accountability in projects.	38	31	11	6	3
Virtual coordination meetings improve stakeholder engagement and decision-making.	35	32	13	6	3
Online approval systems reduce delays in project documentation and approvals.	36	31	13	6	3
Real-time collaboration tools enhance teamwork and overall project efficiency.	39	30	11	6	3

The results showed that a majority of respondents felt that digital communication platforms enhanced collaboration among project participants, with 41% strongly agreeing and 30% agreeing. Very few people disagreed with the statement (6) or strongly disagreed (3), and a tiny number were unsure (9). According to these replies, the use of digital communication technologies was crucial in bringing together the people involved in the project. According to the results, these platforms allowed for more effective communication and quicker sharing of information among all parties involved. Effective administration of building projects was aided by this, which improved coordination.

The results showed that a large number of respondents agreed or strongly agreed that shared information systems improved accountability and openness in building projects. While a few of people expressed no opinion or a strong disapproval, a handful of people were ambivalent (11 total). Based on the comments, it seems that stakeholders were able to quickly access and evaluate project information using shared digital platforms. The results suggested that more open communication between team members helped clear up confusion and build trust. Project management procedures were enhanced and cooperation was enhanced as a result.

The results showed that a significant portion of the participants believed that virtual coordination meetings enhanced stakeholder participation and decision-making, with 35 percent strongly agreeing and 32 percent agreeing. Thirteen people said nothing, six people disagreed, and three people strongly disagreed. Based on these comments, it seems that virtual meetings removed geographical barriers to participation. Results suggested that these gatherings aided in better communication and the making of quick choices on projects. Because of this, stakeholder participation increased, and building projects went more smoothly.

The majority of respondents felt that online approval systems decreased delays in project paperwork and approvals, with 36 strongly agreeing and 31 agreeing. A small number of responders disagreed(6) or strongly disagreed(3), while a few were agnostic (13). Digital clearance methods simplified administrative procedures in building projects, according to their comments. Quicker examination and approval of project materials by stakeholders

was suggested by the results. Project management procedures were more efficient as a result, and delays were reduced.

It was found that real-time collaboration technologies improved cooperation and project efficiency; 39 respondents highly agreed with this statement, and 30 concurred. While a small number of responders were ambivalent, a few objected and a few strongly disapproved. Based on the comments, it seems that real-time collaboration systems allow project teams to be in constant contact with each other. Based on the results, it seems that these technologies helped stakeholders stay informed, work together, and fix problems quickly. Consequently, cooperation and coordination throughout the execution of the building project were enhanced.

The results showed that the efficiency of building projects was greatly enhanced by stakeholder participation that was supported by technology. The respondents felt that the project stakeholders' coordination, transparency, participation, and cooperation were all enhanced by the use of digital communication platforms, shared information systems, virtual meetings, online approval systems, and real-time collaboration tools. The findings indicated that administrative delays in building projects were decreased and communication was improved via the use of technology-enabled cooperation. According to these results, digital cooperation helped stakeholders in Machakos County better coordinate their efforts, which in turn led to better decision-making and administration of the building projects.

4.1.3.5 Construction Project Efficiency

In order to find out how well construction projects met their schedule, money, and quality goals, the research examined project efficiency. The overall performance of the projects and the impact of technology adoption on efficiency gains in construction were both evaluated with the use of this evaluation.

Table 13: Construction Project Efficiency

Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Effective technology adoption improves time performance of construction projects.	43	28	9	6	3
Technology utilization contributes to better cost performance in projects.	39	31	10	6	3
Use of digital and automated systems improves quality standards of projects.	40	30	10	6	3
Technology adoption enhances efficient resource utilization.	38	31	11	6	3
Adoption of modern technologies reduces rework in construction projects.	37	32	11	6	3

The results showed that most respondents either agreed (28), or strongly agreed (43), that efficient use of technology enhanced the timeliness of building projects. Some people were ambivalent (9 responses), while others disagreed (6 responses) or strongly disagreed (3 responses). Based on the comments, it seems that technology tools were crucial in keeping project implementation delays to a minimum. According to the results, digital and automated methods helped with project monitoring and scheduling. Project teams were able to finish tasks within the allotted timeframes, leading to better project delivery.

Results showed that a large percentage of respondents agreed or strongly agreed that greater cost performance in building projects was a result of using technology. There were fewer people who strongly disagreed (3) and fewer who were indifferent (10). According to their replies, technology tools helped cut down on wasteful spending when projects were being implemented. The results suggested that technological advancements in planning,

monitoring, and resource management reduced monetary waste. Better management of building project budgets was aided by this.

Digital and automated technologies raised the bar for building project quality, according to the results, with the majority of respondents agreeing (30) or strongly agreeing (40). While some disagreed with the statement (6) or strongly disagreed (3), a small number of respondents stayed neutral (10). These replies provided evidence that technical methods facilitated precision and accuracy in building processes. Based on the results, it seems that digital technology helped keep building sites error-free and on track. As a result, building projects were able to provide higher-quality results.

The results showed that a large number of respondents agreed or strongly agreed (31) that the effective usage of building resources was promoted by the application of technology. While eleven respondents had no opinion, six disagreed and three strongly disagreed. Based on the replies, it seems that technology tools help with material, equipment, and labor management. Digital technology aided in tracking and allocating resources efficiently throughout the project lifespan, according to the results. There was less waste and more operational efficiency throughout the project's execution because of this.

Modern technology has decreased the need for rework in building projects, according to the results. The majority of respondents either strongly agreed or agreed with this statement. Only eleven people gave a neutral response; six people objected and three people strongly disagreed. According to their replies, technology tools made it easier to keep tabs on building progress and ensure more precise planning. Based on the results, it seems that better coordination and early mistake identification reduced the necessity for redoing tasks. Because of this, the project was able to run more smoothly and with more efficiency.

The results showed that the efficiency of building projects was greatly improved by using technology. There was less rework, better use of resources, higher quality standards, better cost management, and shorter project completion times reported by respondents after using digital and automated technology. Findings indicated that construction project planning,

monitoring, and coordination were all improved by incorporating contemporary technology into conventional processes. According to these results, building projects in Machakos County were able to be successfully completed because the county used new technologies, which increased operational effectiveness.

4.2 Limitations of the Study

During the research procedure, the study ran across many constraints. Concerns about the privacy of their organizations and the details of their initiatives made several respondents reluctant to submit comprehensive responses. Time restrictions also made it difficult to reach out to more people in Machakos County for responses. Due to the hectic schedules of the construction workers and sites, it was often tough to have access to them. Additionally, response bias may have been created as the research mostly used self-reported data. In spite of these caveats, sufficient precautions were taken to guarantee that the data acquired was trustworthy and applicable to studying how the introduction of technology affected operational efficiency in building projects.

4.3 Chapter Summary

In light of the study's aims, this section provided and discussed the results. Analyzed were the demographics of the respondents as well as the impact on construction project efficiency of digital tools, automation, information and communication technology infrastructure, and technology-enabled stakeholder interactions. The chapter also covered the research constraints that were found.

CHAPTER FIVE
SUMMARY, RECOMMENDATIONS AND CONCLUSION

5.0 Introduction

In light of the aims of the study, this section provides a synopsis of the results. In addition, it offers suggestions on how building projects might better use technology. This chapter also provides an overview of the study's findings and recommendations for further research on the topic of technology in building.

5.1 Summary of Findings

The research looked at the personal details of 89 people who were working on building sites in Machakos County. According to the results, there were more men than women involved in the construction industry, as 57 men and 32 women filled out the survey. A total of 34 respondents were in the 31–40 age bracket, 22 were in the 41–50 age bracket, 21 were in the 30–49 age bracket, and 12 were in the 50+ age bracket. According to the respondents' educational backgrounds, the majority had a Bachelor's degree (38), followed by a Diploma (26), a Master's degree (13), a Certificate (9) and a Doctorate (3). Regarding their occupations, 29 people filled out the survey as contractors, 27 as site engineers, 18 as project managers, and 15 as owners. Also, 28 people said they had 5-10 years of experience, 24 said 11-15 years, 20 said more than 15 years, and 17 said they had less than 5 years.

This research looked at how building projects in Machakos County fared while using digital tools. The results demonstrated that many participants understood the value of digital resources for enhancing project efficiency. In particular, thirty people agreed and forty-one people strongly agreed that software for managing projects made construction sites more organized and efficient. Building Information Modeling improved planning accuracy and decreased project mistakes, according to 38 respondents who strongly agreed and 33 who agreed. When asked about the use of mobile reporting technologies to facilitate communication between site teams and project management, 36 respondents gave their enthusiastic agreement, while 32 gave their agreement. Digital documentation and real-time data systems also boosted project efficiency, according to other results. In a survey of construction project managers, forty people gave the impression that digital documentation systems enhanced record management and decreased information loss, while twenty-nine

others got the same impression. Similarly, 31 people agreed and 39 people strongly agreed that having access to data in real-time helped in making decisions throughout project execution quicker. Few respondents were ambivalent or disagreed with all of the claims. According to these results, digital technology significantly improved the efficiency of building projects in Machakos County by facilitating better collaboration, communication, planning, and decision-making.

This research looked at how building project efficiency in Machakos County changed after process automation. The results showed that many participants agreed that automation technology helped boost project efficiency. Prefabrication methods increased project efficiency and cut down on building time, according to 34 respondents who strongly agreed and 33 who agreed. Furthermore, 31 people agreed and 37 people strongly agreed that automated technology boosted production and decreased human error on building sites. Computerized scheduling also increased adherence to project timeframes, according to 36 respondents who strongly agreed and 32 who agreed. The results also demonstrated that mechanized and automated solutions improved operational accuracy and workflow efficiency in the construction industry. When asked if robotic surveying improved the accuracy of site measurements and layout operations, 33 people gave a strong agreement and 34 gave an agreement. Similarly, 31 people agreed and 35 people strongly agreed that building sites were more efficient with the use of mechanical material handling. Very few people who took the survey were ambivalent or strongly disagreed with the claims. These results provided strong evidence that automation technology significantly contributed to the effective execution of construction projects in Machakos County by increasing productivity, improving accuracy, decreasing delays, and promoting overall efficiency.

The impact of Machakos County's ICT infrastructure availability on the efficiency of building projects was the focus of the research. The results showed that the majority of respondents understood the significance of information and communication technology infrastructure in facilitating the use of technology in building projects. Reliable internet access improved communication and coordination in building projects, according to 42 respondents who strongly agreed and 29 respondents who agreed. Also, when asked

whether there was sufficient hardware available to facilitate the successful use of digital tools on building sites, 37 respondents gave their enthusiastic approval and 31 gave their agreement. Network reliability increased continuous access to project information systems, according to 39 respondents who strongly agreed and 30 respondents who agreed. To further aid in the efficient use of ICT infrastructure, further results demonstrated the significance of easily available software systems as well as technical assistance. Software accessibility improved construction activity monitoring and control, according to 38 respondents (32 of whom were in agreement and 38 of whom were in strong agreement). Similarly, 31 people agreed and 36 people strongly agreed that technical support systems helped building projects use their ICT infrastructure effectively. Very few people who took the survey were ambivalent or strongly disagreed with the claims. These results showed that with the right information and communication technology infrastructure, building projects in Machakos County were more efficient in terms of communication, information access, and monitoring.

The purpose of the research was to determine how technological stakeholder cooperation affected the productivity of Machakos County building projects. Many respondents understood the value of digital collaboration tools for better project stakeholder coordination, according to the results. When asked if digital communication platforms increased cooperation among project stakeholders, 41 respondents strongly agreed and 30 agreed. Furthermore, 31 people agreed and 38 people strongly agreed that shared information systems made building projects more transparent and accountable. Virtual coordination meetings enhanced stakeholder participation and enabled better decision-making throughout project execution, according to 35 respondents who strongly agreed and 32 respondents who agreed. Additional research showed that technologically-enabled communication tools helped cut down on construction project delays and boost cooperation. Online approval methods decreased delays in project paperwork and approvals, according to 36 respondents who strongly agreed and 31 respondents who agreed. Similarly, 30 people agreed and 39 people strongly agreed that using technologies to collaborate in real-time made teams operate better and faster. Very few people who took the survey were ambivalent or strongly disagreed with the claims. Based on these results,

it seems that construction projects in Machakos County were better managed and executed because to technology-enabled cooperation, which increased stakeholder communication, transparency, and coordination.

5.2 Recommendations

Digital project management technologies should be more widely used and integrated into building projects, according to the report. In order to better plan, coordinate, and monitor construction operations, organizations were pushed to invest in advanced digital tools like Building Information Modeling and project management software. To make sure that project teams learn how to use digital technology for project execution, the report said that construction firms should provide enough training and capacity development programs. In order to enhance record management and information accessibility throughout the project lifetime, the research further advised that construction stakeholders adopt digital documentation systems. To further facilitate quicker communication and decision-making within project teams, firms were also encouraged to encourage the usage of real-time data platforms and mobile reporting tools. These steps were seen as crucial for improving the efficiency of construction project delivery and fortifying the efficient use of digital technology.

In order to boost productivity on the job site, the research suggested that construction companies use more automated systems. In order to boost production and decrease human error on building sites, organizations were pushed to invest in contemporary construction equipment and automated machines. To reduce construction time and increase speed of project completion, the research also suggested that construction firms use prefabrication methods in project implementation. Computerized scheduling tools would help construction companies with project planning, monitoring, and sticking to deadlines, according to the research. Organizations were also encouraged to use cutting-edge innovation like robotic surveying and automated material handling systems to make site operations more precise and efficient. It was believed that these steps would significantly boost automation in the construction sector and the efficiency of building projects as a whole.

In order to make the most of digital technologies on construction sites, the research suggested that firms in the industry put money into dependable information and communication technology infrastructure. In order to improve team communication and collaboration, businesses were urged to make sure that all project locations had reliable internet access. In order to facilitate the usage of digital tools during project execution, the research also suggested that construction firms should provide sufficient hardware resources, including laptops, tablets, and similar technical equipment. Organizations should fortify their network infrastructure to guarantee constant access to project data and digital platforms used for project management, according to the report. Furthermore, the research suggested that construction companies set up efficient systems of technical assistance to help project teams with information and communication technology infrastructure management and maintenance. In order to increase efficiency in construction project management and better use ICT technologies, these steps were deemed vital.

The research concluded that digital communication platforms will help construction companies improve stakeholder coordination and information sharing. To facilitate effective communication and real-time sharing of project information, firms were urged to use integrated digital systems. The research also suggested that construction firms set up shared information systems to encourage openness and responsibility among all parties participating in a project's execution. To further enhance stakeholder participation and enable fast decision-making throughout project execution, the research also advised that construction companies support the usage of virtual coordination meetings. To further improve project cooperation and optimize documentation procedures, the research suggested that companies use online approval systems and real-time communication technologies. It was believed that these steps would significantly improve efficiency and cooperation in building project management.

5.3 Conclusion

In order to increase productivity on construction sites, the research found that digital tool use was crucial. Throughout a project's lifespan, digital technology allowed for enhanced project management, communication, coordination, and planning of construction

operations. Teams were able to better organize information, keep tabs on the project's development, and make decisions quickly thanks to digital tools. Digital tool integration improved stakeholder communication and decreased operational difficulties throughout project execution, according to the research. Consequently, it was believed that the construction sector could not improve productivity, project management, or the efficient execution of projects without making good use of digital technology.

The research found that construction process automation greatly enhanced the efficacy and efficiency of project execution. Automation has decreased reliance on human processes while increasing productivity and accuracy in construction. Better control over construction operations and effective workflow management were two other ways in which automation bolstered project planning and execution. Adopting current automated technologies helped boost operational efficiency and cut down on project implementation delays, according to the report. Therefore, it was believed that automation technologies were crucial for the construction sector to foster innovation, improve procedures, and increase the successful completion of projects.

A key component in improving building project efficiency, according to the research, was the availability of ICT infrastructure. The project's stakeholders were able to communicate, share information, and work together efficiently because of the well-developed technology infrastructure. Proficient access to project information, activity monitoring, and operational management were all made possible by the introduction of dependable ICT solutions for the construction industry. The research also found that digital technologies were more easily integrated into construction project management when there was a robust information and communication technology infrastructure. Consequently, it was believed that having access to dependable technical solutions was crucial for the construction sector to enhance project supervision, boost coordination, and promote effective project management.

According to the research, one of the most important factors in making construction projects more efficient was stakeholder communication via technology. Stakeholders' ability to work together and share information was greatly enhanced by the use of

technology-enabled platforms for communication and cooperation. In addition to reducing operational delays and facilitating quicker decision-making, technology enabled more effective participation of stakeholders throughout project design and execution. Participants' openness, accountability, and cooperation were all enhanced by the use of digital collaboration tools, according to the research. Consequently, it was believed that the best way to improve project management practices, boost the successful completion of building projects, and increase project coordination was to include technology into stakeholder communication.

5.4 Suggestions for Further Study

The report recommended more investigation into how new technology like AI, drones, and sophisticated robots affect the effectiveness of building projects in Kenya. The difficulties faced by small and medium-sized construction companies when trying to use new technology were also the subject of further research recommendations. The effect of technology adoption on construction project performance and its potential financial consequences might also be the subject of future studies. In order to compare results and make the study more applicable to the construction sector as a whole, the authors of the study recommended that further studies be carried out in other counties in Kenya.

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APPENDICES

APPENDIX I: LETTER OF INTRODUCTION

Dear Respondent,

I am a postgraduate student at the Management University of Africa conducting a research study titled ***The Impact of Technology Adoption on Construction Project Efficiency in Kenya: A Case Study of Machakos County.*** The purpose of this study is to examine how digital tools, automation, ICT infrastructure and stakeholder collaboration through technology influence construction project efficiency.

Your substantial contribution to the management and execution of building projects has led to your selection for this program. For this research to be a success, your opinions are crucial. The survey is comprised of closed-ended questions and should be finished in around ten to fifteen minutes.

All information you submit will be handled with the utmost confidentially and used only for academic reasons; your participation is completely optional. Kindly fill out the survey to the best of your ability and send it back within a week.

Thank you in advance for your time and cooperation.

Yours faithfully,

Carol Mwina

BDS/37/00279/2/24

Management University of Africa

APPENDIX II: RESEARCH STUDY QUESTIONNAIRE

This questionnaire is designed to collect information for a study examining the impact of technology adoption on construction project efficiency in Machakos County. Your responses will contribute to understanding how digital tools and related technologies influence project performance. All responses will be treated confidentially and used strictly for academic purposes.

Section A: Demographic Information of the Respondents

Please provide the following information by ticking (✓) the option that appropriately matches your profile in each category.

1. **Gender**
   Male { }

   Female { }

2. **Age Bracket**
   Below 30 years { }

   31–40 years { }

   41–50 years { }

   Above 50 years { }

3. **Highest Level of Education**
   Certificate { }

   Diploma { }

   Bachelor's Degree { }

   Master's Degree { }

   Doctorate { }

4. **Professional Role in the Project**
   Project Manager { }

   Site Engineer { }

   Contractor { }

   Project Owner { }

5. **Years of Experience in Construction Industry**
   Less than 5 years { }

   5–10 years { }

   11–15 years { }

   Above 15 years { }

Section B: Study Objectives

1: Digital Tool Utilization

Kindly respond on this section based on the above objective by ticking ontheappropriateboxthatbestmatchesyouropinionononascaleof5to1where5=StronglyAgree,4 =Agree,3=Neutral,2=Disagreeand1=StronglyDisagree.

Statement	5	4	3	2	1
Project management software improves coordination and overall efficiency of construction projects.					
Building Information Modeling enhances planning accuracy and reduces project errors.					
Mobile reporting tools improve timely communication between site teams and management.					
Digital documentation systems enhance record management and reduce information loss.					
Real-time data access supports faster decision-making in construction projects.					

2: Automation of Construction Processes

Kindly respond on this section based on the above objective by ticking ontheappropriateboxthatbestmatchesyouropinionon ascaleof5to1where5=StronglyAgree,4 =Agree,3=Neutral,2=Disagreeand1=StronglyDisagree.

Statement	5	4	3	2	1
Prefabrication techniques reduce construction time and improve project efficiency.					
Automated machinery increases productivity and reduces manual errors on site.					
Computerized scheduling improves adherence to project timelines.					
Robotic surveying enhances accuracy in site measurements and layout works.					
Mechanized material handling improves efficiency in resource movement on site.					

3: ICT Infrastructure Availability

Kindly respond on this section based on the above objective by ticking ontheappropriateboxthatbestmatchesyouropinionon ascaleof5to1where5=StronglyAgree,4 =Agree,3=Neutral,2=Disagreeand1=StronglyDisagree.

Statement	5	4	3	2	1
Reliable internet connectivity enhances communication and coordination in construction projects.					
Adequate hardware availability supports effective use of digital tools on site.					
Network reliability improves continuous access to project information systems.					
Software accessibility enhances monitoring and control of construction activities.					
Technical support systems facilitate effective utilization of ICT infrastructure.					

4: Stakeholder Collaboration Through Technology

Kindly respond on this section based on the above objective by ticking ontheappropriateboxthatbestmatchesyouropinionon ascaleof5to1where5=StronglyAgree,4 =Agree,3=Neutral,2=Disagreeand1=StronglyDisagree.

Statement	5	4	3	2	1
Digital communication platforms improve coordination among project stakeholders.					
Shared information systems enhance transparency and accountability in projects.					
Virtual coordination meetings improve stakeholder engagement and decision-making.					
Online approval systems reduce delays in project documentation and approvals.					
Real-time collaboration tools enhance teamwork and overall project efficiency.					

5: Construction Project Efficiency

Kindly respond on this section based on the above objective by ticking ontheappropriateboxthatbestmatchesyouropinionon ascaleof5to1where5=StronglyAgree,4 =Agree,3=Neutral,2=Disagreeand1=StronglyDisagree.

Statement	5	4	3	2	1
Effective technology adoption improves time performance of construction projects.					
Technology utilization contributes to better cost performance in projects.					
Use of digital and automated systems improves quality standards of projects.					
Technology adoption enhances efficient resource utilization.					
Adoption of modern technologies reduces rework in construction projects.					

Thank you for your participation.