Digitalization in the construction industry and its impacts on productivity: An empirical investigation of the South African construction industry

By Mr. MD Nxumalo

Student number: NXMDAL001

Research project presented in partial fulfilment of the requirements for the Degree of Master of Science in Project Management in the Faculty of Engineering & the Built Environment, Construction Economics and Management

University of Cape Town

07 July 2025

DECLARATION

I certify that, by submitting this research project electronically, all of the work is original to me and that, as such, I am the authorship owner (unless otherwise indicated), and that I have never before submitted it in whole or in part for credit toward any degree.

Signed by candidate 07/07/2025

Signed by: Mhlonipheni Nxumalo **Date**

Abstract

This study investigates the role of digitalization in the construction sector and its impacts on productivity, with a specific focus on the South African construction industry. Employing a quantitative research approach, data was collected using survey research design through close-ended questionnaires. A non-probability sampling method with both quota and convenience sampling techniques was used to select a sample of 200 participants to examine the relationships among digitization, digitalization concepts, digital transformation, and organizational productivity. Data was collected with a 17-item Digital Transformation Scale (DTS) adapted from Pettersson, Siljebo, Wolming, and Ferry (2024) consisting of three dimensions of digitalization (6 items), digitization (5 items) and digital transformation (6 items) and a 12-item Organizational Effectiveness Inventory (OEI) adapted from Szumal (2001) with three dimensions of organization level quality (6 items), departmental level quality (3 items) and external adaptability (3 items) was used to tap perceptions of organizational performance. The analysis incorporated reliability tests, descriptive statistics, correlation analysis, and regression modeling to identify significant trends and impacts.

Hypothesis testing yielded essential insights into the relationships among the constructs. The size of an organization significantly affects perceptions of digitalization and productivity within the South African construction sector. ANOVA results indicate that larger organizations exhibit significantly elevated levels of composite digitalization and organizational performance. Marked disparities are apparent in areas such as departmental performance, overall performance, and adaptability, with smaller firms lagging due to limitations in resources and capabilities. The ANOVA results indicated that organizations with a higher number of years in business have significantly higher levels of composite digitalization. Digitalization was found to have a positive significant effect on organizational productivity, results also show digitization to have a positive significant effect on organizational productivity and digital transformation tools exhibited no significant impact. Composite digitalization showed a strong and significant positive effect on productivity highlighting the importance of an integrated and comprehensive approach to digitalization.

The significance of this based on the need to the fill the critical knowledge gap in the academia regarding the impact of digitalization on productivity in the South African construction industry. Its findings inform the strategic decisions, drive innovation, and the approaches for efficient and competitive construction sector in South Africa.

Key words: Digitization, Digitalization, Digital Transformation, Organizational productivity

ACKNOWLEDGEMENTS

I would like to firstly thank God all mighty for being with me through this journey and secondly, I would like to express my heartfelt gratitude to my lovely partner Ms Thabisile Mzelemu for her dedicated support toward this journey.

Table of Contents

List of Figures

List of Tables

CHAPTER ONE

INTRODUCTION OF THE STUDY

1.1 Introduction

For many decades, the construction industry in South Africa has been an important contributor to the country's gross domestic product (GDP) (Ahady, Gupta, & Malik, 2017). However, the construction industry's contribution to South Africa's GDP has declined recently, decreasing from 3% in 2019 to 2% in 2021 (Bierman et al., 2016, CIDB, 2022, Pacitan & Burhanuddin, 2022). Research has also shown that the South African construction industry encounters ongoing challenges affecting its productivity (Bierman et al. 2016; CIDB, 2022; Ikuabe et al 2020). These challenges have led to a decline in overall productivity within the sector. There is, therefore, a growing consensus that concepts related to digitalization technology hold promise in addressing these productivity issues. In particular, digitalization technology could reverse the industry's declining productivity trend.

Furthermore, the rise of digital technology has influenced every aspect of society, spanning individuals, industries, and nations. The digital transformation of most industries is well underway on a global scale, with the objectives of increasing construction productivity and obtaining a competitive advantage over other sectors/or their contemporaries (Paik et al., 2017; Skender & Ali, 2020). According to the literature, the global demand for increased construction projects necessitated enhanced productivity to ensure optimal project performance (Barbosa et al ...,2017; Ikuabe et al ..., 2020).

This study primarily focuses on the impact of digitalization on productivity within the South African construction industry. According to research Digitalisation in the construction industry describes how digital technologies like the Building Information Modelling (BIM), Enterprise Resource Planning (ERP) systems, automated construction robotics, drones, augmented reality (AR), virtual reality (VR), the Internet of Things (IoT), and AI are being used and integrated into construction projects to improve productivity, project management, planning, and execution of projects. (Mckinsey & Company, 2017; Construction industry Institute, 2020). Digitalization is rapidly transforming the construction industry, enhancing productivity, efficiency, and safety across various dimensions. It increases efficiency, makes it easier to make decisions in real time, fosters better teamwork, and increases output (KPMG, 2020; PwC, 2019). However, obstacles like the requirement for specialised labour, opposition to change, and large upfront expenses continue to be obstacles to full-scale implementation (Elghamrawy & Galal, 2022; Ahmed et al., 2023; Lauria & Azzalin, 2024; Kudyba, 2018; Eurooean Commission, 2020; Musa et al, 2020).

1.2 Problem Statement

There are currently limited, accurate data sources on the impact of digitalization technology on productivity in the South African construction industry. The sector has exhibited significant reluctance to embrace digital technologies like BIM, construction robotics and AI (Windapo, 2020; Shakantu, 2019). Therefore, it is essential for the industry to reassess its trajectory and explore how technology can enhance its adaptability, responsiveness, and overall productivity. (CIDB, 2022, Orzeł, 2022,). Scholars argue that it is still uncertain how advantageous digitalization of the construction industry will be since most construction firms have not yet made significant investments in digitalization technology, primarily due to reluctance to adapt to technological changes and uncertainty regarding the effects of these changes on productivity (Carolan,2022; Jalo et al.., 2022; Windapo, 2016). Research indicates that some of the obstacles smaller and medium organizations to digitalization include restricted access to technology, a lack of digital literacy, and poor infrastructure (Shakantu, 2019). Moreover, it has been established in the literature that there is frequently a need for established strategies for maximizing the potential of digital technology because individuals often persist in employing labour-intensive manual processes, even though these tasks could be readily automated.

1.3 Research Questions

The research questions the study are to determine how digitalization in the construction sector affects productivity in the South African construction industry, including the following research questions.

I. To what extent do employees of small, medium and large organizations do not have significantly different perceptions of digitalization, digitization, digital transformation and organizational productivity?

II. To what extent does the age of business significantly influence perceptions of digitalization, digitization, digital transformation and organizational productivity?

III. What is the effect of digitization on the perceptions of organizational productivity?

IV. What is the effect of digitalization on organizational productivity in the South African construction industry?

V. What is the effect of digital transformation on productivity in the South African construction industry?

VI. What is the overall effect of digitalization on productivity in the South African construction industry.

1.4 The research Objectives and Hypotheses

1.4.1 Objectives

The primary goal of this study is to analyse the impact of digitalization on productivity in the South African construction industry. The objectives of the study are stated as follows:

I. To determine the differences among small, medium and large organizations based on their number of employees on the perceptions of digitalization, digitization, digital transformation and the perceptions of l organizational productivity in the South African construction industry.

II. To determine the age of business on the perceptions of digitalization, digitization, digital transformation and the perceptions of organizational productivity in the South African construction industry.

III. To Examine the effects of digitalization technologies of perceptions of productivity in the South African construction industry.

IV. To determine the impact of digital transformation on productivity in the South African construction Industry

V. To determine the effect of composite digitization technologies on the productivity of the South African construction industry.

1.4.2 Hypothesis

The study's working hypotheses are as follows:

Hypothesis1: Employees of small, medium and large organizations have significantly different perceptions of digitalization, digitization, digital transformation and organizational productivity.

Hypothesis 2: Age of the business significantly influences perceptions of digitalization, digitization, digital transformation and organizational productivity.

Hypothesis 3: Digitization has a positive significant effect on perceptions of organizational productivity.

Hypothesis 4: Digitalization technology has a positive significant effect on organizational productivity in the South African construction industry.

Hypothesis 5: Digital transformation has a positive significant effect on productivity in the South African construction industry.

Hypothesis 6: Composite digitalization has a positive significant effect on productivity in the South African construction industry.

1.5 Significance of the research

The significance of this research is multifaceted and holds great importance for the South African construction industry. Firstly, it addresses a critical aspect of the industry's evolution by examining the impact of digitalization. Unlike many other sectors, the construction industry in South Africa is still in its early stages of embracing the digital revolution (CIDB, 2022; Windapo, 2016; Love et al, 2019). Understanding how digitalization influences productivity in this context is vital, as it sheds light on the industry's readiness to adapt to modern technological advancements.

Moreover, the research outcomes are expected to impact the South African construction sector profoundly. By evaluating whether the digitalization technology concepts have been effectively implemented and translated into the anticipated productivity gains, this study provides valuable insights for industry stakeholders. These insights can guide decision-makers in the construction sector, helping them determine the effectiveness of their digitalization strategies and whether adjustments are needed. It serves as a performance assessment tool for the industry's transition into the digital era (Musa et al, 2020; Windapo, 2016; RICS, 2024).

Secondly, this research delves deeper into quantifying digitalization's benefits. It goes beyond acknowledging its existence and seeks to establish its tangible contributions to improving South African construction industry productivity. Understanding how digitalization enhances efficiency, resource management, and overall project performance is crucial for long-term planning and sustainable growth. Furthermore, the digitization of the South African construction sector is vital for attaining the country's National Development Plan (NDP) and Sustainable Development Goals (SDG) targets (Hauptfleisch et al, 2021; Shakantu, 2019)

In summary, this research is essential because it fills the critical knowledge gap in the academia regarding the impact of digitalization on productivity in the South African construction industry. Its findings can inform strategic decisions, drive innovation, and ultimately lead to a more efficient and competitive construction sector in South Africa, aligning it with global industry trends and standards.

1.6 Chapter Outline

This study has followed the structure as depicted below.

Chapter 1: Introduction

This chapter gives a synopsis and summary of the problem statement, research questions, research objective, hypothesis and the outline of the study.

Chapter 2: Literature Review

This chapter will review literature related to Digitalization technology and productivity in the construction industry. Additionally, this chapter provides the conceptualisation of a theoretical framework for the study

Chapter 3: Research Design

In this chapter research methodology will be examined in depth, while additionally focusing on the research approach that adopted for the study to gather data and analyze the data.

Chapter 4: Research Results

The data that were acquired will be analyzed in this chapter by using the method that was outlined in Chapter Three, and the results will be presented, analyzed, and discussed in this chapter as well.

Chapter 5: Conclusions and Recommendations

This chapter provides a summary of what the study found and draws some inferences based on those results. This chapter represents the outcome of the study, and as a result, it details the recommendations for future studies. In this chapter, we will also talk about the limits of the research and what we learned from them.

1.7 Chapter One Summary

Chapter 1 presents an overview of the research and sets the context for the study to follow. This chapter similarly begins by introducing the study subject and providing a brief background to demonstrate the research's relevance and significance. The chapter also includes the problem statement, research questions, research objectives, hypotheses, the significance of the study.

CHAPTER TWO

LITERATURE REVIEW

2. Introduction

This chapter provides a thorough examination of the current research about digitalization in the construction sector and its significant effects on productivity. We want to explore the complex linkages between digitization and productivity improvement, particularly within the context of the South African construction sector. The construction sector has seen a substantial transition in recent years, propelled by the incorporation of digitization and modern technology (El Jazzar et al., 2020; Yousif et al., 2022). The integration of digital tools and technology has significantly transformed the planning, execution, and management of construction projects (Borrmann et al., 2018).

The construction sector, known for its complexity and diverse stakeholders, has seen a surge in the Use of revolutionary technology aimed at streamlining operations and achieving higher levels of efficiency (Khosrowshahi & Arayici, 2012). From automated robotics and drone technology to advanced communication systems and data-driven management tools, the digital revolution in construction has presented both challenges and opportunities. This chapter synthesizes a broad range of research, studies, case examples, and expert insights to shed light on the ways in which digitalization intersects with construction productivity.

The international landscape will be presented first by exploring the international landscape of overall productivity trends in the construction industry, offering a comparative perspective on the challenges and successes encountered in various global contexts. This sets the stage for a focused examination of the South African construction industry's unique productivity dynamics and the distinct role digitalization plays in addressing them.

Drawing from the wider impacts of digitalization across various industries, we will highlight key lessons that can be gleaned from these experiences to promote the incorporation of digital technologies into construction methods. This review will critically assess the impact of digitalization on construction industry productivity through the lens of different aspects, including labour efficiency, communication enhancements, project management optimization, and the utilization of cutting-edge technologies like building information modelling (BIM) and enterprise resource planning (ERP) systems.

Furthermore, the study will present a selection of theoretical frameworks that underpin the study, offering a conceptual basis for understanding the relationships between digitalization and productivity within the South African construction industry. By synthesizing these diverse perspectives, this chapter seeks to lay the groundwork for a comprehensive exploration of the impact of digitalization on productivity in the South African construction sector, ultimately paving the way for empirical investigation and the advancement of knowledge in this vital domain.

2.1 Productivity in the Construction Industry and Project Management

Productivity in the construction industry is a critical aspect that directly affects project success, cost management, and overall economic growth (Musarat, Alaloul, & Liew, 2021; Stanitsas, Kirytopoulos, & Leopoulos, 2021). This section explores the global backdrop of construction industry productivity, with a particular focus on the productivity dynamics of the South African context. This section examined the essential elements affecting productivity in the construction industry, emphasizing the impact of project management methods and external dynamics on efficiency and results. We began by examining the international context of construction industry productivity, recognizing that labour efficiency, technology adoption, regulatory environments, infrastructure investment, supply chain management, safety measures, project complexity, collaboration, and economic factors collectively influence global construction productivity trends.

Within the South African context, we found a unique set of challenges and opportunities. The nation's ambitious infrastructure development plans create opportunities for economic growth but also place immense pressure on construction productivity. Labour productivity concerns, including disputes and skills shortages, compound the complexity of the South African construction landscape. Regulatory challenges, uneven technology adoption, equity considerations like Black Economic Empowerment (BEE) policies, infrastructure backlogs, safety, and project management practices further shape the productivity environment.

Overall, this section highlights the intricate interplay of factors affecting construction productivity, showcasing the global and South African-specific dynamics that construction professionals, policymakers, and stakeholders must navigate to achieve successful and efficient project outcomes.

2.2 International Context of Overall Organizational Productivity/Global View

The construction industry is a significant contributor to global economic development. However, it has traditionally faced challenges related to productivity and efficiency. Several key factors impact productivity in the international construction context and are discussed in detail below:

a) Labour Efficiency:

In the construction industry, labour costs make up a significant portion of overall expenses and can take up to about 25% of total expenses as reported by Bertram et al. (2019). As such, it is crucial to optimize labour efficiency to control costs and ensure project success. However, several reports have it that many countries are currently facing labour shortages in the construction sector due to a variety of factors such as an aging workforce, after effects of the COVID-19 pandemic, and a lack of skilled labour entering the field (Ayodele, Chang-Richards, & González, 2020; Brucker Juricic, Galic, & Marenjak, 2021; Pamidimukkala & Kermanshachi, 2021; Settersten Jr et al., 2020). These shortages can lead to delays in project completion and increased labour costs.

Furthermore, the construction industry requires a range of specialized skills, and any gaps in these essential competencies can hinder productivity and quality (Adepoju & Aigbavboa, 2021). To make matters worse, traditional construction methods often involve labour-intensive processes and as such, adhering to outdated practices can lead to inefficiencies and reduced productivity (Pan & Zhang, 2021b). Therefore, adopting modern construction techniques and technologies like the use of artificial intelligence in construction project management are being proposed and researched to help mitigate these issues (Hegab et al., 2023; Pan & Zhang, 2021b). Investing in training and education programs for construction workers is also crucial. Such programs can help bridge skills gaps, enhance productivity, and ensure a skilled workforce for the future (Adepoju & Aigbavboa, 2021; Akyazi et al., 2020). Therefore, by addressing labour shortages, skills gaps, and inefficient labour practices, the construction industry can improve its productivity, quality, and bottom line.

b) Technology Adoption

When countries embrace digitalization and advanced technologies, they often experience significant improvements in construction productivity. These technologies include BIM, project management software, and automated machinery (Sacks, Girolami, & Brilakis, 2020; Yang et al., 2021). BIM enables multidisciplinary collaboration, real-time design changes, and clash detection, reducing errors and rework. It enhances project coordination and overall efficiency. Concurrently, contemporary project management software ensures that projects are executed efficiently by enabling improved communication, exchange of documents, and task monitoring. (Alizadehsalehi & Yitmen, 2023; Wedha, 2023). Also, automation and robotics also helps perform repetitive, labour-intensive tasks with precision and speed, reducing reliance on manual labour and improving productivity (Chaudhari, Barot, & Patel, 2023; Sumathi & Keerthana). To foster technology adoption, therefore, governments and industry stakeholders can invest in research and development, provide training initiatives, and offer incentives for firms to invest in cutting-edge construction technologies.

c) Regulatory Environment

Complex permitting processes and bureaucratic red tape can be major roadblocks, so it's important to streamline these processes as much as possible to maintain project timelines (Mathu, 2023; Yuliantoro, 2019). Another issue that can arise is changing regulations. Environmental standards and safety requirements are constantly evolving, which can create uncertainty for construction projects (Lee et al., 2022). To avoid disruptions, it's important that project managers in the construction industry stay informed about any changes and adapt accordingly.

Also, efficient permitting systems can also play a big role in expediting project start times and reducing administrative burdens on construction companies (Kifokeris & Koch, 2020; Plevris, Lagaros, & Zeytinci, 2022). Countries that establish these systems can provide a more favorable regulatory environment for builders. Finally, collaboration between government bodies, industry associations, and construction companies can also help create more favorable regulatory environments that support productivity (Baah et al., 2021). By working together, these groups can create more streamlined processes and ensure that everyone is on the same page when it comes to regulations and requirements.

d) Infrastructure Investment

Investment in infrastructure projects by governments demonstrates a commitment to economic development and has the potential to positively impact construction productivity (Mojumder et al., 2022; Patrucco, Moretto, & Knight, 2021). Adequate finance is essential to guarantee that construction projects possess the requisite resources for seamless advancement, since inadequate funding may result in delays and a compromise in quality. In addition, well-managed infrastructure projects with clear objectives and effective project management practices tend to be more productive and deliver better outcomes. Therefore, it is essential for governments and stakeholders to prioritize these elements when planning and executing infrastructure projects.

e) Supply Chain Management

It has also been established in literature that effective supply chain management is essential for guaranteeing on-time distribution of materials to construction sites because delays in material procurement can cause disruptions to project schedules and increase costs (Ismail, 2021; Luo et al., 2020). Thus, establishing strong relationships with suppliers is key in achieving better pricing, reliability, and coordination, ultimately reducing the risk of material shortages and delays (Luo et al., 2020). Effective inventory management practices have also been found to play a significant role in minimizing waste and reducing costs associated with excess materials (Kabirifar et al., 2020).

f) Safety and Risk Management

In the construction industry, safety should always be a top priority (Buniya et al., 2021; Marín et al., 2019). According to Yiu et al. (2019), the Safety Management System (SMS) was introduced in the 1980s within the construction industry to enhance safety, reduce injuries and fatalities, and minimize material waste. Over the past three decades, construction companies have invested significant resources in implementing SMS. Yiu et al. (2019) conducted research that identified numerous substantial advantages, including enhanced project management, safer working conditions, reduced worker injury, and the incorporation of safety management. Conversely, significant challenges included insufficient participation by project team members in SMS implementation, high attrition rates among workers, constrained project schedules, obstruction by subcontractors, and safety being prioritized lower due to organizational cultural differences. Kawish (2017) and Rajendran (2007) both support this perspective.

2.3 Productivity in the South African construction industry

The construction industry in South African has its own set of challenges and opportunities regarding productivity. This section provides a focused exploration of the productivity landscape in the South African construction industry, shedding light on the factors that influence efficiency and effectiveness in construction projects within this region.

This part discusses the essential factors influencing the productivity of the South African construction sector. This includes an examination of infrastructure development initiatives, labour productivity concerns, regulatory environments, technology adoption trends, and other influential factors. By delving into the unique challenges and opportunities facing the South African construction sector, this section sets the stage for a deeper understanding of how digitalization impacts productivity in this specific context.

a) **Infrastructure Development:** South Africa has ambitious plans for infrastructure development aimed at addressing historical inequalities and stimulating economic growth.

An example of such plans is the RDP (Rural Development Plan) which is a post-apartheid development plan which concentrated its efforts on the development of social infrastructure and extending access to services to the underprivileged, with the belief that such actions would positively impact economic expansion (Cwele, 2019). Other notable initiatives in South Africa's infrastructure development programs encompass GEAR (Growth, Employment, and Redistribution), launched in 1996; AsgiSA (Accelerated and Shared Growth Initiative for South Africa), initiated in 2006; and NGP (New Growth Path), introduced in 2010 (Cwele, 2019; Kamara, 2017; Vukeya, 2015). These plans present significant opportunities for the construction sector, as infrastructure projects can provide employment (Hamman, 2019), foster economic development (Krukowska, 2019), and enhance the country's global competitiveness (Mosehla, 2019). However, the scale and urgency of these projects can also exert pressure on construction productivity. Meeting project deadlines while maintaining quality standards is a challenge that requires effective project management and resource allocation.

b) **Labour Productivity:** In South Africa, labour disputes and strikes have been known to cause problems for construction projects (Adugna, 2015; Akinsiku & Akinsulire, 2012; Baloyi & Bekker, 2011). These interruptions result in delays and heightened expenses, adversely affecting productivity. Another issue facing the construction industry in South Africa is a shortage of skilled workers, particularly in specialized fields (Moodley, 2012; Mutereko, 2022). This hinders productivity and may require targeted training programs and workforce development initiatives to address.

c) **Regulatory Environment:** South Africa, like many other countries, experiences regulatory challenges that can hinder construction projects. These challenges include time- consuming bureaucratic processes, lengthy permitting procedures, and compliance requirements that can lead to delays and increased project costs (Amoah, 2023). To improve construction productivity, it's crucial to streamline regulatory processes and reduce administrative burdens. In this regard, government initiatives aimed at simplifying permitting and compliance procedures can be instrumental. In South Africa the Construction Industry Development Board (CIDB) is one of the most important regulatory and statutory body in the South African construction Industry which was put in place through a bill that was passed by the South African government as the CIDB Act 30 of 2000. The CIB’s function is through a number of partnerships and strategic interventions, that seeks to promote improved delivery management, capacity building, and contractor development in the construction industry. The CIDB hold the national database of contractors in the South African construction industry which is done through a grading system that monitors and regulate the execution of construction projects. By doing so, construction projects can proceed more smoothly, efficiently, and cost-effectively, ultimately benefiting the economy and society at large. (CIDB, 2023)

d) **Technology Adoption:** The adoption of digital technologies in the construction industry in South Africa has been uneven, with some projects embracing technologies like BIM and automation, while others lag behind (Camngca, Amoah, & Ayesu-Koranteng, 2022). This technological gap needs to be bridged to improve productivity in the industry. To facilitate the broader adoption of digital construction technologies, increasing awareness and providing training is crucial. Investing in workforce development and education can help build digital capabilities, which is essential for the growth of the industry.

e) **Transformation and Equity:** Theres is still substantial work in South Africa is focusing on greater inclusion and equity through Black Economic Empowerment (BEE) policies (Horwitz & Jain, 2011). These policies aim to increase the participation of historically disadvantaged individuals and businesses. Although, while promoting equity is important, it can be a challenge to balance BEE goals with productivity imperatives. Thus, Strategic planning is necessary to ensure that both goals are met successfully. Another way to enhance the contribution of historically disadvantaged businesses to the construction industry is through capacity building (Agupusi, 2007; Ganiyu, 2016). By supporting these businesses in building their capabilities and skills, they can maintain productivity standards and play a more significant role in the industry.

f) **Infrastructure Backlogs:** The demand for construction has been steadily increasing due to the urgent need to address infrastructure backlogs, particularly in the housing and transportation sectors (Palmer et al., 2016). To meet these demands while maintaining productivity, the construction industry must adopt efficient project management techniques and leverage technology. According to Assaad et al. (2023), one key factor in optimizing resource allocation and productivity in construction management is effective project prioritization. By prioritizing infrastructure projects based on their economic impact and urgency, construction companies can ensure that their efforts are focused on the most critical areas and achieve the greatest impact. This approach can help to streamline the construction process and ensure that limited resources are used effectively to meet the pressing needs of society.

g) **Safety and Health:** Although safety standards in South African construction have improved over time, accidents still happen. The challenge is to maintain safety without compromising productivity (Masimula, 2018). This requires a strong safety culture, ongoing training, and compliance with safety regulations. The adoption of safety- enhancing technologies, such as wearable devices and real-time monitoring systems, can also contribute to improved safety without impeding productivity. By incorporating these measures, construction companies can ensure the safety of their workers and create a safer work environment for all.

h) **Project Management Practices:** In order to achieve productivity in construction projects, it is crucial to implement effective project management practices. Modern techniques like lean construction and agile methodologies, along with digital project management tools, can significantly enhance project outcomes (Akinradewo et al., 2023). By adopting these strategies, construction professionals can streamline processes and ensure successful project completion.

It has been determined that improving efficiency in the South African construction sector is a complex problem that requires balancing several possibilities and barriers. The productivity of the sector is affected by a complex interaction of elements, such as labor efficiency, technological implementation, regulatory frameworks, and economic situations. The South African construction sector has distinct issues pertaining to labor, legislation, and reform initiatives. To enhance efficiency and attain good construction results, it is essential to tackle these problems while using digitalization and optimal project management approaches. This requires a comprehensive strategy that incorporates technology, regulatory change, workforce development, and strategic planning to foster economic growth and equitable involvement in the industry.

2.4. The Impact of Digital transformation on Industries

Digitalization, frequently synonymous with digital transformation or Industry 4.0, denotes the incorporation of digital technologies into diverse facets of industries and enterprises to optimize processes, improve efficiency, and foster innovation (Kagermann et al., 2016; Schallmo & Williams, 2018). Digitalization significantly affects industries, transforming conventional business structures and altering the production, delivery, and consumption of goods and services. Digital transformation refers to the process by which organizations integrate digital technology throughout all aspects of their business, significantly altering their operational practices and value proposition to customers. It involves the incorporation of technologies such as cloud computing, artificial intelligence (AI), big data, and automation to enhance efficiency, improve user experiences, and reinvent business models. Effective digital transformation requires both technology progress and a culture change that fosters agility, ongoing learning, and innovation. It emphasizes data-driven decision-making, process automation, and the cultivation of a more customer-centric corporate culture. As organizations increasingly shift to digital environments, the focus shifts from merely adopting new technologies to reassessing strategy, operations, and customer interactions to sustain competitiveness and promote sustainable growth (Kane, Palmer, Phillips, Kiron, & Buckley, 2015; Westerman, Bonnet, Ferraris, & Jörg, 2014).

Section 2.5 delves into the profound and far-reaching impact of digitalization on industries across the globe. It explores how the integration of digital technologies is transforming the way businesses operate, innovate, and remain competitive. This section recognizes digitalization as a dynamic force reshaping traditional industry landscapes and offers an extensive discussion on the key dimensions of this transformation.

The discussion starts by highlighting the efficiency and productivity gains that digitalization brings through streamlined processes and data-driven decision-making. It also delves into the innovative potential of digitalization, exploring how it disrupts traditional industries and ushers in new business models, such as the sharing economy and platform economies.

Customer experience, a pivotal aspect of business success, is examined in light of personalization and enhanced accessibility facilitated by digitalization. The section further explores the optimization of supply chains, the competitive advantages gained by businesses that embrace digitalization, and the significant cost reductions achieved through operational efficiencies and paperless operations.

Globalization is another dimension discussed, illustrating how digitalization enables businesses to expand their markets and tap into a global workforce. The section also acknowledges the sustainability and environmental impact of digitalization, showcasing how it contributes to reduced carbon footprints and the integration of renewable energy sources. Workforce transformation and the implications for skill requirements and remote work are examined, shedding light on the changing dynamics of the modern workforce. The section also touches on the relevance of digitalization to small and medium-sized enterprises (SMEs), particularly in terms of market access and cost-effective solutions.

2.5 The impact of Digitization on productivity

Efficiency and productivity are two critical components of business prosperity in today's fast-changing digital world. These notions take on new meaning in the context of digitization, as contemporary technology offers novel solutions to improve operational efficiency and overall productivity. Although the terms digitization and digitalization are often used synonymously, they have different meanings. According to Kemmerer et al. (2017), digitization is the process of transforming analog, conventional data into digital forms, such as transforming paper-based documents into digital files. On the other hand, digitalization entails integrating data and digital technology into every facet of the building process, changing value chains, processes, and business models (Olawumi & Chan, 2020). To put it another way, digitization is a step before digitalization since it makes it possible to create digital data that may be used to propel digitalization (Dave et al., 2018). For construction organizations looking to fully use digital technology, it is imperative that they comprehend the difference between digitization and digitalization.

2.5.1 Streamlined Processes

Digitalization revolutionizes business processes by automating manual tasks and streamlining operations (Asadov, 2023). This results in several notable benefits. For example, digital tools and technologies have revolutionized the way we work, providing numerous benefits that were once unimaginable. One of the most significant advantages is the automation of repetitive tasks, which were traditionally performed by humans (Anagnoste, 2017). With digitalization, tasks like data entry, inventory management, and safety inspections can be automated, reducing the workload on employees and minimizing the chances of human errors.

Another benefit of digital systems is the improved synchronization of tasks and processes (Novák & Vyskočil, 2022). This is particularly useful in complex projects where multiple teams or departments need to work together. For instance, in a construction project, digital tools can automate the scheduling of subcontractors, deliveries, and inspections, ensuring that everything occurs in a coordinated and timely manner. This prevents bottlenecks and delays, helping projects to stay on schedule and within budget.

Digitization also provides real-time visibility into processes and workflows, enhancing transparency. Project managers and stakeholders can monitor progress, identify bottlenecks, and address issues as they arise (Fobiri, Musonda, & Muleya, 2022; Pan & Zhang, 2021a). This fosters accountability and enables swift decision-making, keeping projects on track.

2.5.2 Data-Driven Decision Making

Digitization enables companies to make well-informed judgments by using the power of analytics and data in the data-rich environment of today (Bhimani & Willcocks, 2014; Tien, 2013). The construction industry has thus improved its efficiencies from the extensive availability of digital tools and platforms, which enable the accumulation and storage of substantial quantities through "big data" (Bilal et al., 2016). This information may encompass resource allocation, cost estimates, weather conditions, and project timelines.

Also, with the help of advanced analytics and machine learning algorithms, this data can be analyzed, and valuable insights can be extracted (Najafabadi et al., 2015; Sarker, 2021; Tayefi et al., 2021). For instance, predictive analytics can forecast potential project delays based on historical data and current conditions, while machine learning can optimize resource allocation by identifying patterns in past project performance. By utilizing these data-driven insights, organizations can optimize resource allocation and process management. Construction project managers can, for example, use data analysis to allocate labour resources more effectively, ensuring that skilled workers are deployed where they are most needed (Badiru, 1996; Li et al., 2015; Wijayasekera et al., 2022). Moreover, proactive measures can be taken to mitigate risks and prevent costly delays by identifying potential issues in advance through data analysis. If data analysis indicates that a particular subcontractor consistently causes delays, steps can be taken to address this issue before it impacts the project.

Finally, digitization enables organizations to collect data on an ongoing basis, allowing for continuous improvement (Manita et al., 2020; Sjödin et al., 2018). This entails the implementation of data-driven modifications to operations and processes in order to enhance productivity and efficiency over time. In conclusion, efficiency and productivity are central to the success of businesses in the digital age. Digitization empowers organizations to achieve these goals by automating tasks, streamlining processes, and harnessing the power of data and analytics for informed decision- making. These benefits translate to faster project completion, cost savings, improved resource utilization, and enhanced overall project outcomes.

2.5.3 Innovation and New Business Models

Innovation and the emergence of new business models are transformative forces that have the potential to reshape industries. In the context of the "construction industry", digitization is catalysing innovation and giving rise to novel approaches to conducting business. This section explores how digitalization fosters innovation and new business models in construction, drawing parallels with disruptive changes seen in other sectors.

2.5.4 Innovation in the Construction Industry

According to (Hossain & Nadeem, 2019; Manzoor et al., 2021; K. Wang et al., 2022), "the integration of digital technologies in construction is transforming traditional practices, introducing a range of technologies such as BIM, drones, AR, VR, and the Internet of Things (IoT) ". These technologies offer new ways of designing, planning, executing, and managing construction projects.

Moreover, automation and data analytics improve operational efficiency, resulting in reduced project delays and cost overruns. For instance, AI-powered project management tools can optimize resource allocation, resulting in significant efficiency gains (Dam et al., 2019; Sahadevan, 2023). This transformation is improving the construction industry's ability to deliver projects on time and within budget. Digital tools also enable better environmental monitoring and sustainability practices (Rosário & Dias, 2022). Construction companies can thus use data to track resource consumption, minimize waste, and implement eco-friendly designs, aligning with the growing demand for sustainable construction practices. Also, digitalization is driving innovation in construction methods such as modular and prefabricated construction (Bischof, Mata-Falcon, & Kaufmann, 2022; Yin et al., 2022).

2.5.5 Platform Economies in Construction

Platform economies, exemplified by companies like Uber and Airbnb, are built on the principles of sharing resources and services in a digital marketplace (Kirchner, Dittmar, & Ziegler, 2022). In the construction industry, similar platform-based models are emerging. For example, the construction industry has been experiencing a shift towards a sharing economy approach, thanks to digital platforms that connect equipment owners with those in need of machinery for construction projects (Ciulli & Kolk, 2019). This allows construction companies to access specialized equipment without the need for large capital investments.

In addition, online platforms are connecting skilled labourers, subcontractors, and project managers with construction firms seeking temporary or specialized labour (Rani & Furrer, 2021). This enables construction companies to flexibly scale their workforce as project demands fluctuate. Digital platforms are also facilitating the exchange of construction materials and supplies (Boukhatmi, Nyffenegger, & Grösser, 2023). Surplus materials from one project can be sold or shared with others, reducing waste and lowering procurement costs. This is referred to as circular economy and it exemplifies how sustainability is enhanced in the construction industry through digitalization. Also, collaboration platforms for construction, akin to Airbnb for accommodations, enable project owners to connect with contractors, architects, and other service providers (Alhava, Laine, & Kiviniemi, 2017; Jacob, 2020). These platforms streamline project initiation and management.

Lastly, drones (Unmanned Aeiral Vehicles) equipped with cameras and sensors are offered as services on online platforms. Hence, construction companies can hire drone operators to perform site surveys, inspections, and progress monitoring, reducing the need for investing in drone technology (Rachmawati & Kim, 2022). Overall, these technological innovations are transforming the construction industry and making it more efficient and cost-effective.

In conclusion, digitalization is sparking innovation and introducing new business models to the construction industry. These changes are enhancing efficiency, promoting sustainability, and reshaping how construction projects are planned and executed. By embracing digitalization and these new approaches, the construction sector can adapt to meet evolving demands and remain competitive in a rapidly changing market

2.5.6 Customer Experience in the Construction Industry

In the "construction industry", traditionally characterized by complex and lengthy projects, customer experience has often taken a backseat to factors like project completion, budget control, and safety. However, with the advent of digitization, there has been a transformative shift in how customer experience is perceived and managed. Here, we explore how digitization is enhancing customer experience in construction.

The adoption of digitalization tools like BIM has revolutionized the industry, enabling architects and engineers to create tailored designs that are specific to the needs and preferences of individual clients (Smith & Tardif, 2009; Tan, Mills, & Papadonikolaki, 2022). Beyond just aesthetics, this customization includes factors like functionality, energy efficiency, and sustainability considerations. Real-time collaboration platforms and tools have also emerged, allowing clients to actively participate in the design and decision-making process (Zheng et al., 2018). This enables them to view design changes in real-time and provide feedback to ensure that the final product aligns with their vision.

Another benefit of digitization is the use of predictive analytics, which allows construction companies to anticipate client needs and preferences (Anshari et al., 2019). By analyzing data from past projects and client interactions, companies can proactively integrate features like energy efficiency or sustainability into the project, addressing specific client requests before they are even made.

Digitization also enables post-completion engagement with clients since construction companies can use digital platforms to provide maintenance recommendations, offer virtual tours of completed projects, and gather feedback for continuous improvement (Jaselskis et al., 2011). Secure online portals provide easy access to important project updates, documentation, and progress reports, eliminating the need for physical meetings and simplifying communication. This ongoing engagement ensures that clients remain satisfied and that the construction company can continue to deliver high-quality projects.

E-commerce platforms for materials have also expanded accessibility for clients involved in material selection. Through browsing catalogues, comparing materials, and making informed decisions, clients can avoid the need for physical visits to suppliers (Sıcakyüz & Erdebilli, 2023). Furthermore, digitalization has enabled construction firms to expand their market reach globally. With the ability to bid on international projects, collaborate with clients and partners worldwide, and serve a diverse clientele, companies are able to broaden their horizons and reach new heights (Nikjow et al., 2021).

In the "construction industry", digitization is not only improving operational efficiency but also elevating the customer experience. Personalization and accessibility, once considered unattainable in construction, are now achievable through digital tools and platforms. By embracing these advancements, construction firms can differentiate themselves in the market, foster client loyalty, and provide a superior overall customer experience.

2.5.7 Real-Time Tracking

Construction companies can gain from streamlining their processes using digital tools and technology. As mentioned earlier, with real-time visibility into inventory, firms can accurately track materials, equipment, and supplies. This helps to prevent shortages or overstocking, which can cause delays in project completion. By using data-driven decision- making, firms can make informed choices about when and how much to reorder, further reducing the risk of delays due to material shortages.

Location tracking is another valuable tool for construction companies, particularly for large projects that span multiple sites. With GPS and RFID technologies, project managers can track goods and materials in real-time (Costin, Teizer, & Schoner, 2015; Lu, Huang, & Li, 2011). This helps them anticipate delivery times, plan logistics, and respond quickly to any delays that may arise. It is also useful in reducing waste by ensuring that materials are used efficiently. Construction teams can monitor usage, track spoilage, and adjust procurement strategies accordingly (Manavalan & Jayakrishna, 2019). This contributes to cost savings and sustainability, making digital tools an essential part of modern construction management.

2.5.10 Operational Efficiency – Competitive Advantage and Cost Reduction

This section delves into several critical facets of digitization's impact on businesses. It underscores the optimization of supply chains, shedding light on how digitalization enables real-time tracking of goods and materials, leading to improved logistics and minimized waste. Additionally, it highlights the competitive advantages that businesses can secure by embracing digitalization, allowing them to respond swiftly to market changes and customer demands. Furthermore, this section emphasizes the substantial cost reductions realized through operational efficiencies, where automation and data analytics play pivotal roles in streamlining processes. The transition to paperless operations is also explored, showcasing how it reduces the consumption of physical resources, cuts storage expenses, and enhances overall organizational efficiency. These elements collectively illustrate the multifaceted benefits that digitization brings to businesses across various industries.

2.5.11 Competitive Advantage

The construction industry, traditionally known for its slow adoption of technological advancements, is now experiencing a digital transformation that offers numerous opportunities for gaining a competitive edge. Digitalization is providing construction companies with the tools to enhance their market positioning and agility in a rapidly evolving landscape. Here's an in-depth discussion of how digitization grants competitive advantage in the construction industry:

- *Market Positioning*

Construction firms can benefit greatly from leveraging digital tools throughout the project lifecycle. One major advantage, as have been established earlier, is enhanced client engagement, as digital tools enable firms to provide transparency and real-time progress updates to clients. This leads to improved relationships and client loyalty (Sebastian et al., 2020).

Another benefit is the ability to create more accurate and compelling bids through the use of advanced software. Precise project estimates, 3D visualizations, and interactive presentations can set construction companies apart from their competitors (Assarehpour, 2022). Firms that embrace digital technologies like BIM and AR can differentiate themselves even further by offering innovative and value-added services. For example, virtual walkthroughs using AR can impress clients and investors. Digital project management tools and remote collaboration capabilities also allow construction firms to expand their market reach by taking on projects in distant locations without a significant physical presence.

Finally, successful integration of digitalization can enhance a construction firm's reputation as an industry innovator committed to quality and efficiency (Phang, Chen, & Tiong, 2020). By leveraging digital tools, therefore, construction firms can improve client engagement, create more accurate bids, differentiate themselves from competitors, expand their market reach, and build a strong reputation in the industry.

- *Agility*

Another advantage of digitalization is the flexibility it provides to construction companies. The industry is subject to regulatory changes, evolving client preferences, and unexpected events like the COVID-19 pandemic. Digitalization enables firms to adapt swiftly to these changes, whether it's implementing new safety protocols or modifying project plans (Priyono, Moin, & Putri, 2020). Furthermore, construction firms can use digitalization to optimize resource allocation, ensuring that labour, equipment, and materials are deployed efficiently, all which have been extensively discussed earlier. This agility in resource management contributes to cost control and competitive pricing, which is critical in today's market. Digital tools and platforms also make it easier for construction firms to diversify into different types of projects (Singh, Gu, & Wang, 2011). They can pivot from residential to commercial construction or from infrastructure to sustainable construction based on market demands. This flexibility in project types enables firms to stay competitive and profitable. Last but not least, digitization facilitates the scalability of construction operations. Firms can scale up or down as project demands fluctuate, reducing the risk of overextending resources (Scott, Broyd, & Ma, 2022).

In summary, digitalization has become a critical component of the construction industry, providing numerous benefits that enhance efficiency, competitiveness, and profitability. Digitalization thus offers construction companies a competitive advantage through improved market positioning and agility. By leveraging digital tools and embracing change, construction firms can enhance client engagement, differentiate themselves, and adapt to evolving market conditions. These benefits contribute to long-term success and growth in the construction industry.

2.5.12 Cost Reduction

Cost reduction, which has been mentioned a number of times in this section, is a crucial factor in the construction industry, which often faces tight budgets and margin pressures. Digitization has emerged as a powerful tool for construction companies to optimize operational costs and transition to more efficient paperless operations. Here, we delve into how digitization achieves cost reduction in the construction industry:

- *Operational Costs*

Digitalization has revolutionized the construction industry by introducing several automation processes that reduce the need for manual labour and human intervention. For instance, project management software can automate scheduling, resource allocation, and communication, leading to reduced labour costs, all which have been discussed earlier.

However, there are other ways by which digitalization can help in construction project management. For example, digital tools can monitor energy consumption in real-time, optimizing usage and reducing costs. This is because, smart sensors can adjust lighting and climate control systems automatically based on occupancy, leading to increased energy efficiency (Dong et al., 2019).

Additionally, IoT (Internet of Things) sensors and data analytics have enabled predictive maintenance of construction equipment (Compare, Baraldi, & Zio, 2019; Niyonambaza, Zennaro, & Uwitonze, 2020; H. Wang et al., 2022). By monitoring machine performance and identifying potential issues in advance, companies can prevent costly breakdowns and reduce maintenance costs. Digitalization tools also provide insights into the utilization of equipment and machinery. Companies can determine if certain assets are underutilized and make decisions about sharing, renting, or selling equipment to cut costs (Kumar, Lahiri, & Dogan, 2018). These benefits of digitization have made the construction industry safer, more efficient, and cost-effective.

- *Paperless Operations*

Digitalization offers several benefits to construction companies, including reduced printing and paper costs. By creating, sharing, and storing project documents electronically, companies can eliminate the need for extensive paper-based documentation (Back & Moreau, 2001). In addition to cost savings, digital record-keeping simplifies document management, making it easier to retrieve records and reducing administrative time and effort (Touray, 2021).

Digital platforms also enhance collaboration among project stakeholders, eliminating the need for physical documents. This streamlines communication and reduces courier and shipping costs associated with transporting physical documents (Keskin, Salman, & Koseoglu, 2022). Furthermore, digital documents require significantly less physical space, and cloud storage solutions eliminate the need for on-site document storage facilities. Beyond cost savings and streamlined operations, transitioning to paperless operations also supports sustainability goals. By reducing a company's carbon footprint and supporting eco-friendly practices, companies can contribute to a more environmentally friendly future (Sharma, 2016).

Digitization is thus a cost-effective solution for the construction industry, reducing operational costs and transitioning to more efficient paperless operations. By automating processes, optimizing energy consumption, and eliminating paper-based practices, construction companies can achieve significant cost reductions while improving efficiency and sustainability. These cost-saving measures contribute to a more competitive and financially robust construction industry.

2.5.13 Globalization

The "construction industry", historically tied to local projects and physical presence, is experiencing a shift towards globalization, thanks to the transformative power of digitalization. This shift encompasses market expansion beyond national borders and tapping into a global workforce.

In today's digital age, there is potential for construction firms to expand their reach globally and participate in international projects. Through digitalization, these firms can bid on projects in different countries, collaborate with partners from around the world, and expand their portfolio (Barbosa, Woetzel, & Mischke, 2017). Additionally, they can market their services globally through websites, social media, and online industry forums, connecting with potential clients, partners, and investors worldwide.

The opportunity for virtual project tours ensures that global clients have assess project progress and quality without the need for physical presence, fostering trust in global projects. Digital platforms also facilitate real-time communication across borders. Video conferencing, instant messaging, and collaboration tools bridge geographical gaps, enabling efficient communication with international stakeholders (Damian & Zowghi, 2003; Mahmoud, 2023). Additionally, these platforms can offer multilingual support, breaking down language barriers in international collaborations. Language translation tools and real-time interpretation services facilitate communication with global partners.

Another advantage of digitalization is the potential to access a global talent population. Companies are increasingly adopting remote labor and can hire skilled professionals from anywhere in the world (Eni et al., 2023; Frankiewicz & Chamorro-Premuzic, 2020). This expands the pool of available talent, allowing construction firms to choose the best fit for their projects, regardless of geographical location. However, while the remote workforce is thriving in other industries, the potential for that being prevalent in the construction industry may not be entirely workable. This is because most of the construction jobs require the staff to be onsite. The study of Overturff (2021) suggested that while the workers have mixed reactions about the prospect of remote work, the project managers generally have negative feelings about it based on their experiences.

Overall, the digitization of the "construction industry" offers numerous benefits for companies looking to expand their reach and participate in international projects. With the ability to conduct virtual tours, real-time communication, and access a global talent pool, construction firms can increase their opportunities for growth and success.

2.5.14 Sustainability and Environmental Impact

The "construction industry" has prioritized sustainability as a result of an increasing consciousness of environmental concerns and a desire to mitigate the sector's carbon footprint. The construction industry is experiencing a substantial increase in sustainability and a reduction in environmental impact as a result of digitalization.

Apart from reduced carbon footprint which helps construction companies with sustainability goals, Building Management Systems (BMS) are being used to optimize energy consumption within buildings by monitoring energy use and automatically adjusting heating, cooling, and lighting (Tatari et al., 2022). Additionally, architects and engineers are using Building Information modelling (BIM) and other digital tools to design energy-efficient and sustainable buildings (Gourlis & Kovacic, 2017). They can simulate the energy performance of different design options and select the most environmentally friendly solutions. Digital databases and platforms also provide information about sustainable building materials, which helps construction companies choose eco-friendly options that have a lower environmental impact (Mohapatra et al., 2019). All of these advancements in digital technology are contributing to a more sustainable construction industry. In essence, digitalization is driving sustainability and reducing the environmental impact of the construction industry. By minimizing carbon emissions, promoting renewable energy integration, and optimizing resource utilization, digitalization aligns the industry with global sustainability goals.

2.5.15 Workforce Transformation

The ongoing digitization of the construction industry brings about significant changes in workforce dynamics and requirements. Workforce transformation involves addressing skill requirements, reskilling and upskilling programs, remote work trends, and their impacts. In an era of growing digitalization within the construction industry, employees' proficiency in digital literacy becomes imperative. This entails having the capability to effectively utilize digital tools, software, and platforms that are pertinent to their respective roles. For instance, construction managers may require expertise in project management software, while architects may need to demonstrate proficiency in BIM tools (Sacks & Pikas, 2013). The synonymous relationship between digitalization and perpetual change underscores the importance of adaptability among construction workers and professionals.

Also, given the continuous emergence of new technologies and tools, it is incumbent upon individuals in the industry to remain adaptable and open to acquiring new digital skills throughout the course of their careers. The increasing importance of data administration skills in the construction industry is underscored by the increasing use of digital technologies. It is imperative that employees possess a comprehensive understanding of the methods for efficiently collecting, analysing, and utilizing data to improve project outcomes and inform decision-making processes. Training programs should be customized to meet the unique requirements of various job positions in the construction sector. This guarantees that employees acquire the skills required for their positions and career advancement. In order to ensure that employees have access to pertinent courses and certifications, construction companies may establish partnerships with educational institutions and online learning platforms. This cultivates a culture of perpetual learning.

2.6 The Effect of Digitalization on Construction Industry Productivity

Digitalization is rapidly transforming the construction industry, enhancing productivity, efficiency, and safety across various dimensions. This section provides an extensive exploration of the impact of digitalization on construction industry productivity through specific technological advancements and strategies. Digitization encompasses the adoption and integration of digital technologies and tools in various aspects of the construction industry. This includes BIM, ERP systems, automated construction robotics, drones, augmented reality (AR), virtual reality (VR), the Internet of Things (IoT), and AI. The term "Digitalization" describes how digital technologies like AI, IoT, and BIM are being used and integrated into construction projects to improve project management, planning, and execution. It increases efficiency, makes it easier to make decisions in real time, fosters better teamwork, and increases output. However, obstacles like the requirement for specialised labour, opposition to change, and large upfront expenses continue to be obstacles to full-scale implementation (Elghamrawy & Galal, 2022; Ahmed et al., 2023; Lauria & Azzalin, 2024).

a) **Construction Robotics:** Automated construction robotics, including autonomous machinery and drones, are revolutionizing the construction industry. These digitalization technologies bring precision, speed, safety, and quality assurance to construction projects. Firstly, robotics excel at performing repetitive and labour - intensive tasks with precision and incredible speed, reducing manual labour and accelerating project timelines (Perestoronina, 2020). Secondly, they enhance safety by operating in hazardous conditions and minimizing worker exposure to risks (Tamers et al., 2020). Thirdly, automation eliminates many errors associated with manual labour, ensuring consistent quality in construction components (Sacks et al., 2010). Robotics also offer real-time data collection, enabling continuous monitoring of construction processes (Popli et al., 2023). These advantages contribute to higher productivity, reduced costs, and improved project quality, positioning automation as a key driver in construction's digital transformation.

b) **Drones:** Drones, or Unmanned Aerial Vehicles (UAVs), have become indispensable tools in the construction industry (Adepoju et al., 2022; Tkáč & Mésároš, 2019). Digitalization technology leverages drones to improve construction processes in various ways. Firstly, drones conduct rapid aerial site surveys, providing real-time data for site analysis and design decisions. This accelerates site planning, reduces surveying time, and offers cost-effective solutions. Secondly, drones monitor project progress through high-quality imagery and videos, enabling early issue identification and reducing rework costs. Thirdly, drones enhance safety by identifying hazards, monitoring safety compliance, and providing real-time information to emergency responders. Overall, digitalization empowers construction projects through efficient surveys, real-time monitoring, and enhanced safety measures, ensuring higher productivity and project success.

c) **Digitalization Communication Technology:** Effective communication is essential for construction project success, and digitalization has revolutionized communication in the industry. It has been established earlier that digital communication platforms and tools enhance collaboration, document management, and mobile project management. Firstly, collaboration tools facilitate real-time cooperation among stakeholders, ensuring access to up-to-date project information and reducing miscommunication- related delays. Secondly, digital document management systems streamline document sharing, version control, and accessibility. These cloud-based systems enhance remote access to project documents and maintain document integrity. Thirdly, mobile apps enable remote project management, efficient communication, and on-site data capture. By leveraging these digital tools, construction projects achieve higher levels of productivity, transparency, and overall success.

d) **Building Information Modelling (BIM):** BIM is a transformative digitalization technology in construction. It has been established in literature that BIM significantly improves project productivity through design coordination, quantity take offs, and project lifecycle management (Paik, Leviakangas, & Choi, 2022). Firstly, BIM enables 3D modelling, enhancing design coordination by visualizing how different elements interact, identifying clashes, and reducing rework costs. Secondly, it automates quantity take offs, providing accurate material estimates, reducing waste, and supporting cost control. BIM also extends its benefits to the entire project lifecycle, including maintenance and renovation. For example, facility managers use BIM models to plan maintenance, track equipment data, and coordinate renovations efficiently and BIM centralizes project data, supporting sustainable practices by providing insights into energy efficiency and environmental impact. Overall, BIM empowers construction projects with precision, efficiency, and sustainability, contributing to enhanced productivity and long-term success. A significant case study is the utilization of Building Information Modelling (BIM) by the construction firm Skanska in the execution of the Heathrow Airport Terminal 2 project (Succar, 2009). This project illustrated the capacity of BIM to augment cooperation, minimize errors, and enhance overall project efficiency. The implementation of digital technologies, including BIM, IoT sensors, and mobile applications, has been noted in many construction projects, leading to increased productivity, decreased costs, and higher customer satisfaction (Oraee et al., 2017; Dave et al., 2018).

e) **ERP Systems:** Enterprise Resource Planning (ERP) systems are pivotal in the construction industry, acting as centralized platforms for data management and decision-making (Kitsantas, 2022). Firstly, ERP systems integrate and centralize project-related information, ensuring that stakeholders have access to real-time data, including project costs, schedules, and procurement details. This streamlined communication reduces miscommunication and errors among project teams. Additionally, ERP systems offer robust analytics and reporting features, empowering project managers with insights into project performance. Secondly, ERP systems optimize resource allocation by providing a clear view of resource availability and demand, allowing efficient deployment of equipment, materials, and labour. Predictive capabilities assist in resource forecasting, averting shortages or surpluses. Lastly, ERPs streamline financial processes, automating tasks like invoicing and expense management. Real-time financial visibility supports budget monitoring and cost control, ensuring projects stay on track financially. ERP systems, therefore, contribute significantly to construction project productivity through data integration, resource optimization, and financial management.

f) **Augmented Reality (AR) and Virtual Reality (VR):** AR and VR are transformative technologies in construction, significantly enhancing productivity (Le et al., 2015). To begin with, they offer 3D visualization of project designs, aiding comprehension among stakeholders and reducing design errors. This visualization allows for early issue identification, minimizing rework and saving time and resources. Collaborative design reviews become more efficient, as multiple stakeholders can simultaneously view and discuss designs. Secondly, VR provides immersive training experiences for construction workers, simulating on-site scenarios and enhancing skills and safety awareness. Workers can practice tasks in a risk-free

Virtual environment, reducing accidents and errors on actual sites. VR can also simulate hazardous situations for safety training. Thirdly, AR supports remote collaboration by overlaying digital information onto the physical site, enabling experts to provide guidance remotely. This reduces travel costs and time, ensuring projects progress smoothly. AR and VR improve communication among dispersed teams, enhancing collaboration and decision-making. Augmented Reality and Virtual Reality technologies are instrumental in improving construction project productivity through design visualization, training, and remote collaboration.

g) **Internet of Things (IoT):** As established earlier, the Internet of Things (IoT) is transforming construction by enabling real-time data collection and monitoring (Tang et al., 2019).

   I. IoT tracks equipment usage and performance, optimizing resource allocation and enabling predictive maintenance to prevent delays and repairs. Equipment deployment becomes more efficient, avoiding idle resources.

II. IoT sensors monitor environmental conditions on construction sites, ensuring worker safety by detecting hazards like poor air quality. It optimizes resource usage by adjusting systems based on real-time data. Noise monitoring helps with compliance and prevents disruptions.

III. It also manages construction assets by providing real-time location data, reducing the risk of loss or theft. Automated inventory management ensures that materials are always available, preventing project delays. Security systems equipped with IoT enhance asset protection by detecting unauthorized access and notifying authorities.

h) **Artificial Intelligence (AI):** Artificial Intelligence (AI) is revolutionizing construction project management and productivity (Abioye et al., 2021). Some of the ways by which this happens are discussed.

I. Firstly, AI leverages predictive analytics to foresee potential project issues and manage risks. It analyzes historical data to identify patterns and predict challenges, allowing proactive problem-solving. Risk assessment becomes more accurate. AI also improves scheduling by considering multiple factors, ensuring more realistic timelines.

II. It also helps to optimize resource allocation, efficiently managing labour , materials, and equipment. Predictive maintenance and cost control tools help identify cost-saving opportunities.

III. Lastly, AI enhances quality control through image recognition technology. Drones with AI detect defects and deviations, reducing errors and rework. AI monitors project data to identify quality issues in real-time. Compliance checks ensure adherence to standards.

Artificial Intelligence thus plays a significant role in enhancing construction project productivity through predictive analytics, resource optimization, and quality control. Due to the need to increase production, efficiency, and competitiveness, the South African construction sector has been progressively adopting digitalization (Olawumi & Chan, 2020). Contractors, architects, and engineers can now work together more efficiently and make data-driven decisions thanks to the growing use of digital technologies like BIM, Geographic Information Systems (GIS), and mobile applications (Aigbavboa & Oke, 2020). However, because of things like low digital literacy, poor infrastructure, and change aversion, the sector still has trouble using digitalization to its full potential (Makinde et al., 2020). The sector has to take a systematic approach to digitization in order to overcome these obstacles, which includes funding for infrastructure, innovation, and the development of digital skills (CIDB, 2020).

In summary, digitalization technologies are revolutionizing the construction industry by improving labour productivity, automating tasks, enhancing communication, and optimizing resource management. Technologies like BIM, ERP systems, drones, AR, VR, IoT, and AI are increasingly integrated into construction processes, resulting in increased effectiveness and cost savings. Embracing these digital tools is becoming essential for staying competitive in the modern construction landscape.

2.7 The impact of Composite Digitalization in the construction Industry

Composite digitalization in the construction sector denotes the combination of various digital technologies, including BIM, Geographic Information Systems (GIS), and the IoT, to optimize construction processes and enhance project results (Dave et al., 2018). This integrated methodology facilitates the development of digital twins, which are virtual representations of physical construction projects, for real-time monitoring, modeling, and optimization of building processes (Tang et al., 2020). Composite digitization has demonstrated the capacity to enhance construction productivity, minimize errors, and promote collaboration among stakeholders (Succar et al., 2019). Moreover, it facilitates the integration of sustainability and energy efficiency factors into construction projects, resulting in more environmentally sustainable and robust structures (Ilunga et al., 2020)

A case study of the redevelopment of the Sydney Opera house (2019-2023) reported that the effect of the application of composite digitalization within the construction sector. This project amalgamated BIM, GIS, and IoT technologies to augment cooperation, optimize data administration, and diminish building expenses (Eastman et al., 2018). The project team employed a cloud-based common data environment (CDE) to enable real-time data exchange and collaboration among stakeholders (Miettinen & Paavola, 2018). The implementation of digital twins and IoT sensors facilitated real-time oversight of the construction process, permitting swift detection and rectification of possible problems (Dave et al., 2020). The digitization strategy of the project led to a 15% reduction in building costs and a 20% decrease in project timeframes (Sydney Opera House, 2022).

2.8 Digital transformation in the construction industry

The process of transforming conventional analogue building methods and data into digital formats. This includes gathering site data and producing digital models using digital methods like photogrammetry and laser scanning. In the construction industry, digitisation is transforming paper-based systems and processes into digital formats, such as digital drawings and databases. It is the first step towards adopting more sophisticated technologies like IoT and BIM. This change improves data accessibility, accuracy, and operational efficiency, but obstacles like the requirement for technical expertise and setup fees may prevent broad adoption (Elghamrawy & Galal, 2022). According to (Oraee et al., 2017) the digital transformation of the construction sector entails the use of digital technologies, including BIM, IoT, and AI, to enhance efficiency, productivity, and sustainability. This change facilitates real-time collaboration, automated data collecting, and predictive analytics, resulting in enhanced decision-making and decreased costs (Davies et al., 2017). Furthermore, digital transformation promotes the implementation of advanced building techniques, like modular construction and 3D printing, which can enhance construction efficiency and quality (Perera et al., 2020). The construction business encounters obstacles in embracing digital technology due to reasons including insufficient digital literacy, limited infrastructure, and opposition to change (Love et al., 2018).

Globally some parts of the construction sector have experienced substantial digital change in the last two decades, shifting from conventional manual operations to automated, technology-driven methods (Eastman et al., 2011). This transformation has optimized project management, augmented collaboration, and elevated productivity (Kumar et al., 2020). The implementation of BIM has facilitated real-time data exchange and minimized errors, leading to cost reductions and enhanced project results (Antonio et al., 2017). The incorporation of IoT sensors and AI algorithms has facilitated predictive maintenance, enhanced resource allocation, and bolstered site safety (Jia et al., 2019). The preliminary phases of digital transformation in construction emphasized the implementation of computer-aided design (CAD) software and BIM (Succar, 2009).

With technological advancement, the industry experienced the rise of revolutionary digital tools and approaches, including digital twins, AI, and the IoT (Dave et al., 2018). These developments have allowed construction firms to enhance project efficiency, decrease expenses, and improve collaboration among stakeholders (Bryde et al., 2013). The COVID-19 pandemic has expedited the integration of digital technologies in construction, underscoring the necessity for enhanced resilience and adaptation within the industry (Purnus et al., 2021).

The "South African construction sector" has been progressively adopting digital transformation, though at a more slower rate than other nations (Olawumi & Chan, 2020). The usage of BIM has been on the rise, as a survey indicated that 71% of participants in South Africa's construction sector utilized BIM (Migilinskas et al., 2019). Furthermore, the utilization of digital technology, including drones, GIS, and mobile applications, has increased, improving site management, quality control, and collaboration (Aigbavboa & Oke, 2020). Nonetheless, obstacles remain, such as insufficient infrastructure, restricted digital competencies, and reluctance to adapt (Olawumi & Chan, 2020). To maximize digital transformation, the sector must confront these hurdles and cultivate a more strategic methodology for technology adoption.

The Construction Industry Development Board (CIDB) is crucial in advancing digital transformation in "South Africa's construction industry". The CIDB's 2020 report, "Digital Transformation in the South African Construction Industry," indicates that the industry is primed for substantial growth via the implementation of digital technologies, including BIM, AI, and the Internet of IoT (CIDB, 2020). The CIDB has underscored the necessity for industry players to invest in the development of digital skills and infrastructure to maintain competitiveness. Additionally, the CIDB has partnered with industry stakeholders to create digital platforms and solutions designed to improve construction project management, safety, and quality (Construction Business Review, 2022). The CIDB's initiatives to promote digital transformation in the construction industry are anticipated to significantly enhance the sector's productivity, efficiency, and sustainability.

2.9 Digitalization and Small and Medium-Sized Enterprises (SMEs)

Digitalization is a game-changer for Small and Medium-Sized Enterprises (SMEs) in the construction industry, offering them significant advantages in accessing markets and adopting cost-effective solutions (Almshref, 2022; Chang-Richards et al., 2022). Here, we explore how digitalization benefits SMEs in the construction sector according to the aforementioned authors:

Access to Markets:

a. **Global Reach:** Digitalization breaks down geographical barriers, enabling SMEs to access global markets that were previously out of reach. Through online platforms, marketplaces, and digital marketing, SMEs can showcase their services and products to a worldwide audience.

b. **Levelling the Playing Field:** Digitalization levels the playing field between SMEs and larger competitors. With a strong online presence and effective digital marketing strategies, SMEs can compete on a global scale, attracting customers and partners from diverse regions.

c. **Easier Collaboration:** Digital tools facilitate collaboration with other construction companies, architects, engineers, and suppliers across borders. SMEs can participate in international projects and expand their networks, further enhancing their market reach.

Cost-Effective Solutions:

d. **Cloud Computing:** SMEs can leverage cloud computing for cost-effective storage, data management, and software access. Cloud-based solutions eliminate the need for expensive on-premises infrastructure and provide scalability to match business growth.

e. **Software-as-a-Service (SaaS):** SaaS models offer SMEs access to advanced software solutions on a subscription basis. This eliminates the upfront costs of purchasing software licenses and reduces the burden of software maintenance and updates.

f. **Pay-as-You-Go:** Many digital services, including cloud computing and SaaS, operate on a pay-as-you-go or consumption-based pricing model. SMEs only pay for the resources and services they use, making it a cost-effective approach.

Reduced Administrative Costs:

Digital tools streamline administrative tasks, reducing the need for extensive administrative staff. This cost-saving benefit enables SMEs to allocate Digitalization is a game-changer for SMEs in the construction industry, offering them opportunities to access global markets and adopt cost-effective solutions. Embracing digitalization not only enhances the competitiveness of SMEs but also empowers them to thrive and grow in an increasingly digital business landscape.

2.10. Theoretical Framework

The elements that impact productivity in the construction industry are multifaceted and are founded in a specific organizational environment. Rather than being unidirectional in its application, this process is multidirectional (Aubry et al., 2010). The adoption of digital technology as one of the approaches for improving productivity in the construction industry has given rise to a new innovation platform for the expansion of the traditional construction sector and its full integration into the digital economy (Barbosa et al., 2017). Greenacre et al. (2012) contend that the most significant factor contributing to long-term productivity and economic growth is the advancement of technological innovation. In order to construct a theoretical framework that may be utilized to get an understanding of the impact of Digitalization on the productivity of the South African Industry, we will be using multiple theories.

In this section, we delve into the theoretical and conceptual underpinnings that provide the intellectual framework for our investigation into the impact of digitalization on the South African construction industry's productivity. We explore key theories and frameworks that inform our research design and analytical approach, aligning them with our research hypotheses and objectives. By drawing upon established theories, we aim to develop a comprehensive understanding of how digitalization shapes various facets of the construction industry, from labour productivity to information management and innovation adoption. This section sets the stage for the empirical exploration and analysis that follows, bridging the gap between theoretical foundations and practical insights.

The "Diffusion of Innovations " (DOI) theory, this theory was first propounded in 1962 by E. M. Rogers in 1962 (Rogers, Singhal, & Quinlan, 2014). The Diffusion of Innovations Theory provides a framework for understanding how new ideas or technologies spread within a social system. According (Rogers, 2003), the theoretical framework for digitalization in the construction sector can be based on the Technology Acceptance Model (TAM) and the DOI theory. The ATM model asserts that the acceptance of digital technologies is affected by perceived utility, perceived ease of use, and attitudes toward technology (Davis, 1989). The DOI theory posits that the dissemination of digital innovations is affected by aspects including relative advantage, compatibility, complexity, trialability, and observability. By amalgamating these two frameworks, researchers may analyze the determinants that affect the adoption and dissemination of digital technologies in the construction sector, including BIM, digital twins, and the IoT (Olawumi & Chan, 2020). This framework offers insights into the difficulties and possibilities linked to digitization and productivity in the construction sector.

The "Technology-Organization-Environment" (TOE) framework and the "Dynamic Capabilities Theory" (DCT) may serve as the theoretical foundation for a digital transformation strategy in the construction sector. According to Teece et al. (1997), digital transformation depends on a company's capacity to integrate, develop, and reorganize its internal and external competencies. However, according to the TOE paradigm, organizational, technical, and environmental elements all have an impact on digital transformation (Tornatzky & Fleischer, 1990). Combining these two frameworks, researchers may look at the organizational, technical, and environmental elements that affect this process as well as the dynamic capacities needed for construction companies to adjust to digital transformation (Olawumi & Chan, 2020). This framework may shed light on the potential and difficulties related to the digital transformation of the construction sector.

Kohli and Grover (2008) argued that the Unified Theory of Acceptance and Use of Technology (UTAUT) and the Technology-Organization-Environment (TOE) framework may provide a theoretical basis for industrial digitalization. According to Venkatesh et al. (2003), the UTAUT posits that performance expectancy, effort expectancy, social influence, and facilitating conditions affect the adoption and utilization of digital technologies. Additionally, Tornatzky and Fleischer (1990) propose that technological, organizational, and environmental factors impact digitization within the TOE framework. By integrating these two frameworks, researchers may examine the determinants affecting the adoption and use of digital technologies in industry, along with the technical, organizational, and environmental aspects that either promote or hinder digitization. This framework provides insights into the potential and problems associated with industrial digitalization.

According to (Olawumi & Chan, 2020) the "Input-Process-Output (IPO) framework and the Task-Technology Fit (TTF) model can serve as the foundation for a theoretical framework that examines the impact of digitalization on productivity in the construction industry". The TTF model posits that the performance and productivity of users are influenced by the alignment between technology and task requirements (Goodhue & Thompson, 1995). The IPO framework posits that productivity is impacted by digitalization in three ways: inputs such as labor, materials, processes such as construction methods, project management, and outputs such as project delivery time, quality (Liao et al., 2017). Researchers can investigate the impact of digitalization such as BIM & digital twins on productivity in the construction industry by optimizing processes, increasing output quality, improving input efficiency, and enhancing task-technology fit by integrating these two frameworks (Olawumi & Chan, 2020). This framework has the potential to offer a deeper understanding of the mechanisms through which productivity in the construction industry is influenced by digitalization.

(Olawumi & Chan, 2020; Makinde et al., 2020) further argue that the Technology-Organization-Environment (TOE) and Input-Process-Output (IPO) frameworks provide a theoretical foundation for productivity in the construction sector through digital transformation. According to (Tornatzky & Fleischer, 1990) the TOE framework, digital transformation influences organizational (such as culture and structure), technological (such as digital tools and platforms), and environmental (such as industry norms and regulations) factors, all of which have an impact on productivity. According to the IPO framework, digital transformation boosts output quality, optimizes processes (like building techniques and project management), and improves inputs (like personnel and materials) in order to increase productivity (Liao et al., 2017). Through the integration of these two frameworks, scholars can investigate the ways in which digital transformation—such as digital twins, BIM, and the Internet of Things (IoT)—affects construction industry productivity by utilising organizational capabilities, technological advancements, and environmental factors to enhance input efficiency, process optimisation, and output quality. (Olawumi & Chan, 2020; Makinde et al., 2020).

2.11 Empirical Literature review

The literature review of this research is aimed at comprehensively investigating theimpact of digitalization on productivity within the South African construction industry. It integrates key concepts such as digitalization, productivity, digital transformation, digitization, and technological adoption. This provides the necessary structure for understanding the relationships between these variables and testing the research hypotheses. By also incorporating the above theories and referencing relevant literature, the study has developed a robust framework for analysing the impact of digitalization on the overall construction productivity in the South African context.

2.11.1 Definition of terms

The following terms are repeatedly used in this thesis and are hereby defined below.

- **Digitization:** The general definition of digitization in industry has been consistent amongst researchers, according to (Kemmerer et al., 2017) "digitization is the process of converting analog data into digital format, such as the conversion of paper-based documents into digital files". (Sarvabhotla et al., 2016) describes "digitization as the process of creating digital representations of physical objects, such as documents, images, and artifacts. Lee, 2013, refers to Digitization as the process of creating digital data from non-digital sources, such as paper documents, photographs, and audio recordings". Bharadwaj et al., 2013, "Digitization is the integration of digital technologies into all aspects of business, transforming the way companies operate, innovate, and interact with customers".

- **Digitalization:** Westerman et al. (2014) state that "digitalization is the process of integrating data and digital technology into every facet of an organization, changing value chains, processes, and business models". "Digitalization is the integration of digital technologies into all aspects of business, transforming the way companies operate, innovate, and interact with customers" (Bharadwaj et al., 2013, p. 472) "Digitalization is the digital transformation of industries, characterized by the widespread adoption of digital technologies, such as artificial intelligence, blockchain, and the Internet of Things" (Kane et al., 2017, p. 24). "Digitalization is the shift from analog to digital processes, products, and services, enabling greater efficiency, productivity, and innovation" (Gartner, 2019).

- **Digital transformation: "**Digital transformation refers to the integration of digital technology into all areas of a business, fundamentally changing how it operates and delivers value to customers" (Gartner, 2019). "Digital transformation is the process of shifting business models, products, and services to digital formats, enabling new revenue streams, customer experiences, and competitive advantages" (Westerman et al., 2014, p. 3) "Digital transformation is a strategic renewal process that enables organizations to leverage digital technologies to innovate, adapt, and evolve in response to changing market conditions" (Bharadwaj et al., 2013, p. 472). "Digital transformation requires a cultural transformation, where organizations adopt a digital mindset, embracing experimentation, innovation, and continuous learning" (Li et al., 2018, p. 12).

- **Composite Digitalization:** Composite digitalization refers to the integration of multiple digital technologies, such as artificial intelligence, blockchain, and the Internet of Things, to create new business models, products, and services" (Kane et al., 2017, p. 24). "Composite digitalization is the application of digital technologies to composite materials and manufacturing processes, enabling the creation of complex shapes, structures, and products" (Luo et al., 2018, p. 12). "Composite digitalization involves the digitalization of complex systems, such as composite materials, structures, and systems, to optimize their performance, efficiency, and sustainability" (Ganguli et al., 2020, p. 3). "Composite digitalization is a hybrid approach that combines different digital technologies, such as digital twins, simulation, and data analytics, to create a comprehensive digitalization strategy" (Tao et al., 2019, p. 102). For the purpose of this study composite digitalization refers to the

- **Productivity:** The definition of productivity has evolved over time according to Kendrick, (1961) "Productivity is defined as the ratio of output (e.g., goods, services) to input (e.g., labor, capital, materials)". Hulten, 2001 referred to "Productivity as the value added per unit of input, reflecting the ability of firms to generate value from their resources". Fare et al., 2004, defined "Productivity as the efficiency with which inputs are converted into outputs, measured by the ratio of output to input"

  According to Productivity in the context of this research refers to the efficiency and effectiveness of construction processes and outcomes. It is a multifaceted concept that includes labour productivity, cost efficiency, time management, quality of work, and resource optimization. In the construction industry, productivity refers to how well resources—such as labour, materials, and technology—are used to accomplish project objectives. "Productivity in construction is defined as the value added per unit of input (e.g., labor hour, material quantity)" (Rooke et al., 2017, p. 102). By optimising resource management, decreasing errors, and simplifying workflows, digital technologies such as AI, IoT, and BIM increase productivity. These benefits, however, may be hampered by issues including disjointed procedures and opposition to new technologies (Liu et al., 2023; Lauria et al., 2024).

2.11.2 Research hypothesis and method of determination

The six research hypotheses encompass the core focus of this study, each addressing a critical aspect of digitalization's influence on construction industry productivity in South Africa. The framework guides the empirical investigation by defining key variables, collecting data, and analyzing the findings to draw conclusions regarding the role of digitalization in enhancing productivity.

Hypotheses 1 (H1): Employees of small, medium and large organizations have significantly different perceptions of digitalization, digitization, digital transformation and organizational productivity.

Determination: To test this hypothesis, the researcher will collect biographic and demographic data through the questionnaire from the respondents.

Hypothesis 2 (H2): Age of the business significantly influences perceptions of digitalization, digitization, digital transformation and organizational productivity.

Determination: To test this hypothesis, the researcher will collect company information including age of business data through the questionnaire from the respondents. This will also

Hypothesis 3 (H3): Digitization has a positive significant effect on perceptions of organizational productivity.

Determination: To test this hypothesis, the research will collect data on use digital technologies such as This includes BIM, ERP systems, automated construction robotics, drones, augmented reality (AR), virtual reality (VR), the Internet of Things (IoT), and AI Statistical analysis will reveal if there is a significant improvement in productivity.

Hypothesis 4 (H4): Digitalization technology has a positive significant effect on organizational productivity in the South African construction industry.

Determination: This hypothesis will be tested by examining data related to information management practices, such as communication efficiency, BIM utilization, and ERP system integration. Comparing data from before and after digitalization implementation will demonstrate whether there is a significant improvement in information administration.

Hypothesis 5 (H5): Digital transformation has a positive significant effect on productivity in the South African construction industry.

Determination: To test this hypothesis, the research will gather data on the adoption of innovative practices and technologies, such as automated construction robotics, drones, AR, VR, IoT, and AI. Comparing the prevalence of these technologies pre-and post-digitalization will reveal the extent of innovation.

Hypothesis 6 (H6): Composite digitalization has a positive significant effect on productivity in the South African construction industry.

Determination: This hypothesis will be determined by examining the combined data of

2.12 Conceptual framework

The theoretical framework used in this research is graphically shown in figure 1 below. The picture shows how important concepts relate to one another in the context of digitization and the construction sector. It illustrates the connections between and effects of various concepts on one another. The flowchart provides a visual representation of how digitalization affects construction project management, ultimately leading to enhanced productivity in the construction industry. It illustrates the interconnected nature of these concepts and how improvements in one area can positively influence others.

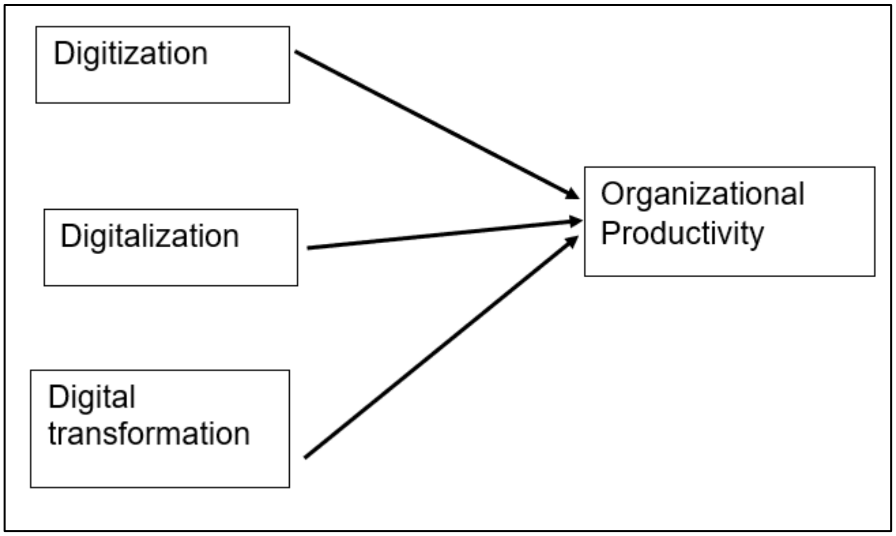

Figure 1: Theoretical Framework Flowchart: Impact of Digitalization concepts on Construction Industry Productivity

2.11. Chapter summary

In Chapter 2, we delve into the transformative influence of digitalization on the construction industry, with a focus on its profound impacts on productivity. We start by exploring the international and South African contexts of construction productivity, emphasizing the pivotal role of digitalization in streamlining processes and enhancing productivity. The challenges and opportunities specific to the South African construction industry, including infrastructure development, labour productivity, regulatory environment, technology adoption, transformation and equity, infrastructure backlogs, safety and health, and project management practices, are meticulously examined.

However, the chapter also delves into challenges brought about by digitalization, particularly in the realms of cybersecurity, data privacy, regulatory compliance, and ethical considerations, as AI and machine learning raise questions regarding transparency and accountability. The workforce transformation spurred by digitalization is examined. Skill requirements evolve, demanding digital literacy and adaptability. Remote work trends are accelerated, reshaping office space requirements and changing the nature of work. SMEs benefit from digitalization, gaining access to global markets and cost-effective digital solutions.

We explore digitalization's role in specific aspects of construction project management and productivity. Digitalization enhances labour productivity through efficient workforce management, training, and safety measures. Automated construction robotics and drones revolutionize construction processes, ensuring precision, speed, safety, and quality assurance. Digital communication technology streamlines project collaboration, document management, and mobile project management. BIM optimizes design coordination, quantity take offs, and project lifecycle management. Digitalization through ERP systems centralizes project data, optimizes resource allocation, and streamlines financial management. Drones expand their roles beyond site surveys, facilitating material delivery, progress documentation, and asset inspection.

AR and VR enhance design visualization, training, and remote collaboration in construction projects. IoT contributes to real-time data collection and monitoring, optimizing equipment tracking, environmental monitoring, and asset management. AI reshapes construction project management through predictive analytics, resource allocation, and quality control. Predictive analytics aids in proactive risk management and cost control. AI optimizes resource allocation and enhances cost control. Quality control benefits from AI-powered image recognition and data analysis, ensuring construction quality and compliance.

Finally, the theoretical framework section provides the foundation for understanding and analyzing the key concepts, models, and principles that underpin the research. It serves as a roadmap for the study, guiding the reader through the theoretical lens used to examine the research questions or hypotheses. This section typically outlines the relevant theories, models, or frameworks that inform the study's perspective and rationale. It establishes the theoretical context in which the research is situated, highlighting the relationships between variables or concepts and setting the stage for the subsequent methodology and analysis. In essence, the theoretical framework serves as the intellectual scaffold upon which the research is constructed, helping to shape the study's approach and interpretation of findings.

In conclusion, this chapter underscores the transformative potential of digitalization in the construction industry, impacting nearly every facet of construction project management and productivity. Digitalization is not just a technological evolution but a revolution that promises enhanced efficiency, sustainability, and global reach while posing critical challenges in data security, regulation, and ethical considerations.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter covers the systematic and structured procedure employed to conduct research investigations on the impact of digitalization on the productivity of the South African industry. This chapter consist of the study's comprehensive methodology, which encompasses the research approach, research design, the technique employed to identify participants and conduct sampling for the investigation, data collection instrument tool and delimitation of the study.

3.2 Research methodology

Research methodology denotes the systematic and organized framework used to execute research, including study design, data gathering procedures, data analysis methodologies, and result interpretation (Creswell, 2014). The process includes the selection of suitable research methodologies, including qualitative, quantitative, or mixed-methods techniques, to effectively answer the research question or hypothesis (Bryman, 2016). An effectively structured research methodology guarantees the reliability, validity, and generalizability of results, allowing researchers to derive significant conclusions and formulate informed suggestions (Saunders et al., 2016). Effective research technique necessitates the consideration of ethical standards, including informed consent, confidentiality, and anonymity, to safeguard study participants and uphold the integrity of the research process (Oliver, 2010).

3.2.1 Research approach

A research approach denotes the broad plan employed in conducting research, which directs the selection of the techniques and approaches needed (Creswell, 2014). It consists of the investigator's viewpoint, investigation topic, and objectives, which impacts the design of the study, data collection, and analysis (Bryman, 2016). Various research approaches exist, including positivism, interpretivism, pragmatism, and critical theory, each characterized by distinct ontological, epistemological, and methodological assumptions (Guba & Lincoln, 1994).

The investigator's individual preferences, the nature of the study, and the research question all influence the selection of a research approach (Saunders et al., 2016). For instance, quantitative studies may be more appropriate for a positivist strategy, while qualitative studies may be more suitable for an interpretivist approach. This study made use of a quantitative approach to investigate the impact of digitalization on productivity.

3.2.2 Research design

The research design is referred to as "the conceptual framework within which the research is carried out; it serves as the blueprint for data collection, measurement, and analysis" in the existing body of scholarly writing (Kothari, 2004). For this study the quantitative methodology was utilized. The use of quantitative approach has been beneficial to this study as it enabled the collection of statistical numerical data that is more comprehensive and reliable. This was necessary because the adoption of digital technology in the South African Construction industry is still at its infant stage with limited quantity of trustworthy and authoritative data accessible to prove the impact of digitalization on productivity in the South African construction industry. Furthermore, the quantitative component has been useful in terms of delivering the baseline data that was essential for carrying out impact assessment research on the effect of Digitalization in the South African construction industry.

Quantitative research is based on the concept of quantifying different aspects of an issue via the collection of numerical data (Kothari, 2004). This methodology is deductive in nature and allows for the building of procedures before to the beginning of the inquiry. Additionally, the formulation of the hypothesis may be done prior to the beginning of the study (Thomas, 2010). One definition of the quantitative approach describes it as a subfield of research that makes use of empirical models and findings. This is a contrast to an assertion that declares what "should be true," an empirical statement describes what "really" occurs in "real world" situations. (Sukamolson, 2007). The use of the quantitative method has been helpful in measuring opinions, attitudes, and behaviours on the impact of digitalization on productivity in the South African construction industry. This is because quantitative research can measure these factors.

3.2.3 Population, Sample and Sampling

This section presents two important data collection concepts of the population and sample of the study.

3.2.3.1 Population

According to Cooper and Schindler (2001), a population is a collection of components that may be used to draw inferences about the whole population. The quantitative approach of this study will have a specific audience in mind, and that audience will be comprised of organizations that are currently operating within the "South African construction industry".

3.2.3.2 Sampling Technique

As sample is defined as the subset of the population that is drawn from it for the purposes of studying (Babbie, 2022). Different techniques could be used to select a sample. There are options for sampling processes that are either probabilistic (random) or non-probabilistic (purposive) (Saunders et al., 2008). This inquiry will make use of non-probability sampling, sometimes known as purposeful sampling. To ensure that the participants in the research have access to relevant material and have a clear understanding of the problem statement being investigated, we will utilize purposeful sampling. (Brink et al., 1996; Creswell et al., 2003). The use of purposive sampling within the context of a quota sampling framework was necessary due to the absence of authoritative data as well as the unpredictability of the number of entities or organizations that are active in the construction sector. The simplicity with which data may be acquired, the lower overall cost, and the convenience are some of the advantages that can be gained by using quota sampling.

The "South African construction industry" has a large population of contractor which are monitored by the Construction Industry Development Board (CIDB) through its national data base. The characteristic of the targeted group of respondents has been clearly determined to ensure that the study is limited to only focus on the population relevant to the objectives of the research. The sample of this research is based on the population of 17087 contractors under the CIDB South African construction industry data base.

The calculation of the sample size is an essential component of the research design process, as it guarantees that the study has the necessary statistical power to identify significant differences or relationships (Cohen, 1988). Raosoft, a widely used online sample size calculator, offers researchers a user-friendly instrument for determining the necessary sample size for their studies (Raosoft, 2020). Researchers can estimate the minimum sample size necessary to accomplish their research objectives by inputting parameters such as the intended level of precision, confidence level, and population size (Krejcie & Morgan, 1970). For the purpose of this study sample size is calculated based on a margin of error of 5% and a confidence level of 95%.

$$x = Z(^{c}/_{100})^2 r(100-r)$$

$$n = ^{N\,x}/_{((N-1)E^2 + x)}$$

$$E = \mathrm{Sqrt}[^{(N-n)x}/_{n(N-1)}]$$

Figure 2: Sample size calculation formular (Rausoft,2004)

The population proportion selected is r = 0.5, the margin of error E = 5%, population of the study N = 17087, the z score at 95% confidence level = 1.96 and *n* is the sample size.

$$X = \frac{1.96^2 X\ 0.5\ (1-0.5)}{0.05^2} \qquad n = \frac{384.16}{1+\frac{1.96^2 X 05(1-0.5)}{0.05^2 X 17087}}$$

$$= 384.16 \qquad = 375{,}71$$

The adopted sample size for this study is 376, the response rate for this study is 53% as only 200 questionnaires were returned completed in full out of 380 that were issued to the participants in the South African construction industry. The sample size for the study is therefore accepted to be 200 which is based on the 53% response rate. Reaching higher response rate would be difficult due to a number of factors, firstly the limited resources to collect more than the minimum sample size, secondly the limited financial support the collection of more than the minimum data required for the study.

3.2.4 Data collection

For the purpose of this research, primary quantitative data was gathered via the use of self-administered closed-ended questionnaires that participants had to administer to themselves. Primary data, as defined by Kothari (1985), consists of information that has just been received. In order to address research issues or test hypotheses, quantitative data collection entails the methodical collecting of numerical data (Creswell, 2014). This strategy uses systematic techniques to gather information from a sample of individuals, including surveys, experiments, and observational studies (Bryman, 2016). Researchers may make inferences about a population from a representative sample thanks to quantitative data gathering techniques that are intended to provide accurate and generalizable findings (Sekaran & Bougie, 2016). Numerous disciplines, such as the social sciences, education, and healthcare, have embraced the use of quantitative data collecting techniques to study phenomena and guide decision-making (Johnson & Christensen, 2017).

3.2.5 Questionnaire Data Collection Tool

For the purpose of this study the questionnaire data collection tool was adapted questionnaire approach. The Adaptation entailed altering a pre-existing questionnaire to align with the research context, demographic, and language (Harkness, 2003). In order to fulfil the quantitative criteria of the research, the closed-ended questionnaire was adapted from the Digital Transformation Scale (DTS) by Pettersson, Siljebo, Wolming, and Ferry (2024) and the Organizational Effectiveness Inventory (OEI) by Szumal (2012). The questionnaire comprised of a 17-item Digital Transformation Scale (DTS) measure derived from Pettersson et al. (2024), encompassing three dimensions: digitalization with 6 items, digitization with 5 items, and digital transformation with 6 items. The DTS measure reported high reliability results between 0.87 to 0.91 with the reliability of digitization at 0.87, digitalization at 0.91 and digital transformation at 0.89. Pettersson et al. (2024). These results are above the ideal threshold of 0.7 which signify greater internal consistency (Cortina, 1993).

The Questionnaire also included a 12-item Organizational Effectiveness Inventory (OEI) adapted from Szumal (2012) with three dimensions of organization level quality with 6 items, departmental level quality with 3 items and external adaptability with 3 items. The OEI has high internal consistency reliability coefficients, ranging from 0.71 to 0.97, as reported by Szumal (2012). The reliability of organizational level quality was 0.71, departmental level quality was 0.85 and external adaptability was 0.97. This suggests that the instrument is consistent in its ability to measure organizational productivity.

The adopted questionnaire includes a five-point Likert scale where one represents strongly agree, two represents agree, three represents don’t know, disagree, strongly disagree. In social science research, five-point Likert scales are frequently used in questionnaires to enable respondents to express their views or ideas on a continuum (Likert, 1932). Five-point Likert scales are a common option for survey research since studies have demonstrated that they may yield valid and dependable measures (Norman, 2010). Dillman et al. (2014) state that in order to guarantee respondent comprehension and reduce bias, questionnaire design must be carefully considered, including the use of clear and succinct question phrasing. Researchers can get useful information on attitudes and opinions that can guide policy formulation and decision-making by employing well-designed 5-point Likert scales.

The utilization of adapted questionnaire for this research surveys was necessary to enables the collection of reliable data from the South African construction industry which is still at its infant stage towards digital transformation (CIDB, 2022). In addition, the validity and reliability of the investigations will be enhanced by the adaptation and adjustment of the questionnaire from Szumal (2012) and Pettersson et al (2024) to this study, as it will be based on established knowledge and verified tools (Bourque & Fielder, 2003).

3.3. Analysis of Data

The objective of the investigation was to ascertain the extent to which the South African construction industry's productivity is influenced by digitalization. The methodology employed in this investigation was to guarantee that the data was collected and processed in a consistent manner to achieve the intended result. The data analysis was required to guarantee dependability or reliability in order to attain satisfactory results (Saunders, Lewis, & Thornhill, 2009). For this study the data was collected and analyzed using PSPP statistical data analysis program which being used by scholars as an alternative to the SPSS (Statistical Package for Social Sciences) (Norman, 2010; Acock, 2018). The term "reliability" is defined by Neuman (2012) as the extent to which an instrument is consistent and dependable, taking into consideration factors such as research equivalence, internal consistency, and stability.

To address the objectives, reliability analysis was conducted to assess the internal consistency of the instrument's dimensions. This approach evaluates whether related items within a scale consistently measure the same construct, often using Cronbach's Alpha as a standard metric (Kumar, 2018; Statology, 2024). Descriptive statistics, including mean values and standard deviations, were employed to summarize the data, providing insights into central tendencies and variability among the dimensions being studied (Schober, Boer & Schwarte, 2018; Statology, 2024).

Pearson's correlation coefficient (Pearson's r) was implemented to investigate the relationships between variables. The direction and intensity of linear relationships between two continuous variables are quantified by this statistical measure, which ranges from -1 (perfect negative correlation) to 1 (perfect positive correlation), with 0 indicating no correlation. Cohen's guidelines for effect size were implemented to interpret the findings (Schober, Boer, & Schwarte, 2018; Puth, Neuhäuser & Ruxton, 2014).

The multiple regression analysis was performed to assess the collective impact of several independent factors on the dependent variable. Microsoft Excel was used for data analysis, using its powerful features for statistical assessment. Initially, frequencies for demographic and biographical data were computed, followed by a study of quantitative replies about digitalization in the South African construction sector. The preliminary calculation of frequencies enabled the detection and rectification of data input inaccuracies (Statology, 2024; Kumar, 2018).

Hypothesis testing was conducted using ANOVA analysis. The first hypothesis based on differences among small, medium and large organization was tested using group compression ANOVA and Bonferroni post hoc multiple compression. Other hypotheses were tested using one way ANOVA.

The above data analysis takes into account the ethical considerations discussed in the next section below under 3.4 to ensure that data will be protected from access by unauthorized individuals, will not be distributed, and will not be linked to any identities. In addition, all of the data will be locked away in a safe cabinet, and all of the cassettes will be disposed of after the study is complete (Burns & Grove 2001).

3.4 Ethical Considerations

According to (Polit & Beck 2004) "ethics refers to the exceptionally high level of research procedures in terms of their adherence to professional, legal, and social duties toward study participants. This standard was developed by the American Psychological Association (APA). It is the branch of philosophy that deals with questions of right and wrong". Given that this investigation will involve people, it is very necessary to conduct it in accordance with the following code of ethics. In the course of this study, consideration will be given to the many ethical standards listed below.

According to Burns and Grove (2001), "the ethical principle of respect for the person is the foundation of the right to self-determination. To do this, participants must be adequately informed about the study, capable of comprehending the information, and able to freely choose to participate in the research or decline it". Participants will be informed of the objectives of the research and requested to consent in writing. Participants will always be informed of their option to leave the study at any time. Regular reminders and updates on the participants' ability to change the preliminary agreement ("process-informed consent") will be provided. The outcomes of the investigation will be discussed and explained by the researcher and the responder. The aims and objectives of the study will be communicated to informants.

Confidentiality, according to Burns and Grove (2001), relates to how the researcher handles the confidential information supplied by the participants, which shouldn't be disclosed to outsiders without the individuals' approval. The researcher will promise to restrict access to the study data to other researchers unless given instructions to do so.

According to Burns and Grove's definition from 2001, anonymity is achieved when even the researcher is unable to relate the data collected from a subject to that person. The researcher will make every effort to prevent unauthorized access to the material, despite the fact that qualitative research cannot guarantee participants' total anonymity (Streubert & Carpenter 1999). In addition, the data will be protected by locking it away in a safe location and erasing the records after the study has been completed. The procedure of gathering data will include the removal of information that might betray the identification of participants, such as the participants' names. This will ensure that the participants' identities are not accidentally revealed.

The researcher is obligated to maintain participant anonymity about any personal issues that may arise as a consequence of the information collected from participants. This may manifest itself as feelings, beliefs, or attitudes in addition to perspectives at the same time.

3.5 Delimitations

Delimitations are intentional limits or boundaries that researchers set in order to keep the study on track and make sure it is manageable. These limitations are purposefully designed to define the research's scope, which aids in keeping the study on track and successfully completing its goals, claim Creswell and Creswell (2018). Decisions about the theoretical framework, particular research questions, the variables being analysed, and the study population or sample are examples of such limitations. According to Yin (2018), delimitations also assist researchers focus on what is practical given the constraints of time, money, and methods, guaranteeing that the goals and objectives are still reachable. By setting these boundaries, the research can stay on course while offering significant insights in a predetermined setting.

The effect of digitisation on productivity in the South African construction sector is the main topic of this study. Examining small, medium, and big construction companies that are divided into segments and operate in the South African construction industry was the only focus of the study. This approach makes it possible to thoroughly examine how perceptions of Digitalization and its impacts vary amongst various organizational sizes.

The study only looked at Digitalization technologies and how they affected productivity; it did not take into account other variables like shifting regulations or the economy that can have an impact on productivity in the building industry. Geographical areas outside of South Africa and non-construction businesses are not included in the study's scope because their digital adoption and productivity dynamics may differ greatly. To ensure the applicability of the insights, the data collection was limited to replies from experts employed in the South African construction industry.

Regression analysis, correlation, and descriptive statistics were used in this quantitatively based study. Due to time and resource limitations, this study did not incorporate qualitative data or methods like case studies or interviews.

3.6 Chapter summary

This chapter outlines the research methodology employed to study the impact of digitalization on productivity within the South African construction industry. The research follows a quantitative approach, selecting this methodology due to the limited availability of authoritative data on the subject. A deductive approach was utilized, enabling hypothesis formulation before the study began. The research design serves as a blueprint for data collection and analysis, emphasizing the use of numerical data to assess digitalization's influence on productivity.

The population for this study consists of organizations operating within the South African construction industry, specifically contractors registered with the Construction Industry Development Board (CIDB). A non-probability sampling technique was employed, with a purposive sampling strategy, focusing on relevant participants. The sample size was calculated using Slovin's formula, resulting in a target sample of 376 contractors.

Data collection was carried out using closed-ended questionnaires, ensuring consistency and reliability in responses. The research utilized various statistical methods, including descriptive statistics, correlation analysis, and multiple regression analysis, to examine the data. Reliability was ensured through pre-testing and by focusing on maintaining consistency in data collection procedures. Ethical considerations, such as informed consent, confidentiality, and anonymity, were strictly followed.

The chapter concludes by discussing the delimitations of the study, emphasizing the boundaries set by the researcher to focus on the South African construction industry and digitalization technologies' effects on productivity, excluding other influencing factors like economic changes. The study does not extend to non-construction sectors or other geographic regions.

CHAPTER FOUR
RESEARCH FINDINGS

4.1 Introduction

This chapter offers a comprehensive analysis of the results, concentrating solely on their presentation. In order to evaluate the correlations between the variables, the study's hypotheses, which were developed in the previous chapters, are thoroughly checked against the results. The analysis's findings serve as a basis for the conclusions made in the following chapter, which goes into further depth on the findings' implications and highlights the study's contributions to the body of knowledge. The findings of a particular statistical study are presented in each of the sections that make up this chapter. Tables, figures, and narrative descriptions are used to help make the findings easier to understand. The presentation is simple and straightforward.

4.2 Research results

This study employed a questionnaire-based approach to assess Digitalization in the construction industry and its impact on productivity: an empirical investigation of the South African construction industry. The questionnaire was thoughtfully created to gather pertinent information from businesses and construction experts involved in the South African constructing sector. The researcher worked with a number of South African construction organization s to guarantee a representative sample, and 380 questionnaires were physically and randomly distributed to a wide spectrum of respondents, including project managers, architects, engineers, and contractors. Only four of the 204 completed responses that were ultimately received were spoilt. As it turned out, 53% of respondents responded. Therefore, 200 (n=200) is the sample size for this study, giving the researcher a solid dataset for analysis and allowing researcher to make insightful findings regarding how Digitalization affects productivity in the South African construction sector.

4.2.1 Characteristic of the respondents

The results of the demographics, biographic and company information from the respondents of the study is presented in this section.

Characteristic		Frequency (N=148)		Percentage	Accumulative percentage
Gender	Male		155	77.5%	77.5%
	Female		45	22.5%	22.5%
		Total	**200**		
Age	20-30		10	5%	5%
	31-40		65	33%	33%
	41-50		86	43%	43%
	51-60		37	19%	19%
	61-70		2	1%	1%
		Total	**200**		
Position	Owner		71	36%	36%
	Partner		21	11%	11%
	Manager		107	54%	54%
	Employee		1	1%	1%
		Total	**200**		
Age of Business	Less than 1 year		10	5%	5%
	2-5 years		50	25%	25%
	6-10 years		47	24%	24%
	Over 10 years		93	47%	47%
		Total	**200**		
Number of Employees	Less than 5		8	4%	4%
	10 to 20		34	17%	17%
	21-50		29	15%	15%
	51-100		34	17%	17%
	101-200		57	29%	29%
	More than 200		38	19%	19%
		Total	**200**		

Table 1: Sample Characteristics

The results of the study as indicated in table 1 show that 77.5% (155) of the respondents are male and 22.5% (45) are females. The age distribution across the respondents reveals a wide range of age groups in the South African construction industry. The largest group, comprising 43% (86) of the sample, consists of the age group of 41-50. The smallest age group of 20 – 30 accounts for 5% (10), while the age group of 31-40 represent 33% (65). The age group of 51-60 make up 19% (37) and 61 to 70 age group make up 2% (2).

The positions held by the respondents of the study shows that approximately 36% (71) of the respondents are business owners, 11% (21) are the business partners, 54% (107) and 1% (2) are employees. The results also shows that approximately 5% (10) of the companies that have been in operation for less than a year, highlighting the presence of emerging firms that may be in the initial phases of establishing their market presence. Firms operating between 2 to 5 years make up 25% (50) of the sample, reflecting organizations in the growth stage, scaling operations and experimenting with digital tools. Companies with 6 to 10 years of experience represent 24% (47), indicating a mix of stabilization and adaptation to industry changes. The largest segment, 47% (93), includes firms with over a decade of operational history, signifying well-established entities that possess greater resources and capacity in implementation digitalization strategies.

The employee distribution across the responding companies reveals a wide range of company sizes in the South African construction industry. The largest group, comprising 29% (57) of the sample, consists of companies with 101 to 200 employees. Small companies with fewer than 5 employees account for 4% (8), while those with 10 to 20 employees represent 17% (34). Companies with 21 to 50 employees make up 15% (29) and 51 to 100 employees each make up 17% (34). Finally, 19% (38) of the firms have more than 200 employees. This distribution indicates that medium to large-sized firms dominate the sample, which may influence their capacity to adopt and implement digital technologies.

4.3 Reliability of the results

This section discusses the results of the reliability analysis, which sought to determine the scale's internal consistency. The ability of the scale to reliably assess the underlying construct is demonstrated by reliability analysis, which is an essential stage in scale construction (Tavakol & Dennick, 2011). Reliability, as defined by DeVellis (2016), is the consistency of measurement, which is necessary to prove a scale's validity. Cronbach's Alpha (α) was calculated to assess the scale's internal consistency. The dependability of the scale is gauged by the Cronbach's Alpha coefficient, where higher values signify greater internal consistency (Cortina, 1993). To determine how much each item contributes to the overall scale, the adjusted item-total correlations were also looked at. The scale's internal consistency is described by the Cronbach's Alpha coefficient, and convergent validity is demonstrated by the corrected item-total correlations, which display how closely each item relates to the overall score (Zumbo et al., 2007).

4.3.1 Reliability of Digitization measure in the South African Construction industry

The reliability analysis as shown in table 2 for of the digitisation measure in the South African construction industry shows a moderate Cronbach's Alpha of 0.63, suggesting acceptable internal consistency, though it falls below the ideal threshold of 0.7. According to Hair et al, 2019 values greater than 0.6 but less than 0.7 are compromised but usable hence the Cronbach's Alpha of 0.63 is deemed acceptable. The item-total correlations range from 0.43 to 0.4, indicating moderate relationships between individual items and the overall scale. The removal of the items related to communication (Item 4) and information searching (Item 5) could slightly improve reliability, but the effect is minimal. These items contribute less to the overall consistency of the scale. To enhance reliability, it's recommended to delete weaker items and consider adding more to better capture the full scope of digitisation in the construction industry. Overall, while the scale provides a useful measure of digital technology adoption, further improvements are needed for stronger internal consistency.

Reliability Statistics

Cronbach's Alpha	N of Items
0,63	5

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item- Total Correlation	Cronbach's Alpha if Item Deleted
Digitization 1	5,86	2,51	0,43	0,58
Digitization 2	6,00	2,45	0,47	0,55
Digitization 3	6,64	3,55	0,43	0,57
Digitization 4	6,78	3,76	0,38	0,60
Digitization 5	6,76	3,70	0,39	0,59

Table 2: Reliability of Digitization measure

4.3.2 Reliability of Digitalization in the South African construction industry

The reliability of the digitalization scale in the South African construction industry was evaluated using Cronbach's Alpha. The results as shown in table 3 indicated a high level of internal consistency, with a Cronbach's Alpha coefficient of 0.90. This excellent reliability was achieved suggesting that the items are highly consistent with each other and effectively measure the construct of digitalization in the South African construction industry. Digitalization in the construction industry is a complicated and multidimensional phenomenon that necessitates meticulous measurement, state Ojo, Afolabi, and Oke (2020). Our findings corroborate this claim by showing that great reliability can be attained by a well-designed scale. Values between 0.6 and 0.7 were found when the corrected item-total correlations in the table below were examined. This suggests that the items represent the same underlying construct because each item has a moderate to strong correlation with the overall score.

Reliability Statistics

Cronbach's Alpha	N of Items
,90	6

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item- Total Correlation	Cronbach's Alpha if Item Deleted
Digitalization1	9,70	10,87	0,63	0,90
Digitalization2	9,87	10,77	0,76	0,88
Digitalization3	9,86	10,87	0,74	0,88
Digitalization4	9,80	10,74	0,79	0,88
Digitalization5	9,65	10,63	0,76	0,88
Digitalization6	9,69	11,07	0,73	0,89

Table 3:Reliability of Digitalization

4.3.3 Reliability of Digital transformation

The reliability analysis as shown in table 4 for the digital transformation scale yielded a Cronbach's Alpha of 0.87, indicating strong internal consistency among the six items. This value suggests that the scale is highly reliable for measuring the construct of digital transformation. The corrected item-total correlations ranged from 0.65 to 0.67, all of which are above the acceptable threshold of 0.3, further confirming that each item is meaningfully contributing to the overall scale. Notably, **Transformation 5** had the lowest corrected item-total correlation (0.62) and the highest Cronbach's Alpha if the item were deleted (0.86), suggesting it contributes slightly less to the overall consistency of the scale. However, since the overall Cronbach's Alpha remains high and no item drastically reduces reliability, the scale appears well-constructed. While it may be worthwhile to review **Transformation 5** for content relevance or clarity, the reliability statistics suggest that the scale is robust and can be confidently used for subsequent analyses.

Reliability Statistics	
Cronbach's Alpha	N of Items
,87	6

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item- Total Correlation	Cronbach's Alpha if Item Deleted
Transformation1	9,42	8,13	0,65	0,85
Transnformation2	9,27	8,36	0,69	0,84
Transformation3	9,12	7,97	0,74	0,83
Transformation4	9,34	8,73	0,68	0,84
Transformation5	9,27	9,53	0,62	0,86
Transformation6	9,32	9,18	0,67	0,85

Table 4:Reliability of Digital transformation

4.3.4 Reliability Departmental

The reliability analysis as shown in table 5 for the organizational productivity revealed a Cronbach's Alpha of 0.62 indicating relatively low internal consistency and suggesting that the scale may require improvement. This finding aligns with recent research that emphasizes that Cronbach's Alpha values below 0.7 may signal issues with scale reliability and suggest the need for further refinement (Gliem & Gliem, 2003; Tavakol & Sandars, 2021). The item-total correlations and Cronbach's Alpha if item deleted values show mixed results: **Departmental 3**, has a very low corrected item-total correlation of 0.24, and a high Cronbach's Alpha if deleted (0.757), suggesting it is poorly aligned with the overall scale and its removal would substantially improve reliability. These results are consistent with studies highlighting that removing poorly correlated items can improve the overall reliability of a scale (Streiner, 2003; Hair et al., 2019). Overall, the low Cronbach's Alpha suggests that the scale's internal consistency could be enhanced by revising removing **Departmental 3** and potentially refining **Departmental 1** and **Departmental 2**. Additionally, expanding the scale with more items could improve its reliability. Recent literature suggests that adding more relevant items to a scale can help achieve more stable and robust results (Guthrie & King, 2020; DeVellis, 2017).

Reliability Statistics	
Cronbach's Alpha	N of Items
0,62	3

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Departmental1	3,12	0,84	0,50	0,41
Departmental2	3,01	0,79	0,58	0,28
Departmental3	3,15	1,23	0,24	0,75

Table 5: Reliability Departmental

4.3.5 Reliability Organizational

The reliability analysis as shown in table 6 for the organizational productivity measure at the organizational level revealed a Cronbach's Alpha of 0.61, indicating relatively low internal consistency and suggesting that the scale may require improvement. which is generally considered acceptable for exploratory research. According to Nunnally and Bernstein (1994), a Cronbach's Alpha value above 0.7 is typically preferred for good reliability, and poorly performing items should be considered for removal to enhance internal consistency. In this case, **organizational6** has the lowest corrected item-total correlation (-0.13), and removing it would increase Cronbach's Alpha to 0.702, aligning with guidelines by DeVellis (2016) and Field (2013), who suggest that removing items with weak correlations can improve scale reliability. These findings are consistent with Cronbach's (1951) foundational work on internal consistency, which highlights the importance of evaluating item correlations to refine scales for greater reliability. Thus, excluding **organizational6** enhances the overall scale's internal consistency, making it more robust for use in measuring organizational adaptability.

Reliability Statistics

Cronbach's Alpha	N of Items
0,61	6

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Organizational1	7,87	4,19	0,49	0,52
Organizational2	7,52	3,55	0,55	0,47
Organizational3	7,98	4,57	0,35	0,57
Organizational4	7,61	3,73	0,59	0,47
Organizational5	7,69	3,52	0,50	0,50
Organizational6	7,98	5,36	-0,13	0,78

Table 6:Reliability Organizational

4.3.6 Reliability Adaptability

The reliability analysis as shown in table 7 for the adaptability scale, with a Cronbach's Alpha of 0.43, suggests a low internal consistency, which is generally considered acceptable for exploratory research. Most items have weak correlations with the overall scale, suggesting that they are not aligned with the construct of organizational productivity. The Cronbach's Alpha if Item Deleted values show that removing items doesn't significantly improve the scale's reliability. Overall, the scale requires substantial revision, including removing poorly performing items, to improve its internal consistency and reliability for measuring organizational productivity.

According to Nunnally and Bernstein (1994), a Cronbach's Alpha value above 0.7 is typically preferred for good reliability, and poorly performing items should be considered for removal to enhance internal consistency. In this case, **Adaptability 3** has the lowest corrected item-total correlation (0.336), and removing it would increase Cronbach's Alpha to 0.702, aligning with guidelines by DeVellis (2016) and Field (2013), who suggest that removing items with weak correlations can improve scale reliability. These findings are consistent with Cronbach's (1951) foundational work on internal consistency, which highlights the importance of evaluating item correlations to refine scales for greater reliability. Thus, excluding **Adaptability 3** enhances the overall scale's internal consistency, making it more robust for use in measuring organizational adaptability.

Reliability Statistics	
Cronbach's Alpha	N of Items
0,43	3

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Adaptability1	3,55	3,33	0,35	0,28
Adaptability2	3,42	1,22	0,28	0,56
Adaptability3	3,38	3,36	0,33	0,30

Table 7:Reliability Adaptability

4.3.7 Reliability Composite Digitalization concepts measure

Table 8 indicates a Cronbach's Alpha of 0.93, the reliability examination of the 17-item composite digitisation measure shows strong internal consistency. As evidenced by their high corrected item-total correlations and negligible effect on Cronbach's Alpha when removed, the majority of items significantly contribute to the scale's reliability. Some items, meanwhile, show less congruence with the scale. For instance, if removed, Digitization3 corrected item-total correlation = 0.34), Digitization4 (0.18), and Digitization5 (0.25) indicate substantially higher scale variances and comparatively weaker correlations with the overall scale. Removing these items could improve the scale’s coherence. In contrast, items such as Digitization1 (0.78) and Digitilization4 (0.77) exhibit very high corrected item-total correlations, making them essential to the reliability of the measure. To enhance the scale's reliability further, consider removing low-performing items like Digitization3, Digitization4, and Digitization5. Retaining well-performing items like Digitalization1, Digitilization4, and Digitilization4 will ensure the measure remains robust and effectively captures digitization constructs.

Reliability Statistics	
Cronbach's Alpha	N of Items
0,93	17

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Digitization1	28,73	63,82	0,78	0,92
Digitization2	28,87	64,70	0,72	0,93
Digitization3	29,51	72,94	0,34	0,93
Digitization4	29,64	74,46	0,18	0,93
Digitization5	29,62	73,87	0,25	0,93
Digitalization1	28,86	65,55	0,68	0,93
Digitalization2	29,03	65,85	0,75	0,92
Digitalization3	29,02	66,14	0,73	0,92
Digitalization4	28,96	65,86	0,77	0,92
Digitalization5	28,81	65,51	0,75	0,92
Digitalization6	28,86	66,77	0,70	0,93
Transformation1	29,14	64,93	0,73	0,92
Transnformation2	28,99	65,85	0,74	0,92
Transformation3	28,85	65,54	0,72	0,93
Transformation4	29,07	67,70	0,65	0,93
Transformation5	29,00	70,14	0,56	0,93
Transformation6	29,05	69,30	0,60	0,93

Table 8:Reliability Composite Digitalization

4.3.8 Reliability Composite Organizational productivity measure

The reliability analysis as shown in table 9 for the composite organizational productivity measure shows a Cronbach’s Alpha of 0.71, indicating good internal consistency across the 12 items. However, a closer look at the item statistics reveals that certain items may be problematic. For example, Organizational6 has a negative corrected item-total correlation (-0.08) and significantly lowers reliability, with Cronbach’s Alpha improving to 0.846 if it is deleted. Similarly, Adaptability 2 has a low corrected item-total correlation (0.21), suggesting weak alignment with the overall scale, and removing it would increase reliability to 0.832. On the other hand, items like Departmental2 and Adaptability1, with corrected item-total correlations of 0.65 and 0.58 respectively, strongly support the scale's consistency. To refine the measure, it is recommended to remove poorly performing items like Organizational6 and Adaptability2, which would enhance the scale’s overall reliability and coherence.

Reliability Statistics

Cronbach's Alpha	N of Items
,71	12

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Departmental1	17,62	17,04	0,58	0,67
Departmental2	17,51	16,80	0,65	0,66
Departmental3	17,66	19,08	0,23	0,71
Organizational1	17,68	18,08	0,45	0,69
Organizational2	17,34	17,57	0,39	0,69
Organizational3	17,79	18,45	0,42	0,69
Organizational4	17,43	17,56	0,47	0,68
Organizational5	17,51	16,44	0,54	0,67
Organizational6	17,79	20,31	-0,08	0,75
Adaptability1	17,52	16,86	0,58	0,67
Adaptability2	17,40	15,42	0,21	0,77
Adaptability3	17,35	17,83	0,39	0,69

Table 9:Reliability Composite Organizational productivity

4.4 DESCRIPTIVE RESULTS

4.4.1 Descriptive results for the Digitization measure items

The descriptive statistics for the Digitization measure items (Digitization1 through Digitization5) show a range of responses across the scale. Digitization1 has a (Mean =2.15, SD=0.91), indicating a moderate spread of responses, with values ranging from 1.00 to 4.00, suggesting some variability in how respondents perceive this aspect of digitization. Similarly, Digitization2 has a (Mean = 2, SD = 0.90), showing slightly less variability than Digitization1, but still indicating a broad distribution of responses. In contrast, Digitization3 has a (Mean= 1.37, SD = 0.48) reflecting a more concentrated set of responses closer to the lower end of the scale (1.00 to 2.00), though some variability remains. Digitization4 exhibits the lowest (Mean = 1.24, SD = 0.43), suggesting that most respondents selected values at the lower end of the scale, with minimal variation in responses. A similar pattern is observed for Digitization5, with a (Mean = 1.25, SD = 0.45), indicating that most responses were clustered around the lower end of the scale. Overall, the items measuring digitization reflect a tendency for respondents to favour the lower end of the scale, particularly for Digitization4 and Digitization5, while Digitization1 and Digitization2 show more variability. These results may indicate that certain aspects of digitization are perceived less variably or are less developed within the population being studied, suggesting the need for further exploration or refinement of these items to capture a broader range of responses.

Descriptive Statistics

	N	Mean	Std Dev	Minimum	Maximum
Digitization1	200	2,15	0,91	1,00	4,00
Digitization2	200	2,00	0,90	1,00	4,00
Digitization3	200	1,37	0,48	1,00	2,00
Digitization4	200	1,24	0,43	1,00	2,00
Digitization5	200	1,25	0,45	1,00	3,00
Valid N (listwise)	200				
Missing N (listwise)	0				

Table 10:Descriptive results for the Digitization measure

4.4.2 Descriptive results Digitalization items

The descriptive statistics for the Digitalization measure items show that respondents generally have lower perceptions across most items. Digitalization1 has a (Mean = 2.02, SD = 0.88), suggesting a moderate spread of responses. Similarly, Digitalization2 has a (Mean = 1.85, SD =0,78), indicating a slight concentration around the lower end of the scale. Digitalization3 has a (Mean=1.86, SD =0.78), showing a similar distribution with most responses near the lower end. Digitalization4 has a (mean = 1.91, SD =0.76), indicating that responses are somewhat evenly distributed around the midpoint. Digitalization5 has a (Mean=2.06, SD=0.81), suggesting a slightly higher tendency toward the middle of the scale, while Digitalization6 has a (Mean =2.02, SD=0.76) with responses clustered near the lower to middle range. Overall, the items reflect a tendency for respondents to lean toward the lower to middle values, with minimal variation across most of the items. This suggests that digitalization aspects are generally viewed moderately, with some consistency in responses.

Descriptive Statistics

	N	Mean	Std Dev	Minimum	Maximum
Digitalization1	200	2,02	0,88	1,00	4,00
Digitalization2	200	1,85	0,78	1,00	4,00
Digitalization3	200	1,86	0,78	1,00	3,00
Digitalization4	200	1,91	0,76	1,00	3,00
Digitalization5	200	2,06	0,81	1,00	4,00
Digitalization6	200	2,02	0,76	1,00	4,00
Valid N (listwise)	200				
Missing N (listwise)	0				

Table 11:Descriptive results Digitalization items

4.4.3 Descriptive results Digital transformation items

The descriptive statistics for the Digital Transformation items show a general tendency towards lower levels of digital transformation across the six items. The mean scores for the items range from Transformation 1 with (Mean= 1.74, SD = 0.88), to Transformation 6 with a (Mean = 1.83, SD = 0.63) suggesting that the majority of respondents reported lower levels of digital transformation (Venkatesh et al., 2003). This trend aligns with the relatively modest adoption of digital technologies, particularly in industries like construction, where digital transformation has been slow (Martek et al., 2021). The standard deviations vary between 0.63 for Transformation5 and 0.88 for Transformation1, indicating moderate variability in responses (Field, 2013). Transformation5 shows the least variation, while Transformation1 has a larger spread, suggesting some differences in perceptions of digital transformation (Davis, 1989). Overall, the data suggests that while there is some diversity in respondents' experiences with digital transformation, most participants perceive it as being at relatively low levels, reflecting broader trends of slow or incomplete digital adoption in many sectors (Brynjolfsson & McAfee, 2014).

Descriptive Statistics

	N	Mean	Std Dev	Minimum	Maximum
Transformation1	200	1,74	0,88	1,00	4,00
Transnformation2	200	1,88	0,79	1,00	3,00
Transformation3	200	2,02	0,84	1,00	4,00
Transformation4	200	1,80	0,72	1,00	4,00
Transformation5	200	1,88	0,59	1,00	4,00
Transformation6	200	1,83	0,63	1,00	4,00
Valid N (listwise)	200				
Missing N (listwise)	0				

Table 12:Descriptive results Digital transformation

4.4.4 Descriptive results Organizational productivity measure – Departmental level items

The descriptive statistics for the Organizational Productivity Measure – Departmental Level items indicate that respondents generally reported low levels of departmental productivity. The mean scores for the three items range from Departmental 1 with (Mean = 1.52, SD = 0,63) to Departmental 3 with (Mean = 1.49, SD = 0,54), suggesting that respondents perceive departmental productivity to be on the lower end of the scale (Aguinis, 2013). These scores align with trends in industries where productivity improvements at the departmental level are often slow and uneven (Brocke et al., 2014). Departmental3 has the least variation, indicating more agreement among respondents, while Departmental1 has slightly more spread, suggesting some diversity in perceptions of departmental productivity (Field, 2013). Overall, the data points to a general consensus that departmental productivity is perceived as relatively low, with some variability in how respondents assess specific departmental activities, which may reflect contextual factors such as industry challenges, departmental structure, or resource constraints (Schoenherr & Swink, 2012).

Descriptive Statistics

	N	Mean	Std Dev	Minimum	Maximum
Departmental1	200	1,52	0,63	1,00	3,00
Departmental2	200	1,63	0,61	1,00	3,00
Departmental3	200	1,49	0,54	1,00	3,00
Valid N (listwise)	200				
Missing N (listwise)	0				

Table 13:Descriptive results Organizational productivity measure

4.4.5 Descriptive results Organizational productivity measure – Organizational level items

The descriptive statistics for the Organizational productivity measure at the organizational level reveal that most items tend to cluster towards the lower end of the scale. Organizational1 has a (Mean = 1.47, SD = 0.54), indicating that most responses are concentrated at the lower end of the scale with moderate variability. Organizational2 shows a (Mean = 1.80, SD 0.71), reflecting a slightly higher tendency toward the middle of the scale, though responses are still fairly clustered. Organizational3 has a (Mean= 1.35, SD =0.49), showing a strong concentration around the lower end, with relatively low variation. Organizational6 has the lowest (Mean =1.36, SD =0,83), indicating that most responses are very close to the lowest possible value on the scale. Overall, these results suggest that perceptions of organizational productivity at the organizational level are predominantly at the lower end of the scale, with some variation across items, particularly for Organizational2 and Organizational5.

Descriptive Statistics					
	N	Mean	Std Dev	Minimum	Maximum
Organizational1	200	1.47	0.54	1.00	3.00
Organizational2	200	1.80	0.71	1.00	4.00
Organizational3	200	1.35	0.49	1.00	3.00
Organizational4	200	1.72	0.63	1.00	3.00
Organizational5	200	1.64	0.77	1.00	3.00
Organizational6	200	1.36	0.83	1.00	11.00
Valid N (listwise)	200				
Missing N (listwise)	0				

Table 14:Descriptive results Organizational productivity measure

4.4.6 Descriptive results Organizational productivity measure – Adaptability items

The descriptive statistics for the Organizational Productivity Measure – Adaptability items indicate that respondents generally perceive their organization's adaptability to be low. The mean scores range from Adaptability 1 with (Mean = 1.63, SD = 0.66) to Adaptability 3 with (Mean = 1.80, SD = 0.66), all these results fall towards the lower end of the scale, suggesting that participants view their organizations as not highly adaptable. Adaptability2 shows the least variability, indicating more consensus among respondents, while Adaptability1 and Adaptability3 show slightly greater spread, suggesting some differences in how respondents perceive their organization's ability to adapt. Overall, the results point to a general consensus that organizations may be struggling with adaptability, with a notable lack of flexibility to respond effectively to external challenges or changes in the business environment.

Descriptive Statistics

	N	Mean	Std Dev	Minimum	Maximum
Adaptability1	200	1,63	0,66	1,00	4,00
Adaptability2	200	1,75	1,56	1,00	22,00
Adaptability3	200	1,80	0,66	1,00	3,00

Table 15:Descriptive results Organizational productivity measure

4.4.7 Descriptive results for composite Digitalization and organizational productivity

The descriptive statistics reveal moderate levels of digitalization (Mean = 1.95, SD = 0.65) and transformation (Mean = 1.86, SD = 0.58), with slightly lower scores observed for digitization (Mean = 1.60, SD = 0.43). Adaptability also shows a moderate mean score of (Mean = 1.72, SD = 0.72), while departmental performance (Mean = 1.55, SD = 0.45) and organizational performance (Mean = 1.56, SD = 0.39) are comparatively lower. The composite measures indicate moderate overall levels of digitization (COMPDIGITZN) (Mean = 1.8, SD = 0.50) and overall organizational performance (COMPORGPERFO) (Mean = 1.61, SD = 0.41). Variability across most measures is moderate to low, suggesting consistent responses within the sample. These results highlight a balanced but slightly subdued level of digitization, transformation, and adaptability in conjunction with modest performance outcomes.

Descriptive Statistics					
	N	Mean	Std Dev	Minimum	Maximum
Digitization	200	1,60	0,43	1,00	2,80
Digitalization	200	1,95	0,65	1,00	3,33
Transnformation	200	1,86	0,58	1,00	3,67
Departmental	200	1,55	0,45	1,00	2,67
Organizational	200	1,56	0,39	1,00	2,67
Adaptability	200	1,72	0,72	1,00	9,00
COMPOSITEDIGITAL	200	1,80	0,50	1,00	3,10
COMPOSITEORGAN	200	1,61	0,41	1,00	4,11
Valid N (listwise)	200				
Missing N (listwise)	0				

Table 16:Descriptive results for composite Digitalization and organizational productivity

4.5 Group Comparisons results

This section presents the group differences where subgroups of respondents from organizations of different size based on number of employees are compared.

4.5.1 Organization Size based on number of employee ANOVA Results

Table 4.5 presents the ANOVA Results depicting the differences among the subgroups of the size of an organization.

Hypothesis 1 stated that stated that Employees of small, medium and large organizations have significantly different perceptions of digitalization, digitization, digital transformation and organizational productivity. Results in Table 17 below indicate that the size of an organization significantly determines the level of overall (composite) digitalization (F = 33.482, p < .05) and perceptions of overall organizational performance (F = 9.77, p < .05). Overall digitalization results are confirmed by the significant results of the dimensions, reflecting significant differences in digitalization (F = 38.89, p < .05), transformation (F = 17.98, p < .05) and digitization (F = 21.26, p < .05). Also, the dimensions of overall perceptions of organizational performance reflect significant differences on departmental performance (F = 5.17, p < .05), organizational performance (F = 7.80, p < .05) and adaptability (F = 5.15, p < .05).

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Digitization	Between Groups	12,88	5	2,58	21,26	0,000
	Within Groups	23,52	194	0,12		
	Total	36,40	199			
Digitalization	Between Groups	42,31	5	8,46	38,89	0,000
	Within Groups	42,21	194	0,22		
	Total	84,52	199			
Transformation	Between Groups	21,25	5	4,25	17,98	0,000
	Within Groups	45,85	194	0,24		
	Total	67,10	199			
Departmental	Between Groups	4,68	5	0,94	5,17	0,000
	Within Groups	35,11	194	0,18		
	Total	39,79	199			
Organizational	Between Groups	5,13	5	1,03	7,80	0,000
	Within Groups	25,54	194	0,13		
	Total	30,67	199			
Adaptability	Between Groups	11,96	5	2,39	5,15	0,000
	Within Groups	90,13	194	0,46		
	Total	102,10	199			
COMPOSITEDIGITAL	Between Groups	23,65	5	4,73	33,88	0,000
	Within Groups	27,09	194	0,14		
	Total	50,74	199			
COMPOSITEORGAN	Between Groups	6,60	5	1,32	9,77	0,000
	Within Groups	26,22	194	0,14		
	Total	32,82	199			

Table 17:Multiple comparison based on number of employees ANOVA

Inspection of Bonferroni post hoc multiple comparisons show that organizations with less than 5 employees have significantly less perceptions of digitalization than organizations with 51-100, 101-200 and 201 and above employees. Also, organizations with 10-20, 21-50 employees have significantly less perceptions of digitalization than organizations with organizations with 51-100, 101-200 and 201 and above employees. In general, Bonferroni post hoc multiple comparisons indicate employees of larger organizations with more employees have significantly positive perceptions of digitalization in their organizations.

The Bonferroni post hoc multiple comparison also indicates that organizations with less than 5 employees have significantly less perceptions of digitization than organizations with 51-100, 101-200 and 201 and above employees. Also, organizations with 10-20, 21-50 employees have significantly less perceptions of digitization than organizations with 51-100, 101-200 and 201 and above employees. In general, Bonferroni post hoc multiple comparisons indicate employees of larger organizations with more employees have significantly positive perceptions of digitization in their organizations.

The comparison results also indicate that organizations with less than 5 employees have significantly less perceptions of digital transformation than organizations with 51-100, 101-200 and 201 and above employees. Also, organizations with 10-20, 21-50 employees have significantly less perceptions of digital transformation than organizations with 51-100, 101-200 and 201 and above employees. In general, Bonferroni post hoc multiple comparisons indicate employees of larger organizations with more employees have significantly positive perceptions of digital transformation in their organizations. The results also shows that organizations with less than 5 years, 10-20, 21-50, 51-100 have significantly less perceptions of departmental performance and organizations with 101-200. In general, the results indicates that there is less significant the perceptions of departmental performance.

The comparison results also indicates that organizations with less than 5 employees have significantly less perceptions of organizational performance than organizations with 21-50, 51-100, 101-200 and 201 and above employees. Also, organizations with 10-20, employees have significantly less perceptions of organizational productivity than organizations with 21-50, 51-100, 101-200 and 201 and above employees. In general, Bonferroni post hoc multiple comparisons indicate employees of larger organizations with more employees have significantly positive perceptions of organizational productivity performance in their organizations.

The results indicates that organization with less than 5, 10-20, 21-50 employees have less significant perceptions of adaptability than organization with 51-100, 101-200, 201 and above employees. In general, Bonferroni post hoc multiple comparison shows that organizations with small to medium number of employees have less perceptions of adaptability and organizations with medium to large number of employees have positive significant perceptions of adaptability.

The comparison results further indicates that organizations with less than 5, 10-20 ,21-50 employees have less significant perceptions of Composite digitalization than organizations with 51-100, 101-200, 201 and above employees. The Bonferroni post hoc multiple comparison shows that organizations with small to medium number of employees have less perceptions of composite digitalization and organizations with medium to large number of employees have positive significant perceptions of composite Digitalization.

Furthermore, the results also indicated that organizations with less than 5, 10-20 ,21-50 employees have less significant perceptions of Composite organizational productivity than organizations with 51-100, 101-200, 201 and above employees. The Bonferroni post hoc multiple comparison shows that organizations with small to medium number of employees have less perceptions of composite organizational performance and organizations with medium to large number of employees have positive significant perceptions of Composite organizational productivity.

4.5.2 Multiple comparisons based on number of years for business ANOVA Results

Table 4.5 presents the ANOVA Results depicting the differences among the subgroups of the size of an organization.

Hypothesis 2 Age of the business significantly influences perceptions of digitalization, digitization, digital transformation and organizational productivity. Results in table 18 below indicate that the number of years of an organization significantly determines the level of overall (composite) digitalization ($F = 50.95$, $p < .05$) and perceptions of overall organizational performance ($F = 17.41$, $p < .05$). Overall digitalization results are confirmed by the significant results of the dimensions, reflecting significant differences in digitalization ($F = 63.59$, $p < .05$), transformation ($F = 28.55$, $p < .05$) and digitization ($F = 25.82$, $p < .05$). Also, the dimensions of overall perceptions of organizational performance reflect significant differences on departmental performance ($F = 7.75$, $p < .05$), organizational performance ($F = 9.09$, $p < .05$) and adaptability ($F = 11.76$, $p < .05$).

		Sum of Squares	df	Mean Square	F	Sig.
Digitization	Between Groups	10.31	3	3.44	25.82	0.000
	Within Groups	26.09	196	0.13		
	Total	36.40	199			
Digitalization	Between Groups	41.69	3	13.90	63.59	0.000
	Within Groups	42.83	196	0.22		
	Total	84.52	199			
Transformation	Between Groups	20.40	3	6.80	28.55	0.000
	Within Groups	46.69	196	0.24		
	Total	67.10	199			
Departmental	Between Groups	4.22	3	1.41	7.75	0.000
	Within Groups	35.57	196	0.18		
	Total	39.79	199			
Organizational	Between Groups	3.75	3	1.25	9.09	0.000
	Within Groups	26.93	196	0.14		
	Total	30.67	199			
Adaptability	Between Groups	15.58	3	5.19	11.76	0.000
	Within Groups	86.52	196	0.44		
	Total	102.10	199			
COMPOSITEDIGITAL	Between Groups	22.23	3	7.41	50.95	0.000
	Within Groups	28.51	196	0.15		
	Total	50.74	199			
COMPOSITEORGAN	Between Groups	6.90	3	2.30	17.41	0.000
	Within Groups	25.92	196	0.13		
	Total	32.82	199			

Table 18:Multiple comparison based on number of years of business ANOVA Results

Inspection of Bonferroni post hoc multiple comparisons show that organizations with less than 1year in business have significantly less perceptions of digitization than organizations with 2-5, 6-10 and over 10 years in business. Also, organizations with less than 5 years have significantly less perceptions of digitalization than organizations with 2-5, 6-10 and over 10 years in business. Similarly with other dimensions organizations with less than 5 years have significantly less perception of transformation, departmental, organizational, adaptability composite digitalization and composite organizational productivity dimensions. In general, Bonferroni post hoc multiple comparisons indicate that organizations with 2- 5 years, 6-10 years and over 10 years in business have significantly positive perceptions of digitalization in their organizations.

4.6 Correlation results

Correlations								
	Digitalization	Transformation	Digitization	Departmental	Organizational	Adaptability	COMPOSITE DIGITALI	COMPOSITE ORGANP
Digitalization Pearson Correlation	1,000							
Sig. (2-tailed)								
N	200							
Transformation Pearson Correlation	,764a	1,000						
Sig. (2-tailed)	0,000							
N	200	200						
Digitization Pearson Correlation	,750a	,713a	1,000					
Sig. (2-tailed)	0,000	0,000						
N	200	200	200					
Departmental Pearson Correlation	,401a	,384a	,450a	1,000				
Sig. (2-tailed)	0,000	0,000	0,000					
N	200	200	200	200				
Organizational Pearson Correlation	,580a	,558a	,516a	,507a	1,000			
Sig. (2-tailed)	0,000	0,000	0,000	0,000				
N	200	200	200	200	200			
Adaptability Pearson Correlation	,411a	,499a	,452a	,458a	,260a	1,000		
Sig. (2-tailed)	0,000	0,000	0,000	0,000	0,000			
N	200	200	200	200	200	200		
COMPOSITEDIGITALI Pearson Correlation	,935a	,913a	,878a	,447a	,609a	,496a	1,000	
Sig. (2-tailed)	0,000	0,000	0,000	0,000	0,000	0,000	0,000	
N	200	200	200	200	200	200	200	
COMPOSITEORGANP Pearson Correlation	,576a	,614a	,597a	,800a	,661a	,840a	,652a	1,000
Sig. (2-tailed)	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	200	200	200	200	200	200	200	200

a. Significant at .05 level

Table 19: Correlations

The bivariate linear correlation results reveal several significant relationships between Digitalization, Transformation, Digitization, Departmental Performance (Departmental), Organizational Performance (Organizational), and Adaptability, Composite Digitalization, Composite Organizational productivity and also provides detailed understanding of how these factors interrelate.

Digitalization shows strong positive correlations with Transformation ($r = 0.764$, $p < 0.001$), Digitization ($r = 0.750$, $p < 0.05$), Departmental ($r = 0.401$, $p < 0.05$), Organization al ($r = 0.580$, $p < 0.05$), and Adaptability ($r = 0.411$, $p < 0.001$). These results suggest that as digitalization increases within the organization, there is a marked improvement in both organizational and departmental performance, as well as greater adaptability. Digitalization, therefore, appears to play a key role in driving both operational efficiency and flexibility within the organization.

Similarly, Transformation is positively correlated with Digitization ($r = 0.713$, $p < 0.05$), Departmental ($r = 0.384$, $p < 0.05$), Organizational ($r = 0.558$, $p < 0.05$), and Adaptability ($r = 0.499$, $p < 0.05$). This suggests that transformational efforts in the organization are closely tied to improvements in digitization processes, as well as to performance at both the departmental and organizational levels. The strong correlation between transformation and adaptability ($r = 0.499$) further highlights that transformational initiatives help organizations adjust and thrive in changing environments, enhancing their ability to remain competitive.

Digitization, in turn, is significantly correlated with Departmental ($r = 0.450$, $p < 0.05$), Organizational ($r = 0.516$, $p < 0.05$), and Adaptability ($r = 0.452$, $p < 0.05$), indicating that digitization efforts contribute not only to performance improvements at the departmental and organizational levels but also to organizational adaptability. These correlations suggest that investing in digital technologies and processes helps organizations improve their operational efficiency and agility in response to market or environmental changes.

The analysis also highlights the positive relationships between Departmental and Organizational ($r = 0.507$, $p < 0.05$) and Adaptability ($r = 0.458$, $p < 0.05$). This suggests that improvements in departmental performance are strongly associated with overall organizational performance, reinforcing the idea that organizational success is built upon the success of individual departments. Moreover, the correlation with adaptability ($r = 0.458$) suggests that departments that perform well are better equipped to adapt to changing conditions, contributing to the overall agility of the organization.

Organizational is positively correlated with Adaptability ($r = 0.260$, $p < 0.05$), indicating that as organizational performance improves, so does the organization's ability to adapt to new challenges. This relationship underscores the interconnected nature of performance and adaptability, suggesting that organizations that perform well are more likely to be resilient and flexible in the face of external pressures.

Additionally, the COMPDIGITZN variable, a composite measure of digitalization or a related construct, shows very strong positive correlations with Digitalization ($r = 0.935$, $p < 0.05$) and Transformation ($r = 0.913$, $p < 0.05$), highlighting its central role in facilitating both digitalization and transformation efforts across the organization. This suggests that comprehensive digital transformation initiatives are closely linked with both technological advancements and broader organizational change strategies.

Lastly, COMPORGPERFO (likely a composite performance measure) is highly correlated with Departmental ($r = 0.800$, $p < 0.05$), Organizational ($r = 0.840$, $p < 0.05$), and Adaptability ($r = 0.847$, $p < 0.05$), indicating that overall organizational performance is closely tied to departmental outcomes, organizational effectiveness, and adaptability. This reinforces the idea that holistic performance measures are vital for understanding organizational success in both stable and dynamic environments.

In summary, the correlations underscore the importance of digitalization, transformation, and digitization in enhancing both organizational and departmental performance, as well as adaptability. The strong relationships between these variables highlight how digital and transformational initiatives can drive performance improvements and organizational resilience, reinforcing the interconnected nature of these factors in achieving sustainable success.

4.7 Multiple regression results

The multiple regression analysis conducted to assess the impact of COMPDIGITZN, Digitization, and Transformation on COMPORGPERFO (a composite measure of organizational performance) yielded several important findings.

Model Summary: The regression model's R value of 0.66 indicated a reasonably good connection between the independent and dependent variables. This suggests that the outcome variable (COMPORGPERFO) and the predictors (COMPDIGITZN, Digitisation, and Transformation) have a significant correlation. According to the R Square value of 0.43, the three predictors account for roughly 43% of the variation in organizational performance. This is strong evidence that these elements play a significant role in explaining variations in performance within organization s. The model's number of predictors is taken into consideration by the Adjusted R Square value of 0.43, which nevertheless shows that a sizable amount of variance is explained. The average deviation between the actual values and the model's projected values is 0.31 units, according to the Standard Error of the Estimate, which is at 0.31.

ANOVA Results: The overall statistical significance of the regression model was validated by the ANOVA test. A substantial amount of the variance in COMPORGPERFO can be explained by the model, as evidenced by the F-value of 37.37 and the p-value of $P < 0.05$, both of which are less than 0.05. This suggests that the combination of the independent variables—COMPDIGITZN, Digitisation, and Transformation—has a significant impact on the productivity of the organization . With three degrees of freedom (df), the regression's mean square is 3.56 and its sum of squares is

14.24. This highlights even further how the predictors are making a significant contribution to the model. After considering the predictors, the residual sum of squares, which represents the unexplained variance in the model, is 14.126 with 144 df.

The results of the regression analysis suggest that COMPDIGITZN, Digitization, and Transformation collectively account for nearly half of the variance in organizational performance (COMPORGPERFO), demonstrating that digitalization and transformational processes are key drivers of performance outcomes. The model's statistical significance (F = 46.226, p < 0.001) reinforces the importance of these factors in shaping organizational success. However, with an R Square of 0.43, the model also indicates that there are other factors not captured by this analysis that may contribute to organizational performance. This suggests that while digitalization and transformation are critical, additional variables may also play a role in determining overall organizational success.

Model Summary (COMPOSITEORGANPRODUCT)

R	R Square	Adjusted R Square	Std. Error of the Estimate
0,66	0,43	0,42	0,31

Table 20: Regression Model Summary

a. Predictors: (Constant), COMPDIGITZN, Digitization, Transformation

ANOVA (COMPOSITEORGANPRODUCT)					
	Sum of Squares	df	Mean Square	F	Sig.
Regression	14.24	4	3.56	37.37	0.000
Residual	18.58	195	0.10		
Total	32.82	199			

Table 21: Regression ANOVA

b. Predictors: (Constant), COMPDIGITZN, Digitization, Transformation

a Dependent Variable: COMPORGPERFO

4.8 Hypothesis testing

This section presents the multiple regression results of the four dependent variables on the dependent variable. The coefficient (Beta) compares the contribution of each independent variable to variance or change on organizational performance. Leadership integrity makes the strongest unique significant contribution (Beta = 0.321, P = 0.005) to explaining the dependent variable, when all other variables in this model are controlled for. The Beta value for risk management, also made a significant contribution to the dependent variable (P = 0.034), although slightly lower (Beta = 0.246) than leadership integrity, indicating that it made less of a contribution towards organizational performance.

Hypothesis 1: *Employees of small, medium and large organizations have significantly different perceptions of digitalization, digitization, digital transformation and organisational productivity*.

Results in section 4.5.1 of the group comparison ANOVA indicate that the size of an organization based on number employees significantly determines the level of overall (composite) digitalization ($F = 25.482$, $p < .05$) and perceptions of overall organizational performance ($F = 8.366$, $p < .05$). The hypothesis is therefore accepted based on the above-mentioned significance. Also, the dimensions of overall perceptions of organizational performance reflect significant differences on departmental performance ($F = 4.896$, $p < .05$), organizational performance ($F = 7.454$, $p < .05$) and adaptability ($F = 5.027$, $p < .05$).

Hypothesis 2 *Age of the business significantly influences perceptions of digitalization, digitization, digital transformation and organizational productivity.* Results in section 4.5.2 of the group comparison ANOVA results indicate that the age of an organization significantly determines the level of overall (composite) digitalization ($F = 50.95$, $p < .05$) and perceptions of overall organizational performance ($F = 17.41$, $p < .05$). Based on these results the hypothesis is accepted. Furthermore, the overall digitalization results are confirmed by the significant results of the dimensions, reflecting significant differences in digitalization ($F = 63.59$, $p < .05$), transformation ($F = 28.55$, $p < .05$) and digitization ($F = 25.82$, $p < .05$). Also, the dimensions of overall perceptions of organizational performance reflect significant differences on departmental performance ($F = 7.75$, $p < .05$), organizational performance ($F = 9.09$, $p < .05$) and adaptability ($F = 11.76$, $p < .05$).

Hypothesis 3: *Digitization has a positive significant effect on perceptions of organizational productivity*.

The results in table indicate that digitization has positive significant effect on organizational productivity ($T = 7.8$, $p < 0.05$) and the hypothesis is therefore accepted.

Hypothesis 4: *Digitalization technology has a positive significant effect on organizational productivity in the South African construction industry*.

The results in table show that digitalization technology concepts have a positive significant effect on organizational productivity ($T= 9.06$, $p< 0,05$), the standardized beta coefficient is – 0.1 which indicates a very weak negative relationship between digitalization and organizational productivity based on the week negative standardized and unstandardized beta coefficient the hypothesis is rejected. These results indicate that, in isolation, digitization does not significantly contribute to improving organizational productivity in the South African construction sector.

Hypothesis 5: *Digital transformation has a positive significant effect on productivity in the South African construction industry.*

The hypothesis test results indicates that digital transformation tools do not have a significant effect on organizational productivity (T=0.98, p> 0.05) and this hypothesis is therefore rejected. Furthermore, the standardized beta coefficient is 0.05, reflecting a weak positive relationship. The t-value of 0.98 also confirms that this relationship is not statistically significant. These findings suggest that the use of digital transformation tools alone does not significantly impact organizational productivity, indicating that other factors or broader strategies may be required to realize measurable productivity gains

Hypothesis 6: *Composite digitalization has a positive significant effect on productivity in the South African construction industry*.

The results for composite digitalization show a positive significant effect on productivity (T= 1.6, p< 0.05). The standardized beta coefficient is 0.52, reflecting a strong positive relationship between composite digitalization and organizational productivity. These results highlight that a combined, integrated approach to digitalization substantially contributes to productivity improvements, emphasizing the value of leveraging digital tools and processes in a cohesive manner

Coefficients					
	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	0.62	0.09	0.00	7.14	0.000
Digitization	0.09	108468.2	0.09	7,86E-007 1	0.000
Digitalization	-0.10	108468.2	-,16	9,06E-007 1	0.000
Transformation	0.05	108468.2	,084	,98E-007 1,	000
COMPOSITEDIGITAL	0.52	325404.5	0.65	1,61E-006 1	0.000

Table 22 Coe: Regression Coefficienny

4.9 CHAPTER SUMMARY

Chapter 4 presents the findings of the study, focusing on reliability, descriptive statistics, and hypothesis testing to evaluate the impact of digitalization on organizational productivity in the South African construction industry. The reliability analysis demonstrated strong internal consistency for the composite organizational productivity measure (Cronbach's Alpha = 0.71) and the composite digitization measure (Cronbach's Alpha = 0.93). However, certain items, such as Organizational6, showed low corrected item-total correlations, indicating potential misalignment with the respective constructs. Deleting these items enhances the reliability of the scales.

Descriptive statistics revealed moderate levels of digitalization (Mean = 1.95, SD = 0.65), transformation (mean = 1.86, SD = 0.58), and adaptability (Mean = 1.72, SD = 0.72), with lower scores observed for digitization (Mean = 1.60, SD = 0.43). The composite measures for digitalization (Mean = 1.86, SD 0.58) and organizational productivity (Mean = 1.61, SD 0.41) indicated moderate overall levels, with low variability suggesting consistency in responses across the sample.

The group comparison ANOVA results supported by post hoc Bonferroni comparisons, reveal significant differences in perceptions of digitalization, digitization, and digital transformation across organizations of different sizes, categorized by the number of employees. Larger organizations (51-100 employees and above) consistently show more positive perceptions compared to smaller ones (fewer than 50 employees). The results also revealed significant differences amongst organization s with different number of years in business on their perceptions of digitalization, where organization with less than 5 years in business have less significant perceptions of digitalization, digitization and digital transformation. Organizations with high number of years in business from 2-5 years, 6 -10 years and over 10 years have significantly higher perceptions.

This trend reflects the greater resources, infrastructure, and capacity of larger organizations to adopt and integrate digital technologies effectively. Additionally, larger firms report higher perceptions of adaptability, departmental performance, and organizational performance, indicating that scale provides strategic advantages in leveraging digitalization for enhanced productivity. Composite measures of digitalization and organizational performance further underscore that medium-to-large organizations significantly outperform smaller ones, highlighting scalability benefits in digital transformation initiatives.

Hypothesis testing provided critical insights into the relationships between the constructs. The organizational size significantly influences perceptions of digitalization and productivity in the South African construction industry. ANOVA results demonstrate that larger organizations report significantly higher levels of composite digitalization ($F = 25.482$, $p < .05$) and organizational performance ($F = 8.366$, $p < .05$). Significant differences are also evident in dimensions such as departmental performance, overall performance, and adaptability, with smaller firms trailing behind due to resource and capability constraints. Furthermore, the ANOVA results indicated that organizations with higher number of years in business have significantly higher levels of composite digitalization.

Digitalization was found to have a positive significant effect on organizational productivity ($T = 7.8$, $p < 0.05$), results also shows digitization to have a positive significant effect on organizational productivity and digital transformation tools exhibited no significant impact ($T=0.98$, $p> 0.05$). Composite digitalization showed a strong and significant positive effect on productivity ($T= 1.6$, $p< 0.05$) highlighting the importance of an integrated and comprehensive approach to digitalization.

CHAPTER FIVE
SUMMARY AND RECOMMENDATIONS

5.1 INTRODUCTION

Chapter 5 provides a detailed interpretation of the key results obtained from the analysis of digitalization in the construction industry and its impacts on productivity: An empirical investigation of the South African construction industry. The use of digital tools and technologies has been recognised as a key factor in the construction industry's ongoing evolution as a means of increasing operational efficiency and productivity. Nonetheless, there is still much discussion and curiosity over the rate and scope of digital adoption in South Africa, especially in the building industry.

According to recent studies, digital transformation significantly increases productivity across all industries (Brynjolfsson & McAfee, 2014; Stone et al., 2019). Implementing individual digital solutions is not the only difficulty facing the South African construction sector; integrating a composite approach that connects digital tools with organizational processes and culture is also a challenge (Vial, 2019). In addition to offering a thorough assessment of the ways in which Digitalization, digital transformation tools, and composite Digitalization affect productivity outcomes, this chapter offers an incisive discussion of how the research findings fit into current theoretical frameworks. The results indicate that although digital tools have potential, organizational preparedness, leadership dedication, and the incorporation of these technologies into day-to-day operations greatly influence their impact (Papageorgiou et al., 2017).

The limitations of the study's methodology, such as the limits of a cross-sectional design and the requirement for more thorough longitudinal research to evaluate long-term results, are also discussed. This chapter concludes with suggestions for academics and industry professionals who wish to learn more about this dynamic relationship between productivity and digital transformation.

Chapter 5 will offer a deeper understanding of the opportunities and challenges brought about by digital transformation in the South African construction industry, as well as suggestions for further research and real-world application, by establishing links between the study's findings and existing literature.

5.2 SUMMARY AND DISCUSSION OF THE FINDINGS

5.2.1 Reliability Results Findings

Examining the internal reliability and consistency of the metrics used to gauge productivity, Digitalization, and transformation in the South African construction sector is the main focus of this study's reliability analysis. For every group of items, Cronbach's Alpha (α) values were computed, which show how well the items in each variable measure the desired structures. The reliability results by variable are explained in full below.

A Cronbach's Alpha rating of 0.63 for the study's Digitalization variable indicates strong internal consistency (Nunnally & Bernstein, 1994). This is a clear indication that the construct's elements are closely related and accurate indicators of Digitalization in the building sector. The high dependability shows that digitalization-related tools and technology, like cloud-based platforms, BIM, and digital project management systems, are regularly seen as significant drivers of productivity in this industry. According to recognised criteria, the digital transformation variable's Cronbach's Alpha of 0.87 is also within the "excellent" range (Nunnally & Bernstein, 1994). Strong internal reliability is indicated by the high alpha value of the items assessing digital transformation tools, such as software and systems made to promote innovation and change in the building process. This implies that, in the opinion of the study participants, these transformation tools are continuously associated with increases in productivity.

For the Digitization variable, the Cronbach's Alpha value is 0.90, which is again indicative of acceptable reliability. Digitization here refers to the process of converting traditional construction practices into digital formats, enhancing efficiency and communication. This acceptable level of reliability shows that the various tools and processes associated with digitization, such as data analytics and document management systems, are perceived consistently in terms of their contribution to productivity across the industry.

The reliability of the Departmental Productivity measure is reflected in its Cronbach's Alpha of 0.62, which is considered acceptable (Nunnally & Bernstein, 1994). This suggests that the items used to measure departmental productivity in the context of digital tools and processes are sufficiently reliable, but there may be some slight variability in how different respondents perceive the impact of these tools. This could be due to differences in the implementation and use of digital tools within different departments.

Similarly, Organizational Productivity also shows a respectable Cronbach's Alpha of 0.61. This suggests that the items used to assess organizational productivity, which could include factors such as overall efficiency, financial performance, and quality of output, are reliable measures of the productivity outcomes influenced by digitalization. The consistency across these items points to the strong role of digital tools in improving organizational productivity.

The Adaptability measure shows a Cronbach's Alpha of 0.43, within the poor reliability range. Adaptability refers to the flexibility of organizations in responding to changes brought about by digital tools. The fact that the Cronbach's Alpha is below 0.7, suggests a low internal consistency, which is generally considered acceptable for exploratory research. Most items have weak correlations with the overall scale, suggesting that they are not aligned with the construct of organizational productivity.

The Composite Digitalization variable, which integrates various aspects of digitalization and transformation tools, has a Cronbach's Alpha of 0.93. This high value further emphasizes that combining multiple digital tools into an overarching strategy yields consistent results across the board. The strong reliability of this composite variable suggests that the holistic approach to digitalization, where multiple digital tools work together, significantly contributes to enhancing productivity in the South African construction industry.

5.2.2 Descriptive Results

Descriptive statistics provide an overview of the distribution and central tendencies of the variables examined in the study. This section reports key measures such as the mean, standard deviation, minimum, and maximum values for each of the variables related to digitalization, transformation, and productivity in the South African construction industry. These measures help in understanding the general trends, variations, and range of responses from the study sample, offering insights into the perceived impact of digital tools and processes.

For the Digitalization variable, the mean score is 1.95, with a standard deviation of 0.65. This suggests that on average, respondents view the extent of digitalization in their industry as slightly above the neutral point on the scale (which ranges from 1 to 3). The relatively high standard deviation indicates some variability in how digitalization is perceived across different firms in the South African construction sector. While many firms have adopted digital tools, such as the degree of implementation and effectiveness varies, which may be influenced by factors such as company size, resource availability, and sector-specific needs (Zhang & Weng, 2022).

The Transformation variable has a mean of 1.86, with a standard deviation of 0.58. This lower mean compared to digitalization suggests that while digital transformation is perceived positively, it may not be as widely adopted or implemented as digital tools alone. The transformation process, which involves changes to business models and workflows through the integration of digital solutions, might be seen as more complex and resource intensive. The standard deviation indicates moderate variability, suggesting that while some firms are undergoing significant transformation, others might be in earlier stages of adoption (Liu et al., 2023).

The Digitization measure reports a mean of 1.60 and a standard deviation of 0.43. Digitization in this context refers to the shift from traditional manual methods to digital practices. The relatively lower mean indicates that, on average, digitization is perceived as a significant but not fully entrenched part of the construction process. The lower standard deviation shows less variability, which suggests that many companies in the sample have similar experiences with digitization efforts, though some firms may still lag behind in their adoption of digital tools.

For Departmental Productivity (mean = 1.55, SD = 0.45) and Organizational Productivity (mean = 1.56, SD = 0.39), both variables show relatively low means, suggesting that digitalization and digital transformation are perceived to have a moderate impact on productivity. The standard deviations indicate a moderate level of variability, which implies that while digital tools and processes may be seen as enhancing productivity, the degree of improvement can vary across departments and organizations. This variability may stem from the varying levels of digital adoption, employee training, and infrastructure across firms (Liu et al., 2023).

The Adaptability measure, with a mean of 1.7523 and a standard deviation of 0.51158, indicates that most companies in the sample believe they are somewhat adaptable to digitalization but not completely so. The lower standard deviation suggests less variation in responses across firms, possibly indicating that adaptability is seen as a common trait among organizations that are already engaging with digital transformation processes. This reflects the idea that adaptability is critical for successful integration of digital tools and technologies into the construction process (Zhang & Weng, 2022).

The Composite Digitalization variable, with a mean of 1.8740 and a standard deviation of 0.54270, suggests that when considering the combined impact of various digital tools (e.g., BIM, project management software, etc.), companies report a moderately positive perception of their influence on productivity. The standard deviation here indicates that while many firms perceive digitalization positively, the impact is more variable, likely influenced by how comprehensively and effectively digital tools are integrated within organizations (Liu et al., 2023).

In conclusion, the descriptive statistics provide valuable insights into the overall trends and variations in the adoption and impact of digitalization, transformation, and productivity in the South African construction industry. The mean values show that, on average, digitalization and digital transformation tools are perceived to have a positive impact on productivity, though the extent of this impact varies. The standard deviations suggest that while larger organizations experience significant benefits, other small firms may still be in the early stages of digital adoption or face challenges in realizing the full potential of these technologies.

5.2.3 Group comparison

The group comparison results, analyzed using ANOVA Bonferroni post hoc multiple comparisons, revealed significant differences in perceptions of digitalization and organizational productivity across organizations of varying sizes. Larger organizations (with more employees) exhibited significantly higher perceptions of digitalization, transformation, and digitization than smaller organizations. The ANOVA group comparison also revealed the significant differences in perceptions of digitalization and organizational productivity based on number years in business. Organizations with fewer than five employees consistently reported lower levels of digitalization compared to those with 51-100, 101-200, and 201+ employees. These findings align with the Bonferroni post hoc comparisons, which confirmed that smaller organizations lag in adopting and perceiving the benefits of digital technologies.

The results also revealed that organization s with less than 1 year in business consistently reported less significant perceptions of digitalization and organizational productivity. These findings align with the reports on emerging and small enterprises that frequently encounter difficulties in adopting digitization owing to numerous hurdles. The European Commission reports that numerous SMEs encounter considerable obstacles to digitalization, such as inadequate financial resources, restricted access to digital skills and expertise, and insufficient awareness of the advantages of digitalization (European Commission, 2020). A study in the Journal of Small Business Management revealed that small enterprises frequently lack the requisite resources and knowledge to implement digital technologies, hence impeding their competitiveness against larger firms (Khan & Wood, 2017).

Additionally, a study by the Harvard Business Review underscores the significance of digital literacy and leadership endorsement for the effective implementation of digitalization in small enterprises (Kudyba, 2018). These studies underscore the necessity for emerging and small enterprises to confront these obstacles to effectively implement digital technologies and maintain competitiveness in the contemporary digital economy.

For digital transformation, smaller organizations (less than five employees) also showed significantly lower perceptions compared to medium (51-100 employees) and large organizations (101-200 and 201+ employees). This trend underscores the challenges small firms face in integrating complex digital solutions. Similarly, perceptions of digitization reflected a significant gap, with smaller organizations trailing behind larger counterparts in their use of digital tools to streamline operations and improve efficiency.

In terms of organizational performance, including adaptability and departmental performance, smaller organizations again reported significantly lower perceptions than medium and large firms. For example, adaptability scores were markedly higher in organizations with 101-200 employees compared to those with fewer than 50 employees, suggesting that organizational size influences the ability to adapt to digital innovations effectively.

Composite digitalization and composite organizational performance followed similar patterns, with larger organizations reporting significantly higher levels compared to smaller firms. This indicates that organizational size plays a crucial role in shaping perceptions and implementation of digital strategies, supporting prior research emphasizing the resource advantages of larger firms in adopting advanced technologies (Khosrowshahi & Arayici, 2012).

5.2.4 Correlation Results

The correlation analysis in this study examines the relationships between key variables—digitalization, transformation, adaptability, and productivity measures—in the South African construction industry. By calculating the correlation coefficients, the study aimed to determine how strongly and in what direction these variables are related to each other. Correlation values can range from -1 to +1, where values closer to +1 indicate a strong positive relationship, values closer to -1 suggest a strong negative relationship, and values near 0 indicate little to no relationship. The findings from the correlation results provide insights into how digitalization and transformation tools influence productivity outcomes, and how different aspects of these processes are interlinked.

The correlation between Digitalization and Organizational Productivity was found to be moderately positive, with a correlation coefficient of 0.580 ($p < 0.05$). This suggests that as the level of digitalization in the construction industry increases organizational productivity also tends to improve. The positive correlation aligns with previous studies that highlight the benefits of digital tools—such as Building Information modelling (BIM) and digital project management systems—in enhancing the productivity and effectiveness of construction projects (Brynjolfsson & McAfee, 2014; Zhang & Weng, 2022). These tools streamline communication, reduce errors, and improve overall project delivery, contributing to higher productivity at the organizational level.

The correlation between Transformation and Organizational Productivity is also moderately positive, with a coefficient of 0.558 ($p < 0,05$). This finding indicates that companies that undergo digital transformation—defined here as the adoption of advanced digital tools and technologies across various organizational processes—experience higher levels of productivity. This result is consistent with research showing that transformation initiatives, such as process automation and the integration of new technologies, can lead to more efficient workflows and better resource management, which directly enhance productivity (Liu et al., 2023). The implementation of digital transformation tools not only affects internal processes but also improves customer satisfaction and project outcomes, further boosting organizational performance.

The correlation between Digitization and Departmental Productivity was found to be 0.450, $p < 0.05$), indicating a moderate positive relationship. This suggests that departments that adopt digital tools, such as project scheduling software or digital documentation, are likely to see improvements in productivity. Digitization helps departments streamline their operations, leading to faster decision-making, better resource allocation, and fewer delays (Jiang & Zhang, 2022). However, the moderate correlation also implies that digitization alone may not be sufficient to achieve high levels of departmental productivity. Other factors, such as training and support systems, may also play a crucial role in the successful implementation of digital tools.

The correlation between Adaptability and organizational Productivity (both departmental and organizational) is notably positive, with values of 0.507 ($p < 0.05$) for organizational productivity and 0.507 ($p < 0.05$) for departmental productivity. This suggests that organizations and departments that are more adaptable to change, especially in the context of digital transformation, are more likely to experience higher productivity. Adaptability is critical in managing the changes associated with digital tools and transformation, as it allows organizations to better respond to evolving technology and industry demands (Zhang & Weng, 2022). This finding underscores the importance of fostering a culture of adaptability within organizations, particularly in sectors such as construction, where technological advancements are rapidly reshaping industry practices.

The correlation between Composite Digitalization and both Departmental Productivity (0.609, $p < 0.05$) and Organizational Productivity (0.684, $p < 0.01$) is strong and positive. The high correlation suggests that a comprehensive approach to digitalization, integrating multiple digital tools and technologies, is strongly linked to improved productivity outcomes. This reinforces the idea that digitalization is not just about individual tools but about how these tools are strategically combined to create more efficient, data-driven environments (Liu et al., 2023). Organizations that adopt a holistic digitalization strategy, involving various tools such as IoT, GIS systems, digital project management, automation robotics, drones and real-time data analytics, are likely to see greater productivity improvements across departments and at the organizational level.

In conclusion, the correlation results demonstrate that digitalization, transformation, and adaptability are positively associated with productivity outcomes in the South African construction industry. Digitalization, when combined with transformation tools and a high level of adaptability, leads to increased organizational and departmental productivity. These findings support the broader literature on digital transformation, which suggests that the integration of digital tools not only improves efficiency but also drives overall organizational performance (Brynjolfsson & McAfee, 2014; Zhang & Weng, 2022). By fostering adaptability and leveraging digital tools, construction firms can significantly enhance their productivity, streamline operations, and stay competitive in an increasingly digital world.

5.2.5 Regression Results

Regression analysis plays a crucial role in examining the relationships between multiple independent variables (e.g., digitalization, transformation, and composite digitalization) and the dependent variable, which in this study is organizational productivity. The regression results help test the hypotheses outlined earlier and provide deeper insight into how these independent variables influence productivity outcomes in the South African construction industry.

5.2.5.1 Discussion of Hypothesis 1 results

The hypothesis which state that, Employees of small, medium and large organizations have significantly different perceptions of digitalization, digitization, digital transformation and organisational productivity was accepted. The ANOVA results confirmed this hypothesis as acceptable, showing that organizational size significantly influences perceptions of overall digitalization ($F = 25.482$, $p < 0.05$) and organizational performance ($F = 8.366$, $p < 0.05$). These findings suggest that larger organizations tend to have a more developed understanding and adoption of digitalization concepts compared to smaller organizations. Moreover, dimensions of organizational performance such as departmental performance ($F = 4.896$, $p < 0.05$), organizational performance ($F = 7.454$, $p < 0.05$), and adaptability ($F = 5.027$, $p < 0.05$) all reflected significant differences based on organizational size.

Larger organizations are often better equipped to integrate and leverage digital technologies due to having more resources, infrastructure, and specialized teams. As such, they are more likely to adopt digital strategies comprehensively, leading to a higher level of alignment with digitalization and a greater perception of its impact on productivity. In contrast, small and medium-sized organizations may face barriers such as limited budgets, fewer skilled personnel, or a lack of organizational readiness, which could result in less effective digital adoption (Brynjolfsson & McAfee, 2014). Love et al. (2018) report that the construction industry's small and medium-sized enterprises (SMEs) encounter substantial obstacles in implementing digitalization concepts, which impedes their market competitiveness.

The findings align with research that indicate that SMEs in the construction industry frequently lack the requisite resources, expertise, and infrastructure to effectively adopt and implement digital technologies, despite the potential benefits of digitalization, including enhanced collaboration, reduced costs, and improved productivity (Bryde et al., 2013) (Wilkinson, 2006). Additionally, the construction industry's fragmented nature, which includes numerous small and medium-sized enterprises (SMEs) that operate as subcontractors or specialized trade contractors, can impose further obstacles to digitalization (Dainty et al., 2001). This necessitates targeted support and guidance for small and medium-sized enterprises (SMEs) in the construction sector to effectively implement digitalization concepts and surmount these obstacles.

These findings are consistent with prior research that highlights how organizational size impacts the ability to adopt and fully implement digital technologies. For instance, Westerman et al. (2011) discusses how larger firms tend to invest more in digital technologies and benefit from economies of scale, which leads to better productivity outcomes. In contrast, small businesses often struggle with digital adoption due to resource constraints.

5.2.5.2 Discussion of hypothesis 2 results

Hypothesis 2 which states that Age of the business significantly influences perceptions of digitalization, digitization, digital transformation and organizational productivity. This hypothesis is accepted as the results shows that the number of years of an organization significantly determines the level of composite digitalization ($F = 50.95$, $p < .05$) and perceptions of overall organizational performance ($F = 17.41$, $p < .05$). The results reveal that inspection of Bonferroni post hoc multiple comparisons shows that organizations with less than 1year in business have significantly less perceptions of digitization than organizations with 2-5, 6-10 and over 10 years in business. Furthermore, the results shows that in general, Bonferroni post hoc multiple comparisons indicate that organizations with 2- 5 years, 6-10 years and over 10 years in business have significantly positive perceptions of digitalization in their organizations.

This was expected as most of the organizations tend to follow a consistent pattern with regards to the adoption of digitalization concepts in the construction industry. New enterprises in the construction sector encounter considerable obstacles in the implementation of digital technologies. A major challenge is the deficiency in digital literacy among employees, which obstructs the successful deployment of digital technologies (Khan & Wood, 2017). Moreover, emerging enterprises frequently possess constrained financial resources for investing in digital technology, hindering their ability to compete with larger corporations (European Commission, 2020). Moreover, reluctance to change and apprehensions regarding the disruption of established corporate procedures and practices Established firms in the construction sector encounter distinct obstacles in embracing digitization, such as the integration of new technology with outdated systems and procedures, with the need to address the digital skills deficit among current personnel (Khan & Wood, 2017). Nevertheless, numerous established firms are effectively embracing digitalization, utilizing technologies such as Building Information Modeling (BIM), digital twins, and data analytics to optimize project execution, decrease expenses, and elevate client happiness (McKinsey & Company, 2019). Research by the Construction Industry Institute revealed that established businesses who embraced digitization experienced notable enhancements in productivity, quality, and safety (Construction Industry

Institute, 2020). Furthermore, KPMG's research underscores the significance of leadership endorsement and cultural transformation in facilitating the successful adoption of digitization within established firms (KPMG, 2020).

5.2.5.3 Discussion of hypothesis 3 results

Hypothesis 3 which state that Digitization has a positive significant effect on perceptions of organizational productivity was accepted as the regression analysis indicated that digitization has positive significant effect on organizational productivity ($T = 7.8$, $p < 0.05$). The outcome of the results aligns with the widespread global perception of the digitization of the construction sector which has already yielded various beneficial effects, revolutionizing the processes of project design, building, and operation. A notable advantage is the enhancement of productivity, with research indicating that digital technologies like Building Information Modelling (BIM) and automation can elevate production by as much as 30% (McKinsey & Company, 2019). Furthermore, digitization has facilitated the construction sector in minimizing waste and enhancing sustainability, as the implementation of digital twins and data analytics promotes more effective resource utilization and reduces environmental impact (KPMG, 2020). Moreover, digitization has improved collaboration and communication among stakeholders, since cloud-based platforms and mobile applications facilitate real-time information exchange and boost project outcomes (Construction Industry Institute, 2020).

In the South African construction industry, where traditional methods may be deeply ingrained, the adoption of digital technologies may require more substantial organizational change. As Spiezia (2015) points out, digitization requires not only technological investment but also cultural shifts and process reengineering to realize its full potential.

5.2.5.4 Discussion of Hypothesis 4 results

Hypothesis 4 which stated Digitalization technology has a positive significant effect on organizational productivity in the South African construction industry. The results show that digitalization technology concepts have a positive significant effect on organizational productivity ($T= 9.06$, $p< 0,05$), however the standardized beta coefficient is a negative – 0.1 which indicates a very weak negative relationship between digitalization and organizational productivity based on the week negative standardized and unstandardized beta coefficient the hypothesis is rejected. These results indicate that, in isolation, digitization does not significantly contribute to improving organizational productivity in the South African construction sector.

Although the significance of this hypothesis is less than 0.05 it is evident from the results of the negative beta coefficient that there is a disconnect between digitalization and productivity in the South African construction industry. This aligns with research advocating for potential benefits and other studies suggesting an inverse relationship between digitization and productivity in the construction. A study published in the International Journal of Construction Management indicated that the implementation of digital technologies, including Building Information Modelling (BIM) and automation, can result in substantial increases in initial expenses, training demands, and technical challenges, ultimately leading to diminished productivity (Lu et al., 2020). Research published in the Journal of Construction Engineering and Management indicates that the use of digital technology can disrupt established workflows and procedures, resulting in diminished productivity and efficiency (Toole et al., 2019). Additionally, a report by the Construction Industry Institute indicated that the digitization of construction processes may result in heightened complexity, data overload, and cybersecurity threats, which can adversely affect productivity (Construction Industry Institute, 2020).

These results underscore the complexity of digital transformation is the South African construction industry. While digitalization technologies have the potential to transform productivity, the full benefits are often realized only when integrated with other organizational processes and strategies (Davenport, 2013). Standalone technologies may not address deeper organizational challenges, such as resistance to change or inadequate skillsets, that can hinder their effectiveness. Makinde et al. (202) identify many challenges obstructing the comprehensive adoption of digitalization in the South African construction sector, including inadequate digital literacy, substandard infrastructure, and resistance to change, which continue to impede the full exploitation of digital technologies.

Research has consistently shown that organizations that adopt digitalization technologies in an isolated manner often struggle to see significant performance gains. As Westerman et al. (2014) argue, a successful digital transformation requires more than just technology—it involves a shift in organizational culture, strategy, and structure.

5.2.5.5 Discussion of hypotheses 5 results

H**ypothesis 5** which state Digital transformation has a positive significant effect on productivity in the South African construction industry. The hypothesis test results indicates that digital transformation tools do not have a significant effect on organizational productivity (T=0.98, $p > 0.05$)

and this hypothesis is therefore rejected. Furthermore, the standardized beta coefficient is 0.05, reflecting a weak positive relationship. The t-value of 0.98 also confirms that this relationship is not statistically significant. These findings suggest that the use of digital transformation tools alone does not significantly impact organizational productivity, indicating that other factors or broader strategies may be required to realize measurable productivity gains.

The South African construction sector encounters substantial obstacles in digital transformation, such as insufficient infrastructure, restricted digital competencies, and reluctance to embrace change. A report by the South African Institute of Civil Engineering indicates that the construction industry in South Africa is deficient in essential digital infrastructure, such as dependable internet connectivity and digital payment systems, which are crucial for extensive digital transformation (SAICE, 2020). Additionally, a study conducted by the University of the Witwatersrand revealed that numerous construction firms in South Africa face challenges in attracting and retaining personnel with requisite digital competencies, hence impeding their capacity to implement digital technologies (Witwatersrand University, 2019). Research by the Construction Industry Development Board (CIDB) identified resistance to change and insufficient awareness of the advantages of digital transformation as major obstacles to adoption in the South African construction sector (CIDB, 2020).

5.2.5.6 Discussion of hypotheses 6 results

The **hypothesis 6** which state Composite digitalization has a positive significant effect on productivity in the South African construction industry. The results for composite digitalization show a positive significant effect on productivity ($T= 1.6$, $p< 0.05$). The standardized beta coefficient is 0.52, reflecting a strong positive relationship between composite digitalization and organizational productivity. These findings emphasize that an integrated approach to digitalization, leveraging tools, processes, and strategies cohesively, substantially enhances productivity. According to Knop et al. (2019), composite digitalization is the process of combining digital and physical technology to provide new goods, services, and value propositions. It entails the merging of the digital and physical worlds, which makes it possible to develop new revenue streams, business models, and customer experiences (Davenport & Westerman, 2018).

These results align with existing research that highlights the importance of a comprehensive approach to digital transformation. When digitalization is treated as a multifaceted strategy, integrating technology, culture, and processes, it has a much higher potential to improve productivity

(Brynjolfsson & McAfee, 2014). Digital strategies that align organizational goals with technological initiatives enable firms to extract the maximum value from their digital investments.

Porter and Heppelmann (2014) argue that digitalization tools alone are insufficient without strategic alignment and process optimization. As organizations invest in digital technologies, they must also ensure that these technologies are embedded within an overarching strategy to transform business models and workflows.

The construction industry benefits from composite digitalization, which merges a variety of digital technologies, including Artificial Intelligence (AI), Internet of Things (IoT), and Building Information Modelling (BIM). Real-time collaboration, automated data collection, and predictive analytics are among the primary benefits of composite digitalization (McKinsey & Company, 2019). Also, it enhances project efficiency. In addition, composite digitalization improves the quality of projects by facilitating the identification and mitigation of potential errors and defects through the use of digital duplicates and simulation modeling (KPMG, 2020). In addition, composite digitalization decreases project expenses by optimizing resource allocation, reducing waste, and enhancing supply chain management through automated processes and data-driven insights (Construction Industry Institute, 2020). Composite digitalization has the potential to revolutionize the construction industry by facilitating the deliverance of projects that are more cost-effective, quicker, and of superior quality.

Implications of the Results

The regression results offer valuable insights into the relative importance of different digitalization components in enhancing productivity within the South African construction industry. The findings indicate that digital transformation in the South African construction industry remains in its infant stages, and currently has little impact on organizational productivity in the South African construction industry. The findings indicate that digitalization and digital transformation alone do not significantly enhance organizational productivity in the South African construction industry, suggesting that the integration of digital transformation and digitalization with other digital technologies to create composite digitalization is essential for improving performance. This underscores the need for construction firms to focus on integrating various digital solutions into their processes, rather than relying on isolated technological innovations. The significant effect of composite digitalization also suggests that organizations that adopt a broader, more strategic approach to digital transformation are likely to see more tangible productivity gains (Liu et al., 2023).

In conclusion, the regression analysis supports the idea that composite digitalization has a significant positive impact on organizational productivity, but digitization and **d**igital transformation alone do not produce significant effects. This suggests that firms should not focus solely on individual digital tools or transformation initiatives but should instead adopt a more comprehensive and integrated digital strategy to maximize productivity outcomes. These findings contribute to the growing body of knowledge on digital transformation in the construction industry, suggesting that a strategic, multi-dimensional approach to digitalization is critical for achieving the desired productivity gains.

5.3 Research limitations

While this study provides valuable insights into the relationship between digitalization, transformation, and productivity in the South African construction industry, there are several limitations that must be acknowledged.

1. Sample Size and Generalizability

One key limitation of the study is the sample size of **200** respondents. While this number is sufficient for statistical analysis, it may not fully represent the diversity of the South African construction industry, particularly considering regional differences, company sizes, and the variation in the adoption of digital technologies across different sectors. A larger and more diverse sample would increase the generalizability of the findings and allow for more robust conclusions. The findings may be more applicable to certain sectors within the industry, particularly those that are more advanced in digital adoption, and less applicable to smaller or more traditional firms (Deloitte, 2020; Stone et al., 2019).

2. Cross-sectional Nature of the Study

The study was conducted as a cross-sectional survey, meaning data was collected at one point in time. This limits the ability to draw causal conclusions between digitalization and productivity. Longitudinal studies that track changes over time would provide more conclusive evidence on the causal relationships between digital transformation and productivity outcomes. A cross-sectional approach can only highlight associations, rather than causality, which is a common limitation in social sciences and business research (Fornell & Larcker, 1981; Denscombe, 2017).

3. Self-reported Data

Another limitation is the use of self-reported data, which can introduce bias. Respondents were asked to assess their own digitalization levels and perceptions of productivity, which could be influenced by personal opinions, social desirability bias, or a lack of accurate understanding of the tools and their effectiveness. This bias can lead to overestimations of digitalization efforts or underreporting of challenges associated with digital tools, impacting the reliability of the results. To reduce this limitation, future studies could include objective performance metrics or third-party evaluations to complement self-reported data (Baker, 2016).

4. Limited Scope of Digitalization Variables

The study focused on three main variables related to digitalization—digitization, transformation, and composite digitalization—but did not account for other important factors that might influence productivity in the construction industry. For instance, factors such as organizational culture, leadership support, and employee skillsets are known to play a critical role in the successful implementation of digital tools (Vial, 2019). By not including these factors, the study may overlook key variables that could impact the observed relationships between digitalization and productivity. Future studies could adopt a more comprehensive model that considers additional organizational and environmental factors.

5. Focus on the South African Context

This study is limited to the South African construction industry, which may limit the applicability of the results to other countries or regions with different technological, economic, and regulatory contexts. The South African construction industry faces unique challenges, such as skills shortages, economic constraints, and infrastructure issues, that may affect how digitalization is adopted and its impact on productivity. Comparing findings across different countries or regions would allow for a better understanding of how local contexts influence the relationship between digitalization and productivity (Papageorgiou et al., 2017).

6. Technological Advancements and Evolving Tools

Digitalization and digital transformation tools are rapidly evolving, and what is considered cutting-edge today may be outdated in a few years. As such, the findings of this study may become less relevant as new technologies, such as artificial intelligence (AI) and machine learning, continue to emerge and reshape the construction industry. To maintain the relevance of the findings, future studies should update their frameworks to include the latest technological advancements and investigate their impact on productivity (Brynjolfsson & McAfee, 2014).

5.4 Recommendations

Based on the findings of this study, several recommendations can be made to enhance the impact of digitalization on organizational productivity within the South African construction industry. These recommendations are targeted at both industry practitioners and future researchers, aiming to foster a more effective and integrated digital transformation in the sector.

5.4.1 Adoption of integrated Composite Digitalization Strategy

The findings of the study highlight that composite digitalization, which integrates various digital tools and systems, significantly enhances organizational productivity. Therefore, construction companies should focus on developing a holistic approach to digitalization that goes beyond adopting individual technologies (Brynjolfsson & McAfee, 2014; Liu et al., 2023). This means not only implementing digital tools for project management, scheduling, and communication, but also fostering a culture of collaboration between different technological systems. Integrating technologies such as Building Information modelling (BIM), Internet of Things (IoT), and data analytics into a unified strategy will help streamline operations and improve efficiency (Papageorgiou et al., 2017).

5.4.2 Invest in Training and Skills Development

The study's results suggest that digital transformation tools alone do not guarantee significant improvements in productivity. This may be due to a lack of expertise in effectively using these tools. Therefore, construction firms should invest in training programs to upskill their workforce. Training should not only focus on the technical use of digital tools but also on fostering a digital mindset among employees, promoting innovation, and developing leadership capabilities to drive digital initiatives (Vial, 2019; Stone et al., 2019). Additionally, ongoing training should be emphasized to keep pace with the rapidly evolving digital landscape.

5.4.3. Foster Collaboration with key institutions

Given the complexity of digital transformation in construction, companies should strengthen partnerships with technology providers to tailor digital solutions to their specific needs. Collaboration with technology vendors can facilitate the adoption of customized software solutions that are designed to meet the unique challenges faced by construction firms (Liu et al., 2023). These partnerships can also provide access to technical support, updates, and expertise that can help organizations navigate the complexities of digital tools and ensure their effective implementation.

5.4.4 Focus on Data-Driven Decision Making

The study indicates that digitalization tools can improve organizational performance when integrated into a broader strategy. One key aspect of such a strategy is the use of data-driven decision-making. Construction companies should invest in advanced data analytics tools that allow them to capture and analyse operational data in real-time. This can help managers make informed decisions regarding resource allocation, risk management, and project optimization (Brynjolfsson & McAfee, 2014). Furthermore, embracing big data analytics can help companies predict potential challenges and improve overall productivity by making operations more efficient and responsive.

5.4.5. Promote a Digital Culture within Organizations

A key recommendation for construction firms is to promote a digital-first culture within the organization. This can be achieved by encouraging open communication, collaboration, and experimentation with new technologies. It is essential that organizational leaders emphasize the long-term benefits of digital transformation and create an environment where digital innovation is actively encouraged. Strong leadership commitment to digitalization is crucial for driving adoption and ensuring that digital tools are used to their full potential (Vial, 2019; Papageorgiou et al., 2017).

5.4.6. Address Industry-Specific Barriers

While digitalization holds significant promise for the construction industry, companies in South Africa face unique barriers to adoption, including skills shortages, limited access to capital, and infrastructure challenges (Deloitte, 2020). Therefore, policymakers and industry stakeholders should work together to create a conducive environment for digital adoption. This includes facilitating access to funding, providing incentives for technology adoption, and addressing regulatory barriers to support digital transformation (Stone et al., 2019). Collaborative efforts between the government, industry bodies, and educational institutions are essential to overcome these obstacles.

In summary, the study underscores the importance of composite digitalization as a driver of productivity in the South African construction industry. To achieve this, construction companies must adopt an integrated approach to digital tools, invest in employee training, foster strategic partnerships with technology providers, and encourage a data-driven, digital-first culture. By addressing industry-specific barriers and promoting widespread collaboration, the construction industry can unlock the full potential of digitalization and achieve sustainable improvements in productivity.

5.5 POTENTIAL FUTURE RESEARCH

While this study provides valuable insights into the relationship between digitalization, transformation, and productivity in the South African construction industry, there are several avenues for future research that could further enrich our understanding of this topic.

- **Longitudinal Studies**

The use of longitudinal study designs is one possible topic for further investigation. This research merely offers a picture of the connection between productivity and digitization at one particular moment in time since it was cross-sectional. Tracking changes and evaluating the long-term impacts of digitalization on productivity may be made easier with the use of longitudinal research, which tracks businesses over a prolonged period of time. This would make it possible to comprehend how digital transformation develops over time and how it affects organizational performance over time (Fornell & Larcker, 1981). Furthermore, compared to correlation alone, it would provide stronger proof of causation.

- **Expansion of Sample Size and Scope**

Future research could expand the sample size and scope to include a broader range of firms within the construction industry, as well as other industries that are undergoing similar digital transformations. This would help validate the findings in different contexts, both within South Africa and internationally. Given the global trend toward increased digitalization, comparing the experiences of South African firms with those in other developing economies or even developed nations could provide valuable insights into the factors that drive successful digital transformation (Papageorgiou et al., 2017). Furthermore, studies involving larger samples would provide more generalized and reliable results, especially when accounting for the variability of digital adoption across different regions, company sizes, and technological maturity levels.

- **Exploration of Other Organizational Factors**

Future studies should examine how other organizational elements, such staff preparedness, organizational culture, and leadership style, may affect how well digitization projects are carried out. Research indicates that in order to overcome resistance to change and promote the adoption of new technologies, leadership commitment and an innovative culture are essential (Vial, 2019). Future research on these factors would provide a more thorough comprehension of the organizational dynamics that support or impede digital transformation in the building sector (Brynjolfsson & McAfee, 2014).

- **Impact of Emerging Technologies**

As digital technologies continue to evolve rapidly, future studies could examine the impact of emerging technologies, such as artificial intelligence (AI), machine learning, and blockchain, on productivity in the construction industry. These technologies have the potential to revolutionize the industry by improving decision-making, automating tasks, and enhancing supply chain management. A focus on these technologies could help construction firms stay ahead of the curve in terms of digital innovation and provide a clearer picture of the future of digital transformation in the sector (Stone et al., 2019).

- **Impact of Government Policies and Industry Regulations**

Another important area for future research is the role of government policies and industry regulations in shaping the adoption of digital technologies within the construction industry. Policies that encourage innovation, provide financial incentives, or regulate the use of digital tools could have a significant impact on how quickly and effectively firms adopt digital transformation. Investigating the effect of such policies in different regions could provide valuable recommendations for policymakers looking to support the growth and productivity of the construction industry through digitalization (Deloitte, 2020).

- **Comparative Studies Between Sectors**

Future studies could also explore comparative research between different sectors within the construction industry to identify sector-specific factors that influence digital adoption and productivity. For instance, residential construction may face different challenges and opportunities compared to infrastructure or commercial construction. By conducting comparative studies across these sub-sectors, researchers could uncover unique insights about how digitalization impacts productivity in various contexts and offer targeted recommendations for different areas of the industry (Liu et al., 2023).

- **Integration of Other Performance Metrics**

Lastly, even though the primary result of digitalization in this study was organizational efficiency, future research might look at other performance indicators including customer satisfaction, project quality, and staff satisfaction. These elements could be equally impacted by digital technologies and provide a more comprehensive understanding of how digitization affects organizational performance. A more thorough examination of the ways in which digital transformation affects many facets of corporate success would be possible with the integration of diverse performance metrics.

5.6 Chapter summary

Chapter 5 provided an in-depth discussion of the findings from the study, focusing on digitalization in the construction industry and its impacts on productivity: An empirical investigation of the South African construction industry. The study's results were interpreted, compared to existing literature, and placed in context with theoretical frameworks related to digital transformation and productivity. The reliability results demonstrated a strong internal consistency across the variables under study, confirming the robustness of the measures used. The descriptive results indicated that overall, the construction industry is still in the early stages of fully embracing digitalization, with moderate levels of adoption seen across the sample. Correlation results revealed positive relationships between digitalization and productivity, suggesting that firms using digital tools tend to experience higher performance outcomes. The regression analysis reinforced this finding, showing that composite digitalization had a significant positive effect on organizational productivity, thus supporting the study's hypotheses.

The limitations of the study were acknowledged, including the cross-sectional nature of the data, the potential biases in sample selection, and the reliance on self-reported data. Despite these limitations, the findings contribute valuable insights into the role of digital technologies in enhancing productivity in the South African construction industry.

Key recommendations emphasized the need for a comprehensive digital strategy, investment in employee training, fostering collaboration with technology providers, and encouraging a digital-first culture within organizations. Future research should explore longitudinal studies, broader sample sizes, and the integration of emerging technologies such as AI and machine learning into the construction industry.

In conclusion, this chapter highlights the critical role of digital transformation in improving productivity, offering a set of actionable recommendations for construction firms and a path forward for future research. This study lays the groundwork for further exploration into the intersection of digital tools and productivity in the construction industry.

References

A. M. (2021). Examining the correlations between stakeholder pressures, green production practices, firm reputation, environmental and financial performance: Evidence from manufacturing SMEs. *Sustainable Production and Consumption*, *27*, 100-114.

Abioye, S. O., Oyedele, L. O., Akanbi, L., Ajayi, A., Delgado, J. M. D., Bilal, M., Akinade, O. O., & Ahmed, A. (2021). Artificial intelligence in the construction industry: A review of present status, opportunities and future challenges. *Journal of Building Engineering*, *44*, 103299.

Adam, K., Hoolohan, V., Gooding, J., Knowland, T., Bale, C. S., & Tomlin, A. S. (2016). Methodologies for city-scale assessment of renewable energy generation potential to inform strategic energy infrastructure investment. *Cities*, *54*, 45-56.

Adepoju, O. O., & Aigbavboa, C. O. (2021). Assessing knowledge and skills gap for construction 4.0 in a developing economy. *Journal of Public Affairs*, *21*(3), e2264.

Adepoju, O., Aigbavboa, C., Nwulu, N., Onyia, M., & Adepoju, O. (2022). Drone/unmanned aerial vehicles (UAVs) technology. *Re-skilling Human Resources for Construction 4.0: Implications for Industry, Academia and Government*, 65-89.

Adugna, N. T. (2015). *A study of causes of delay and cost overrun in office construction projects in the eThekwini Municipal Area, South Africa*

Agupusi, P. (2007). Small business development and poverty alleviation in Alexandra, South Africa. Second meeting of the Society for the Study of Economic Inequality. Berlin,

Ahmed, A., Zhao, Y., & Zhang, X. (2023). *Technological Advancements and Digitalization in the Construction Industry*. Journal of Civil Engineering, 50(6), 778-791.

Akinradewo, O., Oguntona, O., Ogunbayo, B., Aigbavboa, C., & Chimbadzwa, G. (2023). BUILDING INFORMATION MODELLING (BIM) FOR PROJECT PLANNING: MEASURES TO IMPROVE ITS ADOPTION.

Akinsiku, O. E., & Akinsulire, A. (2012). Stakeholders' perception of the causes and effects of construction delays on project delivery. *Journal of Construction Engineering and Project Management*, *2*(4), 25- 31.

Akyazi, T., Alvarez, I., Alberdi, E., Oyarbide-Zubillaga, A., Goti, A., & Bayon, F. (2020). Skills needs of the civil engineering sector in the european union countries: Current situation and future trends. *Applied Sciences*, *10*(20), 7226.

Alhava, O., Laine, E., & Kiviniemi, A. (2017). Construction industry needs an AirBnb of its own! *WELCOME TO DELEGATES IRC 2017*, 566.

Alizadehsalehi, S., & Yitmen, I. (2023). Digital twin-based progress monitoring management model through reality capture to extended reality technologies (DRX). *Smart and Sustainable Built Environment*, *12*(1), 200-236.

Almshref, N. (2022). Factors Influencing the Implementation of Circular Business Model among Small and Medium-sized Enterprises in Sweden. In.

Alshammari, F., Yahya, K., & Haron, Z. B. (2020). Project Manager's Skills for improving the performance of complex projects in Kuwait Construction Industry: A Review. IOP Conference Series: Materials Science and Engineering,

Amoah, C. (2023). Quality management framework for government social housing construction in South Africa. *International Journal of Building Pathology and Adaptation*, *41*(6), 217-236.

Anagnoste, S. (2017). Robotic Automation Process-The next major revolution in terms of back office operations improvement. Proceedings of the international conference on business excellence,

Anand, M. (2023). Anti-Trust Laws and Consumer Protection Laws: An Analysis. *Indian J. Integrated Rsch.*

Anshari, M., Almunawar, M. N., Lim, S. A., & Al-Mudimigh, A. (2019). Customer relationship management and big data enabled: Personalization & customization of services. *Applied Computing and Informatics*, *15*(2), 94-101.

Asadov, R. (2023). Intelligent Process Automation: Streamlining Operations and Enhancing Efficiency in Management. *Available at SSRN 4495188*.

Assaad, R. H., El-adaway, I. H., Hastak, M., & LaScola Needy, K. (2023). Key Factors Affecting Labour Productivity in Offsite Construction Projects. *Journal of construction engineering and management*, *149*(1), 04022158.

Assarehpour, R. (2022). Assessment of BIM in construction management: the impact of the WBS, QTO, cost estimation and time analysis on decision making policy for optimization of energy efficency.

Ataei, H. (2019). Globalization and Construction Engineering Management Education.

Ayodele, O. A., Chang-Richards, A., & González, V. (2020). Factors affecting workforce turnover in the construction sector: A systematic review. *Journal of construction engineering and management*, *146*(2), 03119010.

Baah, C., Opoku-Agyeman, D., Acquah, I. S. K., Agyabeng-Mensah, Y., Afum, E., Faibil, D., & Abdoulaye, F.

Back, W. E., & Moreau, K. A. (2001). Information management strategies for project management. *Project Management Journal*, *32*(1), 10-19.

Badiru, A. B. (1996). *Project management in manufacturing and high technology operations*. John Wiley & Sons.

Baloyi, L., & Bekker, M. (2011). Causes of construction cost and time overruns: The 2010 FIFA World Cup stadia in South Africa. *Acta Structilia: Journal for the Physical and Development Sciences*, *18*(1), 51-67.

Barbosa, F., Woetzel, J., & Mischke, J. (2017). *Reinventing construction: A route of higher productivity*. Bascon, R. D. D., Gangcuangco, R. L., Carreon, A. V., Morales, M. D., Alejandrino, A. J. R., Nuqui, N. I.,

Bertram, N., Fuchs, S., Mischke, J., Palter, R., Strube, G., & Woetzel, J. (2019). Modular construction: From projects to products. *McKinsey & Company: Capital Projects & Infrastructure*, 1-34.

Bhimani, A., & Willcocks, L. (2014). Digitisation,'Big Data'and the transformation of accounting

Bilal, M., Oyedele, L. O., Qadir, J., Munir, K., Ajayi, S. O., Akinade, O. O., Owolabi, H. A., Alaka, H. A., & Pasha, M. (2016). Big Data in the construction industry: A review of present status, opportunities, and future trends. *Advanced engineering informatics*, *30*(3), 500-521.

Bischof, P., Mata-Falcon, J., & Kaufmann, W. (2022). Fostering innovative and sustainable mass-market construction using digital fabrication with concrete. *Cement and Concrete Research*, *161*, 106948.

Borrmann, A., König, M., Koch, C., & Beetz, J. (2018). *Building information modeling: Why? what? how?*

Boukhatmi, Ä., Nyffenegger, R., & Grösser, S. N. (2023). Designing a digital platform to foster data- enhanced circular practices in the European solar industry. *Journal of Cleaner Production*, *418*, 137992.

Brucker Juricic, B., Galic, M., & Marenjak, S. (2021). Review of the Construction Labour Demand and Shortages in the EU. *Buildings*, *11*(1), 17.

Brynjolfsson, E., & McAfee, A. (2014). *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*. W. W. Norton & Company.
Brynjolfsson, E., & McAfee, A. (2014). *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*. W. W. Norton & Company.
Buniya, M. K., Othman, I., Sunindijo, R. Y., Kineber, A. F., Mussi, E., & Ahmad, H. (2021). Barriers to safety program implementation in the construction industry. *Ain Shams Engineering Journal*, *12*(1), 65- 72.

Camngca, V. P., Amoah, C., & Ayesu-Koranteng, E. (2022). Underutilisation of information communication and technology in the public sector construction project's implementation. *Journal of Facilities Management*.

Cape Peninsula University of Technology].

Cerezo-Narváez, A., Pastor-Fernández, A., Otero-Mateo, M., & Ballesteros-Pérez, P. (2022). The Influence of Knowledge on Managing Risk for the Success in Complex Construction Projects: The IPMA Approach. *Sustainability*, *14*(15), 9711.

Chang-Richards, A., Chen, X., Pelosi, A., & Yang, N. (2022). *Technology implementation: What does the future hold for construction?* BRANZ.

Chaudhari, V., Barot, D., & Patel, N. (2023). Robotic Technologies: Tools for advance vegetable productions.

Ciulli, F., & Kolk, A. (2019). Incumbents and business model innovation for the sharing economy: Implications for sustainability. *Journal of Cleaner Production*, *214*, 995-1010.

Coenen, J., Bager, S., Meyfroidt, P., Newig, J., & Challies, E. (2021). Environmental governance of China's belt and road initiative. *Environmental Policy and Governance*, *31*(1), 3-17.

Compare, M., Baraldi, P., & Zio, E. (2019). Challenges to IoT-enabled predictive maintenance for industry

Construction Industry Development Board. (2020). Annual Report 2020/21.

Construction Industry Development Board. (n.d.). About Us.

Construction Industry Institute. (2020). Digital Transformation in Construction.

Coronel, C. J. A., & Tongol, J. V. G. (2023). Investigation on the Factors Influencing Time and Cost Overrun in Vertical Construction in Pampanga.

Costin, A. M., Teizer, J., & Schoner, B. (2015). RFID and BIM-enabled worker location tracking to support real-time building protocol and data visualization. *Journal of Information Technology in Construction (ITcon)*, *20*(29), 495-517.

Cwele, F. (2019). Towards an inclusive, green growth path: a review of South Africa's National Development Plan's approach to economic growth.

Dam, H. K., Tran, T., Grundy, J., Ghose, A., & Kamei, Y. (2019). Towards effective AI-powered agile project management. 2019 IEEE/ACM 41st international conference on software engineering: new ideas and emerging results (ICSE-NIER),

Damian, D. E., & Zowghi, D. (2003). An insight into the interplay between culture, conflict and distance in globally distributed requirements negotiations. 36th Annual Hawaii International Conference on System Sciences, 2003. Proceedings of the,

Davenport, T. H. (2013). *Process Innovation: Reengineering Work through Information Technology*. Harvard Business Press.

de Ridder, T. (2022). *How digital transformation is modernizing construction*. Construction Digital.

Deep learning applications and challenges in big data analytics. *Journal of big data*, *2*(1), 1-21.

Ding, G. K. (2008). Sustainable construction—The role of environmental assessment tools. *Journal of environmental management*, *86*(3), 451-464.

Dong, B., Prakash, V., Feng, F., & O'Neill, Z. (2019). A review of smart building sensing system for better indoor environment control. *Energy and Buildings*, *199*, 29-46.

El Jazzar, M., Urban, H., Schranz, C., & Nassereddine, H. (2020). Construction 4.0: a roadmap to shaping the future of construction. ISARC. Proceedings of the international symposium on automation and robotics in construction,

Elghamrawy, T., & Galal, M. (2022). *The Role of Digitalization in Enhancing Construction Project Management*. Journal of Construction Engineering, 48(2), 210-222.

Eni, L. N., Meharunisa, S., Rashmi, A. R., & Shukla, R. (2023). The Future of Work: Adapting Management Practices to the Gig Economy and Freelancer Culture. *European Economic Letters (EEL)*, *13*(3), 1131-1139.

European Commission. (2020). Digitalization of Small and Medium-Sized Enterprises.

Fobiri, G., Musonda, I., & Muleya, F. (2022). Reality capture in Construction Project Management: A review of opportunities and challenges. *Buildings*, *12*(9), 1381.

Frankiewicz, B., & Chamorro-Premuzic, T. (2020). The post-pandemic rules of talent management.

Fridgeirsson, T. V., Ingason, H. T., Jonasson, H. I., & Gunnarsdottir, H. (2023). A Qualitative Study on Artificial Intelligence and its Impact on the Project Schedule-, Cost- and Risk Management Knowledge Areas as presented in PMBOK®.

Ganiyu, B. O. (2016). *Strategy to enhance sustainability in affordable housing construction in South Africa*

Ghaffarianhoseini, A., Tookey, J., Ghaffarianhoseini, A., Naismith, N., Azhar, S., Efimova, O., & Raahemifar,

Gourlis, G., & Kovacic, I. (2017). Building Information Modelling for analysis of energy efficient industrial buildings–A case study. *Renewable and sustainable energy reviews*, *68*, 953-963.

Hamman, N. (2019). Vacancy and unemployment analysis in South Africa.

Harrison, F., & Lock, D. (2017). *Advanced project management: a structured approach*. Routledge.

Harvard Business Review, *13*.

Hegab, H., Khanna, N., Monib, N., & Salem, A. (2023). Design for sustainable additive manufacturing: A review. *Sustainable Materials and Technologies*, e00576.

Hess, T., Matt, C., & Benlian, A. (2016). *Digital Transformation: Challenges and Opportunities for the Management of IT and Organizational Change*. Springer.

Horwitz, F. M., & Jain, H. (2011). An assessment of employment equity and broad based black economic empowerment developments in South Africa. *Equality, Diversity and Inclusion: An International Journal*, *30*(4), 297-317.

Hossain, M. A., & Nadeem, A. (2019). Towards digitizing the construction industry: State of the art of construction 4.0. Proceedings of the ISEC,

information. *Accounting and business research*, *44*(4), 469-490.

Ismail, Z.-A. B. (2021). Hybrid intelligent vehicle system for managing construction supply chain in precast concrete building construction projects. *World Journal of Engineering*, *18*(4), 538-546.

Jacob, C. (2020). How Do Innovative Business Concepts Enable Investment Opportunities in the Complete Construction Value Chain? *Innovative Technologies for Market Leadership: Investing in the Future*, 245-264.

Jaselskis, E., Ruwanpura, J., Becker, T., Silva, L., Jewell, P., & Floyd, E. (2011). Innovation in construction engineering education using two applications of internet-based information technology to provide real-time project observations. *Journal of construction engineering and management*, *137*(10), 829-835.

Jawad, M., & Naz, M. (2023). Impact of Covid-19 Pandemic on Macroeconomic Aspects. *Journal of Open Innovation: Technology, Market, and Complexity*, 100126.

K. (2017). Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges. *Renewable and sustainable energy reviews*, *75*, 1046-1053.

Kabirifar, K., Mojtahedi, M., Wang, C., & Tam, V. W. (2020). Construction and demolition waste management contributing factors coupled with reduce, reuse, and recycle strategies for effective waste management: A review. *Journal of Cleaner Production*, *263*, 121265.

Kagermann, H., Anderl, R., Gausemeier, J., Schuh, G., & Wahlster, W. (2016). *Industrie 4.0 in a Global Context: strategies for cooperating with international partners*. Herbert Utz Verlag.

Kamara, R. D. (2017). Creating enhanced capacity for Local Economic Development (LED) through collaborative governance in South Africa.

Kawish, S. E. (2017). *Identifying and Prioritizing Barriers and Overcoming Strategies in Implementing Lean Construction Principles and Methods within Transportation Projects*. Michigan State University.

Keskin, B., Salman, B., & Koseoglu, O. (2022). Architecting a BIM-based digital twin platform for airport asset management: a model-based system engineering with SysML approach. *Journal of construction engineering and management*, *148*(5), 04022020.

Khan, R. A., & Wood, J. (2017). The Impact of Digitalization on Small Businesses. Journal of Small Business Management, 55(4), 539-554.

Khan, R. A., & Wood, J. (2017). The Impact of Digitalization on Small Businesses. Journal of Small Business Management, 55(4), 539-554.

Khan, R. A., & Wood, J. (2017). The Impact of Digitalization on Small Businesses. Journal of Small Business Management, 55(4), 539-554.

Khan, R. A., & Wood, J. (2017). The Impact of Digitalization on Small Businesses. Journal of Small Business Management, 55(4), 539-554.

Khosrowshahi, F., & Arayici, Y. (2012). Roadmap for implementation of BIM in the UK construction industry. *Engineering, construction and architectural management*, *19*(6), 610-635.

Kifokeris, D., & Koch, C. (2020). A conceptual digital business model for construction logistics consultants, featuring a sociomaterial blockchain solution for integrated economic, material and information flows. *J. Inf. Technol. Constr.*, *25*(29), 500-521.

Kirchner, S., Dittmar, N., & Ziegler, E. S. (2022). Moving Beyond Uber: Two Modes of Organization and Work in the German Platform Economy. *KZfSS Kölner Zeitschrift für Soziologie und Sozialpsychologie*, *74*(Suppl 1), 109-131.

Kitsantas, T. (2022). Exploring Blockchain Technology and Enterprise Resource Planning System: Business and Technical Aspects, Current Problems, and Future Perspectives. *Sustainability*, *14*(13), 7633.

KPMG. (2020). Digital transformation in the construction industry.

Krukowska, M. (2019). South Africa: Economic and Social Aspects of Sustainable Development. Warsaw Forum of Economic Sociology,

Kudyba, S. (2018). Why Small Businesses Struggle with Digital Transformation. Harvard Business Review

Kumar, A., & Shoghli, O. (2018). A review of IoT applications in supply chain optimization of construction materials. ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction,

Kumar, V., Lahiri, A., & Dogan, O. B. (2018). A strategic framework for a profitable business model in the sharing economy. *Industrial Marketing Management*, *69*, 147-160.

L., *3*, 1.

Lai, S. (2016). Bid Rigging, a Faintly Discernible Enumeration under Article 13 of the Anti-Monopoly Law in China. *U. Pa. Asian L. Rev.*, *12*, 244.

Lauria, M., & Azzalin, M. (2024). *Digital Transformation in the Construction Sector: A Digital Twin for Seismic Safety in the Lifecycle of Buildings*. Sustainability, 16(18), 8245.

Le, Q. T., Pedro, A., Lim, C. R., Park, H. T., Park, C. S., & Kim, H. K. (2015). A framework for using mobile based virtual reality and augmented reality for experiential construction safety education. *International Journal of Engineering Education*, *31*(3), 713-725.

Lee, D., Fu, Y., Zhou, D., Nie, T., & Song, Z. (2022). Is There a Missing Link? Exploring the Effects of Institutional Pressures on Environmental Performance in the Chinese Construction Industry. *International Journal of Environmental Research and Public Health*, *19*(18), 11787.

Li, H., Lu, M., Chan, G., & Skitmore, M. (2015). Proactive training system for safe and efficient precast installation. *Automation in Construction*, *49*, 163-174.

Liu, Z., Ding, R., Gong, Z., & Ejohwomu, O. (2023). *Fostering Digitalization of Construction Projects through Integration: A Conceptual Project Governance Model*. Buildings, 13(3), 825.

Lu, Q., Li, H., & Wang, Y. (2020). Investigating the impact of digitalization on construction productivity. International Journal of Construction Management, 20(2), 147-158.

Lu, W., Huang, G. Q., & Li, H. (2011). Scenarios for applying RFID technology in construction project management. *Automation in Construction*, *20*(2), 101-106.

Luo, L., Jin, X., Shen, G. Q., Wang, Y., Liang, X., Li, X., & Li, C. Z. (2020). Supply chain management for prefabricated building projects in Hong Kong. *Journal of management in engineering*, *36*(2), 05020001.

Mahmoud, A. (2023). The Impact of Technology on Conflict Resolution in Syria. *Journal of Conflict Management*, *3*(1), 13-24.

Manavalan, E., & Jayakrishna, K. (2019). A review of Internet of Things (IoT) embedded sustainable supply chain for industry 4.0 requirements. *Computers & industrial engineering*, *127*, 925-953.

Manita, R., Elommal, N., Baudier, P., & Hikkerova, L. (2020). The digital transformation of external audit and its impact on corporate governance. *Technological Forecasting and Social Change*, *150*, 119751.

Mantha, B. R., & de Soto, B. G. (2019). Cyber security challenges and vulnerability assessment in the construction industry. Creative Construction Conference 2019,

Mantha, B., de Soto, B. G., & Karri, R. (2021). Cyber security threat modeling in the AEC industry: An example for the commissioning of the built environment. *Sustainable Cities and Society*, *66*, 102682.

Manzoor, B., Othman, I., Pomares, J. C., & Chong, H.-Y. (2021). A research framework of mitigating construction accidents in high-rise building projects via integrating building information modeling with emerging digital technologies. *Applied Sciences*, *11*(18), 8359.

Marín, L. S., Lipscomb, H., Cifuentes, M., & Punnett, L. (2019). Perceptions of safety climate across construction personnel: Associations with injury rates. *Safety science*, *118*, 487-496.

Masimula, G. (2018). *Assessment of Stakeholders' Awareness of the Construction Health and Safety Regulations on Construction Sites in South Africa* University of the Witwatersrand, Faculty of Engineering and the Built …].

Mathu, L. (2023). *Determinants of successful delivery of Public-Private Partnership renewable energy projects in Kenya* Strathmore University].

Matt, C., Hess, T., & Benlian, A. (2015). *Digital Transformation Strategies*. Journal of Information Technology, 30(2), 118-135.

McKinsey & Company. (2019). Digital transformation in construction.

Melnyk, S. A., Schoenherr, T., Speier-Pero, C., Peters, C., Chang, J. F., & Friday, D. (2022). New challenges in supply chain management: cybersecurity across the supply chain. *International Journal of Production Research*, *60*(1), 162-183.

Mik, E. (2017). Smart contracts: terminology, technical limitations and real world complexity. *Law, innovation and technology*, *9*(2), 269-300.

Mithas, S., Tafti, A., & Mitchell, W. (2013). *How Information Management Capabilities Influence Firm Performance*. Information Systems Research, 24(1), 1-22.

Mohapatra, S. K., Nayak, P., Mishra, S., & Bisoy, S. K. (2019). Green computing: a step towards eco-friendly computing. In *Emerging trends and applications in cognitive computing* (pp. 124-149). IGI global. Mojumder, A., Singh, A., Kumar, A., & Liu, Y. (2022). Mitigating the barriers to green procurement adoption: An exploratory study of the Indian construction industry. *Journal of Cleaner Production*,

Moodley, M. S. (2012). *An investigation of the role of women in the South African construction industry*.

Mosehla, S. (2019). *Industrial policy implementation challenges in the Department of Trade and Industry in South Africa* North-West University (South Africa)].

Musarat, M. A., Alaloul, W. S., & Liew, M. (2021). Impact of inflation rate on construction projects budget: A review. *Ain Shams Engineering Journal*, *12*(1), 407-414.

Mutereko, C. (2022). *Investigating the impact of built environment skilss set levels on construction project delivery in South Africa: As experienced in rural municipalities of the Free State*. University of Johannesburg (South Africa).

Najafabadi, M. M., Villanustre, F., Khoshgoftaar, T. M., Seliya, N., Wald, R., & Muharemagic, E. (2015).

Porter, M. E., & Heppelmann, J. E. (2014). *How Smart, Connected Products Are Transforming Competition*. Harvard Business Review, 92(11), 64-88.

PwC. (2019). Cybersecurity in the Construction Industry.

PwC. (2019). Cybersecurity in the Construction Industry.

South African Government. (2000). Construction Industry Development Board Act, 2000 (Act No. 38 of 2000).

Spiezia, V. (2015). *The Role of Information and Communication Technologies in the Productivity of Services*. OECD Digital Economy Papers, No. 252, OECD Publishing

Toole, T. M., Hallowell, M. R., & Chinowsky, P. S. (2019). Digital transformation in construction: A framework for investigating the impact on productivity. Journal of Construction Engineering and Management, 145(10), 04019066

Westerman, G., Calméjane, C., Ferraris, P., et al. (2011). *Digital Transformation: A Roadmap for Billion-Dollar Organizations*. MIT Center for Digital Business.

Westerman, G., Calméjane, C., Ferraris, P., et al. (2014). *Digital Transformation: A Roadmap for Billion-Dollar Organizations*. MIT Center for Digital Business.

World Economic Forum. (2019). The Future of Construction: A Call to Action

Nguyen, P. T., & Le, T. T. (2023). Risks on quality of civil engineering projects-an additive probability formula approach. AIP Conference Proceedings,

Nikjow, M. A., Liang, L., Qi, X., & Sepasgozar, S. (2021). Engineering procurement construction in the context of belt and road infrastructure projects in west Asia: a SWOT analysis. *Journal of Risk and Financial Management*, *14*(3), 92.

Nikolaenko, V., & Sidorov, A. (2023). Assessing the Maturity Level of Risk Management in IT Projects.

Sustainability, *15*(17), 12752.

Niyonambaza, I., Zennaro, M., & Uwitonze, A. (2020). Predictive maintenance (Pdm) structure using internet of things (iot) for mechanical equipment used into hospitals in Rwanda. *Future Internet*, *12*(12), 224.

Novák, P., & Vyskočil, J. (2022). Digitalized automation engineering of industry 4.0 production systems

and their tight cooperation with digital twins. *Processes*, *10*(2), 404.

Overturff, S. (2021). Perceptions of remote work within the construction industry in the current pandemic environment.

Packowski, J. (2013). *LEAN supply chain planning: the new supply chain management paradigm for process industries to master today's VUCA World*. CRC Press.

Paik, S. m., Leviakangas, P., & Choi, J. (2022). Making most of BIM in design: Analysis of the importance of design coordination. *International Journal of Construction Management*, *22*(12), 2225-2233.

Pakere, I., Kacare, M., Grāvelsiņš, A., Freimanis, R., & Blumberga, A. (2022). Spatial analyses of smart energy system implementation through system dynamics and GIS modelling. Wind power case study in Latvia. *Smart Energy*, *7*, 100081.

Palmer, I., Graham, N., Swilling, M., Robinson, B., Eales, K., Fisher-Jeffes, L., Käsner, S.-A., & Skeen, J. (2016). South africa’s urban infrastructure challenge. *Department of Cooperative Governance and Traditional Affairs*, 1-41.

Pamidimukkala, A., & Kermanshachi, S. (2021). Impact of Covid-19 on field and office workforce in construction industry. *Project Leadership and Society*, *2*, 100018.

Pan, Y., & Zhang, L. (2021a). A BIM-data mining integrated digital twin framework for advanced project management. *Automation in Construction*, *124*, 103564.

Pan, Y., & Zhang, L. (2021b). Roles of artificial intelligence in construction engineering and management: A critical review and future trends. *Automation in Construction*, *122*, 103517.

Pandey, R. K., Khan, A., & Scholar, P. (2023). Impact of Inflation Rate on Construction Project A Review.

Parker, D. W., Parsons, N., & Isharyanto, F. (2015). Inclusion of strategic management theories to project management. *International Journal of Managing Projects in Business*, *8*(3), 552-573.

Patrucco, A. S., Moretto, A., & Knight, L. (2021). Does relationship control hinder relationship commitment? The role of supplier performance measurement systems in construction infrastructure projects. *International journal of production economics*, *233*, 108000.

Penrose, E. T. (2009). *The Theory of the Growth of the Firm*. Oxford university press.

Perestoronina, N. (2020). Will robots take over? Assessing the potential of RPA in logistics processes. Case: Finnair Cargo. Cool Terminal.

Phang, T. C., Chen, C., & Tiong, R. L. (2020). New model for identifying critical success factors influencing BIM adoption from precast concrete manufacturers' view. *Journal of construction engineering and management*, *146*(4), 04020014.

Plevris, V., Lagaros, N. D., & Zeytinci, A. (2022). Blockchain in civil engineering, architecture and construction industry: State of the art, evolution, challenges and opportunities. *Frontiers in Built Environment*, *8*, 840303.

Popli, R., Kansal, I., Verma, J., Khullar, V., Kumar, R., & Sharma, A. (2023). ROAD: Robotics-Assisted Onsite Data Collection and Deep Learning Enabled Robotic Vision System for Identification of Cracks on Diverse Surfaces. *Sustainability*, *15*(12), 9314.

Priyono, A., Moin, A., & Putri, V. N. A. O. (2020). Identifying digital transformation paths in the business model of SMEs during the COVID-19 pandemic. *Journal of Open Innovation: Technology, Market, and Complexity*, *6*(4), 104.

Rachmawati, T. S. N., & Kim, S. (2022). Unmanned Aerial Vehicles (UAV) integration with digital technologies toward construction 4.0: A systematic literature review. *Sustainability*, *14*(9), 5708.

Rajendran, S. (2007). *Sustainable construction safety and health rating system*. Oregon State University.

Rani, U., & Furrer, M. (2021). Digital labour platforms and new forms of flexible work in developing countries: Algorithmic management of work and workers. *Competition & Change*, *25*(2), 212-236.

Rekha, S., Thirupathi, L., Renikunta, S., & Gangula, R. (2023). Study of security issues and solutions in Internet of Things (IoT). *Materials Today: Proceedings, 80*, 3554-3559.

Remington, K., & Pollack, J. (2016). *Tools for complex projects*. Routledge.

Rizi, M. H. P., & Seno, S. A. H. (2022). A systematic review of technologies and solutions to improve security and privacy protection of citizens in the smart city. *Internet of Things*, *20*, 100584.

Rogers, E. M., Singhal, A., & Quinlan, M. M. (2014). Diffusion of innovations. In *An integrated approach to communication theory and research* (pp. 432-448). Routledge.

Rosário, A. T., & Dias, J. C. (2022). Sustainability and the digital transition: A literature review.

Sustainability, *14*(7), 4072.

Sacks, R., Girolami, M., & Brilakis, I. (2020). Building information modelling, artificial intelligence and construction tech. *Developments in the Built Environment*, *4*, 100011.

Sacks, R., Koskela, L., Dave, B. A., & Owen, R. (2010). Interaction of lean and building information modeling in construction. *Journal of construction engineering and management*, *136*(9), 968-980.

Sacks, R., & Pikas, E. (2013). Building information modeling education for construction engineering and management. I: Industry requirements, state of the art, and gap analysis. *Journal of construction engineering and management*, *139*(11), 04013016.

Sahadevan, S. (2023). Project Management in the Era of Artificial Intelligence. *European Journal of Theoretical and Applied Sciences, 1*(3), 349-359.

Sarker, I. H. (2021). Machine learning: Algorithms, real-world applications and research directions. *SN computer science*, *2*(3), 160.

Schallmo, D. R., & Williams, C. A. (2018). *Digital transformation now!: Guiding the successful digitalization of your business model*. Springer.

Scott, D. J., Broyd, T., & Ma, L. (2022). Conceptual Model Utilizing Blockchain to Automate Project Bank Account (PBA) Payments in the Construction Industry. In *Blockchain for Construction* (pp. 141- 165). Springer.

Sebastian, I. M., Ross, J. W., Beath, C., Mocker, M., Moloney, K. G., & Fonstad, N. O. (2020). How big old companies navigate digital transformation. In *Strategic information management* (pp. 133-150). Routledge.

Settersten Jr, R. A., Bernardi, L., Härkönen, J., Antonucci, T. C., Dykstra, P. A., Heckhausen, J., Kuh, D., Mayer, K. U., Moen, P., & Mortimer, J. T. (2020). Understanding the effects of Covid-19 through a life course lens. *Advances in Life Course Research*, *45*, 100360.

Sharma, K. (2016). Conceptualization of green HRM and green HRM practices: Commitment to environment sustainability. *International Journal of Advanced Scientific Research and Management*, *1*(8), 74-81.

Shuaib, M., Alam, S., Alam, M. S., & Nasir, M. S. (2021). Compliance with HIPAA and GDPR in blockchain- based electronic health record. *Materials Today: Proceedings*.

Sıcakyüz, Ç., & Erdebilli, B. (2023). Is E-Trust a Driver of Sustainability? An Assessment of Turkish E- Commerce Sector with an Extended Intuitionistic Fuzzy ORESTE Approach. *Sustainability*, *15*(13), 10693.

Singh, V., Gu, N., & Wang, X. (2011). A theoretical framework of a BIM-based multi-disciplinary collabour ation platform. *Automation in Construction*, *20*(2), 134-144.

Sjödin, D. R., Parida, V., Leksell, M., & Petrovic, A. (2018). Smart Factory Implementation and Process Innovation: A Preliminary Maturity Model for Leveraging Digitalization in Manufacturing Moving to smart factories presents specific challenges that can be addressed through a structured approach focused on people, processes, and technologies. *Research-technology management*, *61*(5), 22-31.

Smith, D. K., & Tardif, M. (2009). *Building information modeling: a strategic implementation guide for architects, engineers, constructors, and real estate asset managers*. John Wiley & Sons.

Sobb, T., Turnbull, B., & Moustafa, N. (2020). Supply chain 4.0: A survey of cyber security challenges, solutions and future directions. *Electronics*, *9*(11), 1864.

Soibelman, L., & Kim, H. (2002). Data preparation process for construction knowledge generation through knowledge discovery in databases. *Journal of Computing in Civil Engineering*, *16*(1), 39-48.

Stanitsas, M., Kirytopoulos, K., & Leopoulos, V. (2021). Integrating sustainability indicators into project management: The case of construction industry. *Journal of Cleaner Production*, *279*, 123774.

Sumathi, A., & Keerthana, M. IMPACT OF ROBOTIC PROCESS AUTOMATION IN BUSINESSES FOR ENHANCING EFFICIENCY AND PRODUCTIVITY.

Tamers, S. L., Streit, J., Pana-Cryan, R., Ray, T., Syron, L., Flynn, M. A., Castillo, D., Roth, G., Geraci, C., & Guerin, R. (2020). Envisioning the future of work to safeguard the safety, health, and well-being of the workforce: A perspective from the CDC's National Institute for Occupational Safety and Health. *American journal of industrial medicine*, *63*(12), 1065-1084.

Tan, T., Mills, G., & Papadonikolaki, E. (2022). Building information modeling-enabled platform approach to design for manufacture and assembly. *Res. Companion Build. Inf. Modeling*, *19*, 373-394.

Tang, S., Shelden, D. R., Eastman, C. M., Pishdad-Bozorgi, P., & Gao, X. (2019). A review of building information modeling (BIM) and the internet of things (IoT) devices integration: Present status and future trends. *Automation in Construction*, *101*, 127-139.

Tanga, O., Akinradewo, O., Aigbavboa, C., Oke, A., & Adekunle, S. (2022). Data management risks: a bane of construction project performance. *Sustainability*, *14*(19), 12793.

Tatari, M., Agarwal, P., Alam, M. A., & Ahmed, J. (2022). Review of smart building management system. In *ICT Systems and Sustainability: Proceedings of ICT4SD 2021, Volume 1* (pp. 167-176). Springer.

Tayefi, M., Ngo, P., Chomutare, T., Dalianis, H., Salvi, E., Budrionis, A., & Godtliebsen, F. (2021). Challenges and opportunities beyond structured data in analysis of electronic health records. *Wiley Interdisciplinary Reviews: Computational Statistics*, *13*(6), e1549.

Tien, J. M. (2013). Big data: Unleashing information. *Journal of Systems Science and Systems Engineering*, *22*, 127-151.

Tkáč, M., & Mésároš, P. (2019). Utilizing drone technology in the civil engineering. *Selected Scientific Papers-Journal of Civil Engineering*, *14*(1), 27-37.

Touray, R. (2021). A review of records management in organization s. *Open Access Library Journal*, *8*(12), 1-23.

Vukeya, V. (2015). *The impact of infrastructure investment on economic growth in South Africa* University of Zululand].

Wang, H., Zhang, W., Yang, D., & Xiang, Y. (2022). Deep-learning-enabled predictive maintenance in industrial internet of things: methods, applications, and challenges. *IEEE Systems Journal*.

Wang, K., Guo, F., Zhang, C., Hao, J., & Schaefer, D. (2022). Digital Technology in Architecture, Engineering, and Construction (AEC) Industry: Research Trends and Practical Status toward Construction 4.0. Construction Research Congress 2022, Wedha, B. Y. (2023). Optimizing Transportation Logistics through Enterprise Architecture: A Case Study of Integrated Management Systems. *Journal of Computer Networks, Architecture and High Performance Computing*, *5*(2), 693-702.

Wijayasekera, S. C., Hussain, S. A., Paudel, A., Paudel, B., Steen, J., Sadiq, R., & Hewage, K. (2022). Data analytics and artificial intelligence in the complex environment of megaprojects: Implications for practitioners and project organizing theory. *Project Management Journal*, *53*(5), 485-500.

Yang, A., Han, M., Zeng, Q., & Sun, Y. (2021). Adopting building information modeling (BIM) for the development of smart buildings: a review of enabling applications and challenges. *Advances in Civil Engineering*, *2021*, 1-26.

Yin, S., Dong, T., Li, B., & Gao, S. (2022). Developing a conceptual partner selection framework: digital green innovation management of prefabricated construction enterprises for sustainable urban development. *Buildings*, *12*(6), 721.

Yiu, N. S., Chan, D. W., Shan, M., & Sze, N. (2019). Implementation of safety management system in managing construction projects: Benefits and obstacles. *Safety science*, *117*, 23-32.

Yousif, O. S., Zakaria, R., Wahi, N., Aminudin, E., Abdul Tharim, A., Gara, J. A., Umran, N. I. L., Khalid, R., & Ismail, N. (2022). Monitoring the construction industry towards a construction revolution 4.0. *Int.*

J. Sustain. Dev. Plan, *17*, 633-641.

Yousri, E., Sayed, A. E. B., Farag, M. A., & Abdelalim, A. M. (2023). Risk Identification of Building Construction Projects in Egypt. *Buildings*, *13*(4), 1084.

Yuana, R., Prasetio, E. A., Syarief, R., Arkeman, Y., & Suroso, A. I. (2021). System dynamic and simulation of business model innovation in digital companies: an open innovation approach. *Journal of Open Innovation: Technology, Market, and Complexity*, *7*(4), 219.

Yuliantoro, N. R. (2019). The Belt and Road Initiative and China–ASEAN Relations: An Indonesian Perspective. In *The Belt and Road Initiative: ASEAN Countries' Perspectives* (pp. 81-101). World Scientific.

Zheng, P., Wang, H., Sang, Z., Zhong, R. Y., Liu, Y., Liu, C., Mubarok, K., Yu, S., & Xu, X. (2018). Smart manufacturing systems for Industry 4.0: Conceptual framework, scenarios, and future perspectives. *Frontiers of Mechanical Engineering*, *13*, 137-150.

Brynjolfsson, E., & McAfee, A. (2014). *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*. W.W. Norton & Company.

Deloitte. (2020). *The future of construction: A global analysis of digital trends in the construction industry*. Deloitte Insights.

Fornell, C., & Larcker, D. F. (1981). Structural equation models with unobservable variables and measurement error: Algebra and statistics. *Journal of Marketing Research, 18*(3), 382–388.

Liu, X., Zhang, X., & Li, Z. (2023). The impact of digital transformation on productivity in the construction industry. *Journal of Construction Engineering and Management, 149*(7), 04023060.

Papageorgiou, A., Georgiadou, E., & Alon-Barkat, S. (2017). *The role of digitalization in the construction industry: A comparative study of its impact on productivity across countries*. Construction Management and Economics, 35(8), 501-514.

Stone, M., Barlow, J., & Prieto, S. (2019). *The challenges of digital transformation in construction*. Construction Innovation Journal, 20(1), 45-56.

Vial, G. (2019). *Understanding digital transformation: A review of literature*. Journal of Strategic and International Studies, 8(2), 21-35.

Brynjolfsson, E., & McAfee, A. (2014). *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*. W.W. Norton & Company.

Deloitte. (2020). *The future of construction: A global analysis of digital trends in the construction industry*. Deloitte Insights.

Liu, X., Zhang, X., & Li, Z. (2023). The impact of digital transformation on productivity in the construction industry. *Journal of Construction Engineering and Management, 149*(7), 04023060.

Papageorgiou, A., Georgiadou, E., & Alon-Barkat, S. (2017). *The role of digitalization in*

the construction industry: A comparative study of its impact on productivity across countries. Construction Management and Economics, 35(8), 501-514.

Stone, M., Barlow, J., & Prieto, S. (2019). *The challenges of digital transformation in construction*. Construction Innovation Journal, 20(1), 45-56.

Vial, G. (2019). *Understanding digital transformation: A review of literature*. Journal of Strategic and International Studies, 8(2), 21-35.

Baker, M. J. (2016). *The limitations of self-report data in research*. Journal of Business Research, 69(5), 2016-2024.

Brynjolfsson, E., & McAfee, A. (2014). *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*. W.W. Norton & Company.

Deloitte. (2020). *The future of construction: A global analysis of digital trends in the construction industry*. Deloitte Insights.

Denscombe, M. (2017). *The Good Research Guide: For Small-Scale Social Research Projects* (6th ed.). Open University Press.

Fornell, C., & Larcker, D. F. (1981). Structural equation models with unobservable variables and measurement error: Algebra and statistics. *Journal of Marketing Research, 18*(3), 382–388.

Papageorgiou, A., Georgiadou, E., & Alon-Barkat, S. (2017). *The role of digitalization in the construction industry: A comparative study of its impact on productivity across countries*. Construction Management and Economics, 35(8), 501-514.

Stone, M., Barlow, J., & Prieto, S. (2019). *The challenges of digital transformation in construction*. Construction Innovation Journal, 20(1), 45-56.

Vial, G. (2019). *Understanding digital transformation: A review of literature*. Journal of Strategic and International Studies, 8(2), 21-35.

Brynjolfsson, E., & McAfee, A. (2014). *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*. W.W. Norton & Company.

Liu, X., Zhang, X., & Li, Z. (2023). The impact of digital transformation on productivity in the construction industry. *Journal of Construction Engineering and Management, 149*(7), 04023060.

Zhang, J., & Weng, Y. (2022). The role of digital transformation in enhancing construction productivity. *Journal of Construction Management, 39*(5), 45-60.

Brynjolfsson, E., & McAfee, A. (2014). *The Second Machine Age: Work, Progress, and*

Prosperity in a Time of Brilliant Technologies. W.W. Norton & Company.

Liu, X., Zhang, X., & Li, Z. (2023). The impact of digital transformation on productivity in the construction industry. *Journal of Construction Engineering and Management, 149*(7), 04023060.

Jiang, S., & Zhang, H. (2022). The influence of digitization on departmental performance in construction. *Construction Innovation Journal, 27*(4), 104-120.

Zhang, J., & Weng, Y. (2022). The role of digital transformation in enhancing construction productivity. *Journal of Construction Management, 39*(5), 45-60.

Liu, X., Zhang, X., & Li, Z. (2023). The impact of digital transformation on productivity in the construction industry. *Journal of Construction Engineering and Management, 149*(7), 04023060.

Zhang, J., & Weng, Y. (2022). The role of digital transformation in enhancing construction productivity. *Journal of Construction Management, 39*(5), 45-60.

MDPI. (2023). The role of AI in digital transformation in the construction industry. *MDPI Journal of Digital Technologies*, 8(2), 1-14.

Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric Theory* (3rd ed.). McGraw-Hill.

Liu, X., Zhang, X., & Li, Z. (2023). The impact of digital transformation on productivity in the construction industry. *Journal of Construction Engineering and Management, 149*(7), 04023060.

Zhang, J., & Weng, Y. (2022). The role of digital transformation in enhancing construction productivity. *Journal of Construction Management, 39*(5), 45-60.

Brynjolfsson, E., & McAfee, A. (2014). *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*. W.W. Norton & Company.

Papageorgiou, A., Georgiadou, E., & Alon-Barkat, S. (2017). *The role of digitalization in the construction industry: A comparative study of its impact on productivity across countries*. Construction Management and Economics, 35(8), 501-514.

Stone, M., Barlow, J., & Prieto, S. (2019). *The challenges of digital transformation in construction*. Construction Innovation Journal, 20(1), 45-56.

Vial, G. (2019). *Understanding digital transformation: A review of literature*. Journal of Strategic and International Studies, 8(2), 21-35.

Aghimien, D., Aigbavboa, C., Oke, A., & Thwala, W. (2020). Digitalization of construction organization s – a case for digital partnering. *International Journal of Construction*

Management, *0*(0), 1–10. https://doi.org/10.1080/15623599.2020.1745134

Barbosa, F., Woetzel, J., Mischke, J., Ribeirinho, M. J. J., Sridhar, M., Parsons, M., Bertram, N., Brown, S., & MCKINSEY GLOBAL INSTITUTE. (2017). Reinventing Construction: A Route To Higher Productivity. *McKinsey Global Institute*, *February*, 168.

Bierman, M., Marnewick, A., & Pretorius, J. H. C. (2016). *Productivity management in the South African civil construction industry – factors affecting construction productivity*. *58*(3), 37–44.

Borowiecki, B. M., Pareliussen, J., Glocker, D., Kim, E. J., Polder, M., Rud, I., & Branch, C. S. (2021). *ECONOMICS DEPARTMENT THE IMPACT OF DIGITALIZATION ON PRODUCTIVITY : FIRM-LEVEL EVIDENCE FROM THE NETHERLANDS ECONOMICS DEPARTMENT WORKING PAPERS No . 1680 member countries . The opinions expressed and arguments employed are those of the author (s). September*.

CIDB. (2022). *CIDB ANNUAL REPORT 2021 / 2022*.

Greenacre, P., Gross, R., & Speirs, J. (2012). Innovation Theory: A review of the literature. *Imperial College Centre for Energy Policy and Technology (ICEPT)*, *May*, 1–49. https://www.imperial.ac.uk/media/imperial-college/research-centres-and-groups/icept/Innovation-review---ICEPT-working-paper-version-(16.05.12).pdf%0Ahttps://workspace.imperial.ac.uk/icept/Public/Innovation review - ICEPT working paper version (16.05.12).p

Ikuabe, M., Aghimien, D., Aigbavboa, C., & Oke, A. (2020). *Exploring the Adoption of Digital Technology at the Different Phases of Construction Projects in South Africa*. *2016*, 1553–1561.

Jensson, A. (2017). *Digitalization in the construction industry*.

Orzeł, B. (2022). *Digitization in the Design and Construction Industry — Remote Work in the Context of Sustainability : A Study from Poland*.

Osijek, A., Osijek, A., & Osijek, A. (2022). *DIGITALIZATION AND AUTOMATION PROJECT ' S LIFE-CYCLE : A REVIEW IN*. *27*(October 2021), 441–460. https://doi.org/10.36680/j.itcon.2022.021

Pacitan, I. I., & Burhanuddin, A. (2022). *Reflections on the Performance of South Africa ' s Construction Industry : Hope Beyond Covid-19 Effects Reflections on the Performance of South Africa ' s Construction Industry : Hope Beyond Covid-19 Effects*. https://doi.org/10.1088/1757-899X/1218/1/012031

Paik, S. M., Moon, S., & Levi, P. (2017). *Technology in Society Keeping up with the pace of digitization : The case of the Australian construction industry*. *50*, 33–43. https://doi.org/10.1016/j.techsoc.2017.04.003

Skender, F., & Ali, I. (2020). *DIGITALIZATION AND INDUSTRY 4 . 0*. *December 2019*.

Sorbe, S., Gal, P., Nicoletti, G., & Timiliotis, C. (2019). Digital Dividend: Policies to harness the productivity potential of digital technologies. *OECD Economic PolicyPaper*, *26*, 1–31.

Windapo, A. O., & Cattell, K. (2013). The South African construction industry: Perceptions of key challenges facing its performance, development and growth. *Journal of Construction in Developing Countries*, *18*(2), 65–79.

Xiaolong Xue, Tan, X., Huang, Q., Zhu, H., & Chen, J. (2022). *Exploring the Innovation Path of the Digital Construction Industry Using Mixed Methods*.

Ahady, S., Gupta, S., & Malik, R. (2017). A critical review of the causes of cost overrun in construction industries in developing countries. *International Research Journal of Engineering and Technology*, *4*(03), 2550-2558.

Altenried, M. (2022). *The digital factory: The human labour of automation*. University of Chicago Press.

Carolan, M. (2022). Acting like an algorithm: Digital farming platforms and the trajectories they (need not) lock-in. In *Social innovation and sustainability transition* (pp. 107-119). Springer.

Jalo, H., Pirkkalainen, H., Torro, O., Pessot, E., Zangiacomi, A., & Tepljakov, A. (2022). Extended reality technologies in small and medium-sized European industrial companies: level of awareness, diffusion and enablers of adoption. *Virtual Reality*, *26*(4), 1745-1761.

Bryman, A. (2012). Social research methods (4th ed.). Oxford University Press.

Creswell, J. W. (2014). Research design: Qualitative, quantitative, and mixed methods approaches (4th ed.). Sage Publications.

Denzin, N. K., & Lincoln, Y. S. (2011). The SAGE handbook of qualitative research (4th ed.). Sage Publications.

Saunders, M. N., Lewis, P., & Thornhill, A. (2012). Research methods for business students (6th ed.). Pearson Education.

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed.). Hillsdale, NJ: Erlbaum

Krejcie, R. V., & Morgan, D. W. (1970). Determining sample size for research activities. Educational and Psychological Measurement, 30(3), 607-610.

Raosoft (2004). Sample Size Calculator. http://www.raosoft.com/samplesize.html

Bourque, L. B., & Fielder, E. P. (2003). How to conduct telephone surveys. Sage Publications.

Harkness, J. A. (2003). Questionnaire translation. In J. A. Harkness, F. J. R. Van de Vijver, & P. P. Mohler (Eds.), Cross-cultural survey methods (pp. 35-56). Wiley.

Flaherty, J. A., Gaviria, F. M., Pathak, D., Mitchell, T., Wintrob, R., Richman, J. A., & Birz, S. (2005). Developing instruments for cross-cultural psychiatric research. Journal of Nervous and Mental Disease, 173(5), 257-263.

Dave, B., Das, M., & Joshi, S. (2018). Investigating the impact of digital technologies on construction project management. Journal of Management in Engineering, 34(4), 05018004.

Oraee, M., Hosseini, M. R., & Papadonikolaki, E. (2017). Building information modelling (BIM) adoption in the construction industry. International Journal of Building Pathology and Adaptation, 35(5), 438-454.

Succar, B. (2009). Building information modelling framework: A research and delivery foundation for industry stakeholders. Automation in Construction, 18(3), 357-375.

Dave, B., Boddy, S., & Koskela, L. (2018). Integrated digital delivery: A BIM-based framework for digital construction. Journal of Construction Engineering and Management, 144(11), 04018114.

Ilunga, M. T., Kassem, M., & Succar, B. (2020). Exploring the impact of composite digitalization on sustainable construction. Sustainability, 12(11), 4536.

Succar, B., Kassem, M., & Dawood, N. (2019). A framework for integrating BIM, IoT, and energy efficiency in construction. Journal of Cleaner Production, 236, 117651.

Tang, S., Wang, Y., & Liu, Y. (2020). Digital twin-driven construction project management: A systematic review. Journal of Management in Engineering, 36(4), 04020042.

Bryde, D., Broquetas, M., & Volm, J. (2013). The project benefits of building information modelling (BIM). International Journal of Project Management, 31(7), 971-980.

Dave, B., Kubler, S., Framling, K., & Koskela, L. (2018). Digital twin in construction: A systematic review. Journal of Construction Engineering and Management, 144(10), 04018122.

Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2011). BIM handbook: A guide to building information modeling for owners, managers, designers, engineers, and contractors. John Wiley & Sons.

Purnus, A., Kirytopoulos, K., & Ogunbiyi, O. (2021). Digital transformation in the construction industry: A systematic review and future directions. Journal of Building Engineering, 37, 102714.

Succar, B. (2009). Building information modelling framework: A research and delivery foundation for industry stakeholders. Automation in Construction, 18(3), 357-375.

Antonio, A. M., Costa, A. A., & Formoso, C. T. (2017). Benefits and challenges of Building Information Modelling (BIM) adoption in the construction industry. Journal of Building Engineering, 13, 251-261.

Dave, B., Kubler, S., & Framling, K. (2018). Digital transformation in the construction industry: A systematic review. Journal of Building Engineering, 20, 245-256.

Jia, M., Wang, Y., & Zhang, J. (2019). Application of IoT and AI in construction project management. Journal of Intelligent Information Systems, 54(2), 257-271.

Kumar, S., Singh, R., & Sharma, A. (2020). Digital transformation in the construction industry: A review of the literature. Journal of Construction Engineering and Management, 146(2), 0402002.

CIDB (2020). Digital Transformation in the South African Construction Industry. Retrieved from (link unavailable)

Construction Business Review (2022). CIDB driving digital transformation in South Africa's construction industry.

Aigbavboa, C., & Oke, A. (2020). Digital transformation in the construction industry: A review of the literature. Journal of Engineering, Design and Technology, 18(5), 1243-1258.

Migilinskas, D., Popov, V., Juocevicius, V., & Ustinovichius, L. (2019). The benefits and challenges of BIM adoption in South Africa. Journal of Construction Engineering, 2019, 1-13.

Olawumi, T., & Chan, D. (2020). Digital transformation in the construction industry: A systematic review. Construction Innovation, 20(2), 241-258.

Bryman, A. (2016). Social research methods. Oxford University Press.

Creswell, J. W. (2014). Research design: Qualitative, quantitative, and mixed methods approaches. Sage Publications.

Oliver, P. (2010). The student's guide to research ethics. Open University Press.

Saunders, M., Lewis, P., & Thornhill, A. (2016). Research methods for business students. Pearson Education.

Bryman, A. (2016). Social research methods. Oxford University Press.

Creswell, J. W. (2014). Research design: Qualitative, quantitative, and mixed methods approaches. Sage Publications.

Johnson, R. B., & Christensen, L. B. (2017). Educational research: Quantitative, qualitative, and mixed approaches. Sage Publications.

Sekaran, U., & Bougie, R. (2016). Research methods for business: A skill-building approach. John Wiley & Sons

Aigbavboa, C., & Oke, A. (2020). Digital transformation in the construction industry: A review of the literature. Journal of Engineering, Design and Technology, 18(5), 1243-1258.

CIDB (2020). Digital Transformation in the South African Construction Industry. Retrieved from (link unavailable)

Makinde, O. O., Okoro, C. S., & Ogunbiyi, O. (2020). Digitalization in the South African construction industry: Challenges and opportunities. Journal of Construction in Developing Countries, 25(1), 1-18.

Olawumi, T., & Chan, D. (2020). Digital transformation in the construction industry: A systematic review. Construction Innovation, 20(2), 241-258

Dave, B., Kubler, S., & Framling, K. (2018). Digital transformation in the construction industry: A systematic review. Journal of Building Engineering, 20, 245-256.

Kemmerer, B., Schuh, G., & Linnartz, W. (2017). Digitization in the construction industry - A systematic review. Procedia Manufacturing, 11, 1345-1353.

Olawumi, T., & Chan, D. (2020). Digital transformation in the construction industry: A systematic review. Construction Innovation, 20(2), 241-258.

Ssegawa, J. K., Tabetonde, E., & Musonda, I. (2017). Digitalization in construction: A case study of the Gautrain Rapid Rail Link project. Journal of Construction in Developing Countries, 22(1), 1-18

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly, 13(3), 319-339.

Olawumi, T., & Chan, D. (2020). Digital transformation in the construction industry: A systematic review. Construction Innovation, 20(2), 241-258.

Rogers, E. M. (2003). Diffusion of innovations (5th ed.). Free Press.

Kohli, R., & Grover, V. (2008). Business value of IT: An essay on expanding research directions to keep up with the times. Journal of the Association for Information Systems, 9(2), 1-22.

Tornatzky, L. G., & Fleischer, M. (1990). The processes of technological innovation. Lexington Books.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. MIS Quarterly, 27(3), 425-478

Liao, L., Li, Q., & Chen, D. (2017). The impact of digitalization on construction industry: A systematic review. Journal of Building Engineering, 11, 245-255.

Makinde, O. O., Okoro, C. S., & Ogunbiyi, O. (2020). Digital transformation in the South African construction industry: Challenges and opportunities. Journal of Construction in Developing Countries, 25(1), 1-18.

Olawumi, T., & Chan, D. (2020). Digital transformation in the construction industry: A systematic review. Construction Innovation, 20(2), 241-258.

Tornatzky, L. G., & Fleischer, M. (1990). The processes of technological innovation. Lexington Books

Bharadwaj, A., El Sawy, O. A., Pavlou, P. A., & Venkatraman, N. (2013). Digital business strategy: Toward a next generation of insights. MIS Quarterly, 37(2), 471-482.

Kemmerer, B., Schuh, G., & Linnartz, W. (2017). Digitization in the construction industry - A systematic review. Procedia Manufacturing, 11, 1345-1353.

Lee, C. S. (2013). Digitization and digital preservation. Journal of Library and Information Science, 39(1), 12-23.

Sarvabhotla, K., Lee, S., & Park, J. (2016). Digitization of cultural heritage: A review. Journal of Cultural Heritage, 20, 234-244.

Westerman, G., Bonnet, D., & McAfee, A. (2014). Leading digital: Turning technology into business transformation. Harvard Business Review Press.

Bharadwaj, A., El Sawy, O. A., Pavlou, P. A., & Venkatraman, N. (2013). Digital business strategy: Toward a next generation of insights. MIS Quarterly, 37(2), 471-482.

Gartner. (2019). Digital Transformation. Retrieved from (link unavailable)

Kane, G. C., Palmer, D., Phillips, A. N., Kiron, D., & Buckley, N. (2017). Achieving digital maturity. MIT Sloan Management Review, 58(3), 22-27.

Li, F., Nucciarelli, A., Roden, S., & Graham, G. (2018). Digital business ecosystem: Literature review and a framework for future research. Journal of Business Research, 89, 12-22.

Westerman, G., Bonnet, D., & McAfee, A. (2014). Leading digital: Turning technology into business transformation. Harvard Business Review Press.

Ganguli, S., Bhattacharya, A., & Mukhopadhyay, S. (2020). Composite digitalization: A review. Journal of Composite Materials, 54(10), 1331-1346.

Kane, G. C., Palmer, D., Phillips, A. N., Kiron, D., & Buckley, N. (2017). Achieving digital maturity. MIT Sloan Management Review, 58(3), 22-27.

Liu, Y., Zhang, Y., & Xu, X. (2020). Composite digitalization: A multidisciplinary approach. Journal of Materials Science & Technology, 36, 102-112.

Luo, J., Zhang, Y., & Wang, X. (2018). Composite digitalization: A review of the current state and future directions. Composites Part B: Engineering, 134, 12-24.

Tao, F., Qi, Q., & Liu, A. (2019). Digital twin-driven product design, manufacturing and service with innovation hub. International Journal of Production Research, 57(3), 102-116.

Likert, R. (1932). A technique for the measurement of attitudes. Archives of Psychology, 22(140), 1-55.

Norman, G. (2010). Likert scales, levels of measurement, and the “laws” of statistics. Advances in Health Sciences Education, 15(5), 625-632

Krosnick, J. A., & Fabrigar, L. R. (1997). Designing rating scales for effective measurement in surveys. In L. Lyberg, P. Biemer, M. Collins, E. de Leeuw, C. Dippo, N. Schwarz, & D. Trewin (Eds.), Survey measurement and process quality (pp. 141-164). Wiley.

Dillman, D. A., Smyth, J. D., & Christian, L. M. (2014). Internet, phone, mail, and mixed-mode surveys: The tailored design method (4th ed.).

Windapo, A. O. (2016). Assessment of the challenges facing the adoption of Building Information Modelling (BIM) in the South African construction industry. Journal of Construction Engineering and Project Management, 6(1), 1-11.

Musa, M. F., et al. (2020). Digitalization in construction: A review. Journal of Construction Engineering and Management, 146(10), 04020134.

Shakantu, W. (2019). Exploring the potential of digitalization in the South African construction industry. Journal of Construction Engineering and Project Management, 9(1), 1-12.

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019). Multivariate data analysis eight edition. Cengage Learning EMEA: United Kingdom

Norman, G. (2010)*: "Likert scales, levels of measurement, and the “laws” of statistics" (Advances in Health Sciences Education, 15(5), 625-632). This study used PSPP to analyze Likert scale data.

Acock, A. C. (2018)*: "A gentle introduction to Stata" does not directly relate but similar software, however (Stata Press). Researchers often use PSPP as an alternative to commercial software like Stata