ASSESSMENT OF EMERGING TECHNOLOGIES ENHANCING PROJECT DELIVERY AMONG MEDIUM AND LARGE CONSTRUCTION FIRMS IN DURBAN

A RESEARCH STUDY SUBMITTED BY:

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A research dissertation submitted in fulfilment of the Requirements of the Masters of Built Environment: Construction Management Degree in the Department of Construction Management and Quantity Surveying, Faculty of Engineering, the Built Environment, Durban University of Technology, Durban, South Africa

July 2022

DECLARATION

I, **Johannes S'thembiso Mchunu,** declare that this dissertation is an outcome of my investigation and research study. I also declare that the sources used in this research have been acknowledged in the references list and adequately cited in the body of the dissertation. Copies of this research work have in no way been submitted elsewhere for any similar purpose. This research was conducted at the Durban University of Technology as a requirement to obtain a Master of the Built Environment degree in Construction Management under the Supervision of Dr. I.C Anugwo.

Submitted by:

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ABSTRACT

The objective of this research was to assess the potential of emerging ICT technologies to enhance construction project design, procurement, and delivery among medium and large construction firms registered on the Durban Construction Industry Development Board (cidb) under grade 4-6 and grade 7-9 c. The study explored how construction companies can use various emerging Information and Communication Technology (ICT) technologies such as Internet of Things (IoT), 3D Printing, Virtual Reality (VR), Building Information Modelling (BIM), Robotics and wireless sensor technology, to improve construction project delivery in the eThekwini region. This study focused on one province, KZN and the eThekwini District Municipality, located on the east coast of South Africa. The questionnaires were formulated to evaluate construction contractors' level of awareness, understanding, knowledge, and commitment to advance business operations using new emerging technologies presently linked to the Fourth Industrial Revolution (4IR). Data collection instruments used for this study comprised an online survey as well as paper-based questionnaires. The data was analysed using percentages, mean scores, and standard deviations, and each question was ranked using the SPSS Statistical Package. The analysis shows that awareness, and knowledge of, new emerging technologies among construction companies in Durban was significantly high within offices. However, awareness, and knowledge of, new emerging technologies was significantly low on construction sites. The study revealed that a remarkable number of respondents were of the opinion that the implementation of emerging ICT technologies and the 4IR would benefit project design, procurement and construction delivery. The study concluded that there is a high level of commitment to implement new emerging technologies among construction companies in Durban. The study recommended that construction companies in Durban should acknowledge the need to enhance business processes in construction and improve levels of performance and competitiveness by implementing new emerging technologies on construction sites. The study proposed that construction companies in Durban should implement new emerging technologies to improve the performance of the sector in KwaZulu-Natal.

DEDICATION

I devote this research study to my wife, Mrs Siphiwe Rejoice Mchunu.

ACKNOWLEDGEMENTS

Many thanks to my saviour Lord Christ Jesus for the kindness upon me to realize this task.

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LIST OF PUBLICATIONS

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LIST OF ABBREVIATIONS

ABBREVIATIONS

1IR	First Industrial Revolution
2IR	Second Industrial Revolution
3D	Three-Dimensional
3IR	Third Industrial Revolution
4IR	Fourth Industrial Revolution
AA	Advance Automatic
AV	Augmented Reality
BAP	Battery Assisted Passive
BIM	Building Information Modelling
BOQ	Bill of Quantities
CAD	Computer-Aided Design
CAT	Computer Aided Technology
CIDB	Construction Industry Development Board
CIRC	Computer Integrated Road Construction
CPS	Cyber-Physical System
CSCM	Construction Supply Chain Management
CWD	Connected Wearable Devices
DFKI	Deutsches Forschungszentrum für Künstliche Intelligenz
DT	Digital Technologies

EC	Eastern Cape
EDI	Electronic Data Interexchange
ERP	Enterprise Resource Planning
EU	European Union
FS	Free State
GDP	Gross Domestic Product
GNP	Gross National Product
GP	Gauteng Province
GPS	Global Positioning System
IAARC	International Association for Automation Robotics in Construction
ICT	Communication and Technology
IoS	Internet of Services
IoT	Internet of Things
IR	Industrial Revolution
ISACR	International Symposium on Automation, Control and Robotics
IT	Information Technology
KZN	KwaZulu-Natal
LP	Limpopo Province
MP	Mpumalanga Province
NC	Northern Cape
NW	North-West
OOCAD	Object Oriented Computer Aided Design

QC	Quantum Computing
QR	Quick Response
RFID	Radio Frequency Identification
RoC	Register of Contractor
RP	Rapid Prototyping
SA	South Africa
SCM	Supply Chain Management
SCO	Smart Construction Object
SM	Social Media
SWE	Smart Work Environments
VR	Virtual Reality
WC	Western Cape

1 CHAPTER ONE: INTRODUCTION

1.1 The Problem and Its Setting

The construction sector is one of the main sources of employment in South Africa, and it remains a vital player that has potential to stimulate the entire economy. The South African construction sector remains crucial for job creation because most of its operations are still labour-intensive (Ogwueleka and Maritz, 2014: 6). The construction sector also plays a major role in supporting other economic sectors through the provision of building and engineering infrastructure assets (Ogwueleka and Maritz, 2014: 6). However, the slow adoption of emerging technologies in the construction industry makes it prone to low productivity and cost overruns due to rudimentary styles of construction planning and delivery (Castro-Lacouture, 2009: 1063).

The 21st century economic environment has ushered both opportunities and challenges, particularly if one considers the disruptive potential of the 4IR. According to Park (2016:1), The Fourth Industrial Revolution (4IR) has had an indisputable impact on the evolution of whole systems throughout countries, companies, industries, and society as a whole, including the construction industry. The emerging technologies, such as Artificial Intelligence (AI), the Internet of Things (IoT), Cloud Computing, Social Media (SM), Data Science (DS), Three Dimensional (3D) printing, Connected Wearable Devices (CWD), Quantum Computing (QC), Robotics, and Genetics are drivers of change at the core of the Fourth Industrial Revolution (Park, 2016: 1). If adopted, these revolutionary technologies can significantly influence disciplines, economies, transactions, communities, and individuals.

The Industrial Revolution (IR) is deemed to have started in Britain more than 200 years ago, marking the transit from an economy based on handiwork to one predominated by industry and automaton manufacture (Housel, 2007: 4). The IR originated with the introduction of machines in the eighteenth century, and gained a tremendous breakthrough in the late nineteen century with the innovation of electric power, petroleum, fuel and later electronics, atomic power and super computers (Lucas, 2002: 4). However, the term Fourth Industrial Revolution (4IR) was first coined in 2011 by the Fraunhofer – Gesellschaft institute and the German Federal government as a collective expression that puts assorted information exchange, computerization and manufacturing technology into one box (Chung and Kim, 2016: 1312). Concisely, the Fourth Industrial Revolution refers to a mixture of Internet of Things (IoT), Cyber-Physical Systems (CPS) Internet services and humankind within a system (Chung and Kim, 2016: 1312). According to Philbeck and Davis (2018: 17), the 4IR represents a series of serious changes in the way that economic, political and social values are invented, exchanged and disseminated. These changes in values are associated with the evolution of new technologies that connect the digital and the physical living worlds. These become more powerful as they come together and develop (Philbeck and Davis, 2018: 17). Thus, the 4IR is disruptive in nature, considering its velocity, scope, and systematic impact on society. Compared to previous industrial revolutions, the 4IR is advancing at an exponential pace (Park, 2016:1; Ramirez, 2018: 3). The 4IR entails change of entire systems across countries, companies, businesses, and communities as they embrace emerging technologies (Park, 2016: 1).

It is evident that many countries and economic sectors around the world are not fully prepared for the 4IR and South Africa (SA) and its construction sector are no exception. According to the Minister of International Relations and Cooperation, (Sisulu, 2019: online), South African industries are far behind in terms of competitiveness due to the advent of the Fourth Industrial Revolution. South Africa's Minister of Communication, Ndabeni-Abrahams (2019: Online) also acknowledged that Artificial Intelligence (AI) technologies are developing at such as a fast pace that the country would not be able to cope. As such there is need to create awareness and foster readiness towards harnessing the benefits of the Fourth Industrial Revolution. Ndabeni-Abrahams (2019:Online) further asserted that the government was striving earnestly to create an enabling Information, Communication and Technology (ICT) infrastructure to enhance awareness, capacity and eagerness among South Africans to deal with the emerging technologies.

1.2 Research Problem Formulation

The construction business currently accounts for approximately 6% of the world's Gross National Product (GNP), and is expected to reach around 14,7% in 2030, making it the largest employing sector in the global economy (Craveiroa, Duartec, Bartoloa, and Bartolod, 2019: 6). A report by Statistics South Africa (2016: Online) and Pillay and Mafini (2017: 1) states that the construction industry accounts for a large portion of the Gross Domestic Product (GDP). According to the Construction Industry Development Board (CIDB) (2016: Online), the South African construction industry accounts for at least 50% of total national investment and 4% of GDP. Construction is an important sector in South Africa, which employed approximately 1 031 000 craft-related workers in the year 2011 alone (Windapo 2016: 3) .

Nevertheless, the South African construction industry is notoriously resistant to change due to its unwavering commitment to protect jobs and unpreparedness to abandon familiar operations (Construction World News, 2018: online). The resistance to change in the construction industry has contributed to the slow paced adoption and implementation of emerging innovative technologies. (Pillay, Ori and Merkofer, 2017: 4). Notwithstanding the general negative attitude towards new technologies within the industry, the Fourth Industrial Revolution presents immense opportunities and potential disruptions to the construction business, especially in developing countries (You and Feng, 2020: 1; Aghimien, Aigbavboa and Matabane, 2021: 318). Given that most developing countries have a huge infrastructural asset' deficit the 4IR has potential to quickly and effectively close the gaps in the design, procurement, operation and maintenance of solid infrastructure assets (You and Feng, 2020: 1).

Although most construction companies have been executing their work for decades, they have not been directly involved in the recent technological revolution. This has led to the slow uptake of innovative technologies that can increase the productivity of the entire industry (Leviäkangas, Paik and Moon, 2017: 33). According to Raphael *et al.* (2019: 1), resistance to new technologies, perhaps due to a lack of sufficient capacity, has resulted in many construction projects in KwaZulu-Natal experiencing delays, rising costs and inconsistencies, as well as poor performance and dissatisfaction among various stakeholders (Raphael *et al.,* 2019: 1). It is clear that most South African construction companies are behind with regard to the utilisation of new and emerging technologies, which makes them lack competitiveness compared to their peers from other countries such as China (Pillay, Ori and Merkofer, 2017: 4).

There is a perception that other sectors of the economy such as the health sector are more receptive to the integration of new and emerging technologies to solve challenges and increase productivity (Pillay, Ori and Merkofer, 2017: 4). Park's (2016: 1) research findings show that a significant 45% of executives agree that the healthcare sector would profit the most from the integration of physical and digital biological systems.

The manufacturing, automotive and banking sectors have already entered into the future through implementing full digital approaches to their day-to-day business, thus enhancing productivity, accuracy, efficiency and customer satisfaction (Osunsanmi, Aigbavboa and Ayodeji, 2018: 206). The construction sectors' clients are yearning for the same satisfaction from services and products offered by construction practitioners. This has forced the construction industry to increasingly adopt the Fourth Industrial Revolution technologies in resolving some of the challenges in the sector (Osunsanmi *et al.,* 2018: 208).

1.3 Research Problem Statement

The construction business in South Africa is resistant to ICT reforms, yet the fourth industrial revolution continues to impact every sector of society, creating uncertainties and disrupting traditional business practices. In spite of its disruptive potential, the 4IR presents an opportunity for South African construction organisations to transform their operations in terms of design, procurement, delivery and maintenance of built environmental infrastructure projects.

1.3.1 Statement of Research Sub-Problems (S-P)

S-P1: There is a perception that construction companies in Durban, South Africa lack understanding of the concept of the Fourth Industrial Revolution ;

S-P2: There are perceptions that construction companies in Durban resist the implementation of new and emerging ICT technologies in their project design, procurement, construction and delivery.

S-P3: There are perceptions that construction companies in Durban lack appreciation of, and readiness to take advantage of emerging ICT technologies in their projects delivery in relation to design, construction, cost, time, quality, and environmental health and safety.

1.4 Research hypothesis

Alternative (a) and Null (o) Hypotheses

H1a: The in-depth understanding and knowledge of the concept of the 4^{th} industrial revolution among construction companies in Durban is at a basic level.

H1o: The knowledge and in-depth understanding of the concept of the 4^{th} industrial revolution among construction companies in Durban is at an advanced level

H2a: The implementation of emerging ICT technologies in project design, procurement and delivery of construction projects in Durban is at an average level

H2o: The implementation of emerging ICT technologies in project design, procurement and construction delivery in Durban is at an advanced level

H3a: The level of readiness for and appreciation of the benefits of the 4^{th} industrial revolution in terms of design, construction, cost, time, quality, and environmental health and safety is at a basic level.

H3o: The level of readiness for and appreciation of, the benefits of the 4^{th} industrial revolution in terms of design, construction, cost, time, quality, and environmental health and safety is at a significant level.

1.5 The Aim of the Research Study

The purpose of this study is to assess the impact of the 4^{th} industrial revolution and emerging ICT technologies on construction companies in Durban and the extent to which these companies actually utilise ICT technologies in their project design, procurement, construction, delivery, operation and maintenance activities.

To achieve this aim, the following objectives were formulated:

1.5.1 The Objectives of the Research Study

i. To explore the level of awareness and knowledge of the concept of the 4^{th} industrial revolution and emerging ICT technologies among construction companies in Durban relation to their project delivery

ii. To assess how construction companies in Durban perceive the implementation of emerging ICT technologies and 4th industrial revolution in their project design, procurement and construction delivery; and

iii. To ascertain the level of readiness among construction companies in Durban to take advantage of the 4th industrial revolution in their project design, procurement and construction in relation to a project cost, time, quality and environmental safety.

Table 1: Relationship between sub-problems, research hypotheses and research objectives

Statement of Sub-problems (S-p)	**Corresponding Hypothesis (H)**	**Objectives**
Sub-problem 1 (S-p 1)	Hypothesis 1 (H1a,o.)	Objective 1
Sub-problem 2 (S-p 2)	Hypothesis 2 (H2a,o)	Objective 2
Sub-problem 3 (S-p 3)	Hypothesis 3 (H3a,o)	Objective 3

1.6 Scope of the Study

This study focused on assessing elements of the 4th industrial revolution and emerging ICT technologies that can enhance construction project delivery within the eThekwini District Municipality of KwaZulu-Natal. The study adopted a qualitative approach and used questionnaires as research instruments to solicit responses from participants. The researcher distributed questionnaires among construction contractors of grades 4 to 9 on the Construction Industry Development Board (CIDB) Register of Contractors (RoC), within the civil and general building contractors' grades/group. The groups of CIDB-registered contractors fell within the medium and large construction companies and were assumed to have a stable financial capability, strategic resources, adequate work experience and track record of project delivery fair/well established organisational structure and managerial capability. Construction contractors in grades 4 to 9 on the Construction Industry Development Board (CIDB) Register of Contractors (RoC) have potential to seamlessly integrate new and emerging ICT technologies that can enhance project delivery experiences within the eThekwini region.

1.7 Importance of the Research

This research sought to make an in-depth assessment of how construction companies in Durban can utilise emerging technologies to enhance construction project delivery. This was achieved by exploring how the application of various emerging ICT technologies can improve project delivery (Manyika, Chui and Miremadi, 2017: 11) and mitigate low productivity (Ameh and Osegbo, 2011: 57), poor infrastructure delivery and lack of local capacity for global competitiveness within the industry.

1.8 Research area

South African (SA) consists of nine provinces, namely North-West (NW), Northern Cape (NC), Free State (FS), Western Cape (WC), Gauteng (GP), Mpumalanga (MP), Limpopo (LP), Eastern Cape (EC), and KwaZulu-Natal (KZN).

This study focused on one province, namely KwaZulu-Natal (KZN) and the eThekwini District Municipality located on the east coast of South Africa (see figure 1). KZN is the second most populated province in the country with a population of 11.1 million, which is 19.8 percent of the provincial share of the national population. The KZN population is divided into four ethnic groups namely, Africans, Coloureds, Indian and Whites. (KWAZULU-NATAL 2016). The eThekwini District Municipality is home to approximately 3.4 million people (Ethekwini, 2016: online).

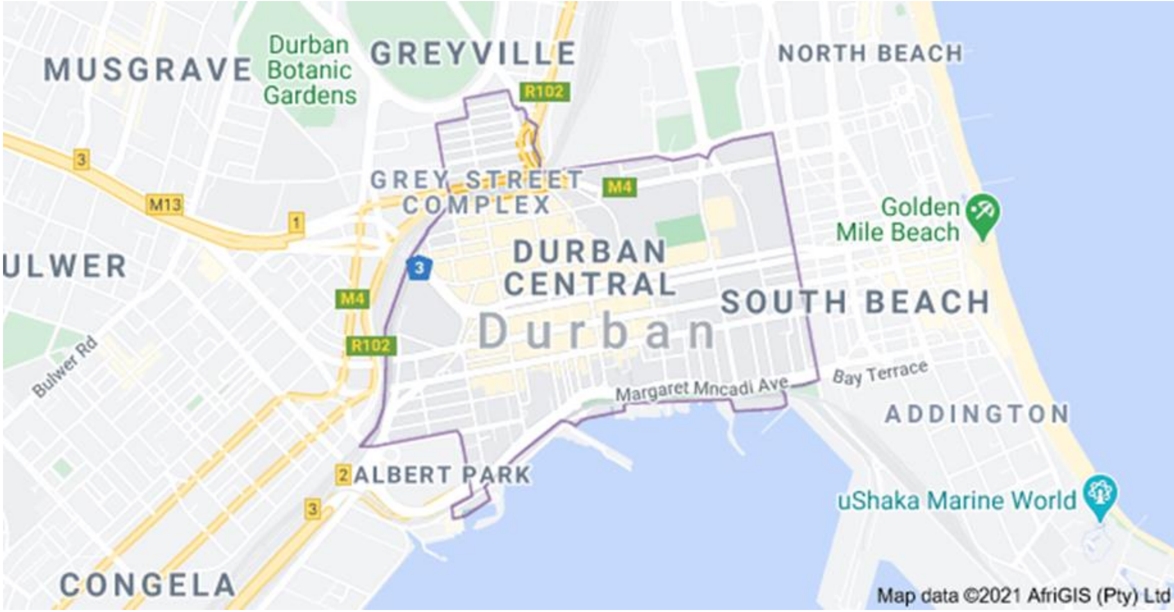

Figure 1: Map of Durban Central

Source: KwaZulu Natal (2020: online)

1.9 Structure of Study

The study is set out as follows:

Chapter 1 covers the current literature regarding the 4th industrial revolution and attendant emerging technologies. It presents a background to the study, the research problem, aims and objectives as well as the theoretical framework.

Chapter 2 identifies key elements of the 4th industrial revolution and associated emerging technologies, as well as their impact on countries, companies, industries, and society as a whole. The chapter also explores issues related to readiness as well as the critical need for the implementation of 4IR technology in the construction industry.

Chapter 3 discusses the research methodology, and research methods as well as the data collection and sampling techniques chosen for the study.

Chapter 4 presents and analyses data in relation to the adopted research methodologies as explained in Chapter 3.

Chapter 5 concludes by summarising the research findings and making recommendations for future research work.

2 CHAPTER TWO: LITERATURE REVIEW

2.1 Brief Historical Background of the Industrial Revolutions Phenomenon

According to Posada *et al.* (2015: 2), the world has witnessed three significant industrial revolutions and the so-called Fourth Industrial Revolution (4IR) is already on its way (see figure 2). Based on historical accounts, the First Industrial Revolution (1IR) relates to mechanisation, which led to improved efficiency from handcraft to mechanised processes. The Second Industrial Revolution (2IR) saw the birth of electricity and advent of mass production, whilst the Third Industrial Revolution (3IR) fostered the optimal utilisation of electronics and information and communication technology. The Fourth Industrial Revolution (4IR) is a fusion of all current and emerging technologies (Chung and Kim, 2016: 1313).

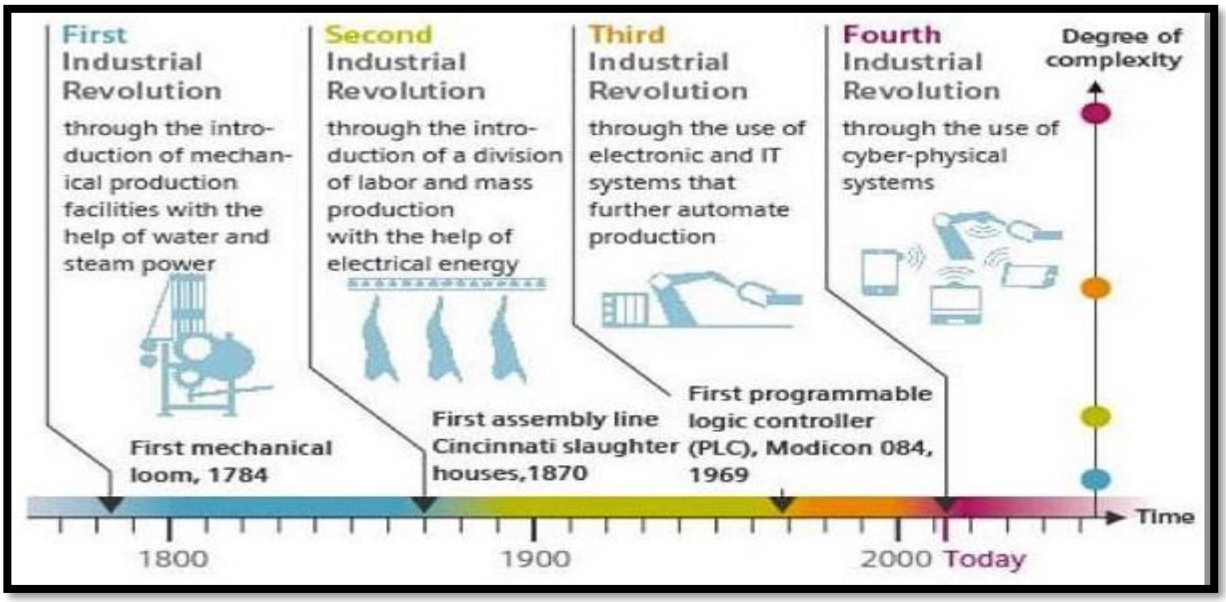

Figure 2: An Overview of all four industrial revolutions from 1784 to 2011

Source: Chung and Kim (2016: 1313)

The 4IR or industry 4.0 phenomenon has significantly impacted economies around the world. According to Leyh, Schäffer, Bley and Bay (2017: 2), the industry 4.0 phenomenon is part of a new and emerging technological development, and the Internet and other emerging technologies are major features of Industry 4.0. The fourth industrial revolution integrates physical objects, operations, intelligent machinery, production lines and processes. It also creates a new mode for smart internet-connection and mobile value chain. (Leyh *et al.,* 2017: 3). Tupa, Simota and Steiner (2017: 1225), state that industry 4.0 is the interconnectedness of machines and machine systems in production lines for optimal utilisation of information systems and production processes and efficiency. Nunes, Pereira and Alves (2017: 1222) see industry 4.0 as a new production system that integrates intelligent factories, machinery, systems, products and processes online, and provides simultaneous data in the physical and virtual world through Cyber Physical Systems.

In addition, Bortolini, Ferrari, Gamberi, Pilati and Faccio (2017: 5703) state that industry 4.0 is about integrating and fitting every stage of all corporate production segments into traditional production processes replaced by the internet and information technology. In other words, Industry 4.0 is the link between people and things and any communication technology or services at all times across the arena (Wagner, Herrmann and Thiede, 2017: 128).

The fourth version of the industrial revolution integrates various digital technologies such as 3D Printing, Internet of Things, advanced robots, artificial intelligence etc. These technologies have the potential to transform the operation and management of the supply chain within the construction industry (Dallasega, Rauch and Linder, 2018; Koh, Orzes and Jia, 2019: 2). Industry 4.0 is an emerging concept associated with technological advances and disruptive developments in the global industrial sector over the past few years (Dallasega, Rauch and Linder, 2018; Koh, Orzes and Jia, 2019: 3).

Research conducted by Economist Intelligence (2016: online) among 622 business executives and leaders across various sectors of the economy to assess the impact of the 4IR on healthcare, education, finance, infrastructure, and energy (see Figure 3) indicate that a large proportion of business executives and leaders, i.e. 45% of 622, believe that the healthcare sector will benefit the most from integrating physical, digital, and biological systems.

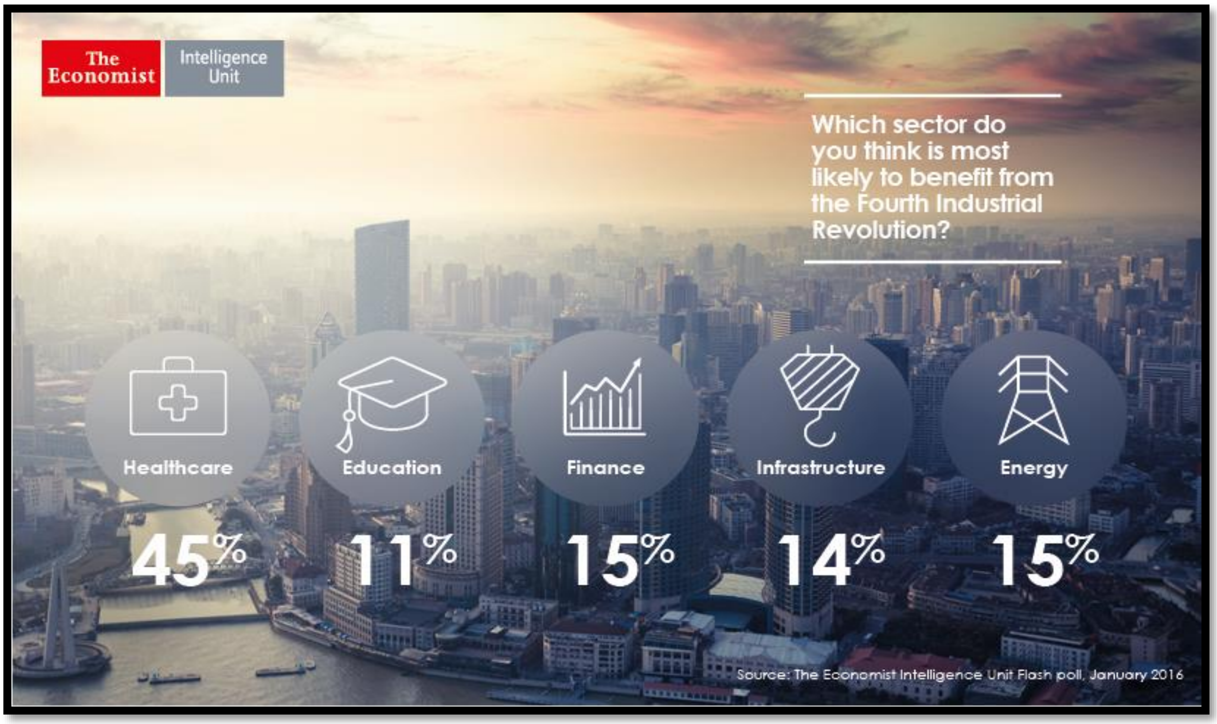

Figure 3: The Economic Intelligence Unit Flash Poll

Source: The Economic Intelligence (2016: online)

According to Heck and Rogers (2014: 6), one characteristic of industry 4.0 has been the increased industrial competitiveness across various sectors of the economy through the use of smart equipment. Smart equipment utilises information to foster demographic changes, encourage optimal utilisation of available resources and accelerate energetic and efficient production processes especially in urban regeneration and integration (Heck and Rogers, 2014: 6). Kagermann (2015: 23) states that the four key components of the 4IR are cyber-physical systems (real-world and virtual communication), Internet of Things (IoT), and agile factories. Globally, the digitalization process is already underway and it is predicted that by 2020, 6.5 billion people and 18 billion objects would be connected to mobile networks (Kagermann, 2015: 24).

2.2 The Concept of the Fourth Industrial Revolution

The 4th Industrial Revolution evolved through the utilisation of cyber-physical systems (CPSs), Internet of Things (IoT) and services (Lee *et al.,* 2018: 3). It allows and encourages physical systems and technological infrastructure to interact and communicate with each other and connect seamlessly with people in real time to become more efficient in service and product delivery (Buhr, 2015: 3).

Buhr (2015: 10) claims that the 4th industrial revolution would seamlessly integrate human factors in the centre of production with the demands of a high-level skilled workforce in order to ensure an effective management of complex projects. This process would foster continuous improvement of production and dynamic working routines within various industries, such as the construction industry (Buhr 2015: 10). Oesterreich and Teuteberg (2016: 122) acknowledges that there are huge potential advantages and benefits embedded in the 4th industrial revolution and associated emerging and innovative technologies. Many companies in the construction industry are committed to transforming and managing the integration of these new and emerging technologies to ensure their competitiveness as partners in fields such as automotive or mechanical engineering (Oesterreich and Teuteberg, 2016: 122). Gower (2018: online) cited Gustav Rohde (2018) notes that some international engineering companies such as Aurecon are concerned that if African businesses do not comply with the Fourth Industrial Revolution, they are likely to be at risk of becoming outdated, isolated and unable to compete in both domestic and global market conditions. The fourth effort for industrial change must be seen as an opportunity for African societies and businesses to play a more positive role in embracing the digital age (Gower, 2018: online). The new and emerging technologies of the 4IR would provide the African continent with huge potential opportunities to undertake a paradigm shift towards acquiring in-depth scientific capability and critical knowledge to solve complex problems such as infrastructure deficit and lack of sustainable economic growth and development (Gower, 2018: online).

According to Gower (2018: online), the South African industry has played a major role in digital innovation. However, Jarbandhan (2017: 70) in his research found that industry players in South Africa are underprepared for the Fourth Industrial Revolution.

Gower (2018: online) went on to say that by 2030 at least one-third of economic activity, i.e. about 60% of jobs, will be automatically operational.

Sutherland (2020: 234), in his research, stated that South Africa is not ready for the Fourth Industrial Revolution as its economy is still focused on agriculture, mining and the informal sector, and is burdened by unemployment while most of its citizens lack advanced skills and in general, basic skills.

In short, up to 375 million people worldwide will need to change jobs or learn new skills as normal jobs will have mechanized duplicates. However, all past industrial changes have led to more job opportunities, thus the Fourth Industrial Revolution and new emerging technologies will create new industries and increase job opportunities in all sectors. (Gower 2018: online).

Eberhard *et al.* (2017: 48) states that big data analysis, digitisation and robotisation enforce automation and employee replacement in areas such as logistics, legal contract law, copyright law functions, accountancy, transportation, production work, housing maintenance, health care, and other high-quality medical services. The speed and rate of change coming about due to the Fourth Industrial Revolution should not be overlooked. These changes will bring about changes in power, wealth and knowledge. Only by being aware of these changes and the speed at which they happen can we ensure that advances in knowledge and technology are accessible to all and benefit all (Xu, David and Kim 2018: 90).

According to Balogh (2017: 73) "we are seeing the beginning of a new era that will dramatically change the way we live, work and develop together as a society, and the individuals, communities and nations that are able to embrace this change will be the ones who will succeed, as has been throughout history ". The technological transformation is accompanied by a broader social and economic development, political, demographic and environment changes that, affect all regions of the world and all aspects of our lives (Balogh, 2017: 73).

The technology combination (4IR) forces companies to re-evaluate how they do business. The key point, however, is the same: business leaders and senior executives need to understand their changing nature, challenge the ideas of their operating team, and innovate tirelessly and continuously (Schwab, 2017: 5).

2.3 The 4IR Applications and Techniques within the construction sector

2.3.1 Understanding the Concept of Smart Construction

In recent years, as a result of the 4th industrial revolution and rapid development and maturity of emerging information technology, an agile construction system has become increasingly important and so is the need for the industry to integrate into the best engineering and construction management services and product delivery systems (Yang, Wang and Sun, 2018: 458). Smart Construction Systems (SCS) integrate Virtual Reality (VR), Argument Reality (AR), sensor technology, robots, Building Information Modelling (BIM), air drones, and Internet of Things (IoT), which undoubtedly make construction a must-have among hi-tech industries (Liu, Lu and Niu, 2018: 2). Smart Construction Objects (SCOs) are construction resources (e.g. machinery, equipment and building materials) that are made “agile” by integrating technologies that provide independence, awareness, and interpersonal skills. This “intelligence” can make it easier to make informed decisions (Niu *et al.,* 2016: 1).

According to LI (2017: 302) the elements of Smart Work Environments (SWE) enable the construction industry to effectively monitor its operations, personnel, tools, and equipment in the workplace and improve environmental safety management and sustainability practices. LI (2017: 302) states that the provision of technological infrastructure promotes virtual and physical communication based on ubiquitous technology, as well as IoT. Therefore, this approach offers a promising opportunity within SWE and physical cyber systems. Besides, in the construction industry, labour costs are high and handicrafts tend to be flawed and inaccurate. The use of automated solutions based on robots and robotic arms would reduce personnel problems and challenges in construction sites, which means that site safety can be improved. The utilization of computerized solutions that are based on automation and robotic arms would lessen the labour crisis and challenges on construction sites, substantially meaning that safety on sites could be improved (LI, 2017: 302).

According to Lacovidou, Purnell and Lim (2018: 215), in recent decades, advanced “smart” technologies have emerged, including radio frequency identifications tags (RFID), visual character recognition, 3D scanning lasers and building information models (BIM), etc. These technological elements have become important tools in the construction industry.

2.3.2 Understanding issues of Smart construction in on-site projects

In order for construction processes to qualify as smart, technology components such as elements of fourth industrial revolution are crucial. According to Wang *et al.* (2016: 1), the basic technologies are composed of a so-called Cyber Physical System (CPS), and Computer-Aided Technology (CAT), such as Radio frequency identification (RFID) and Internet of Things (IoT).

The smart technologies expand the 4IR magnitudes and promote linkage, which provides intelligence to the new construction system and enables construction site participants to track and monitor the site activities(Frank, Dalenogare and Ayala, 2019: 10). As has been shown in Figure 4, these technologies, according to the studies (Osunsanmi *et al.,* 2018: 206) provide a guide to the introduction of construction industry 4.0 in the South African construction industry. The name Construction 4.0 is coined from the concept of industry 4.0, which is linked to the 4IR.

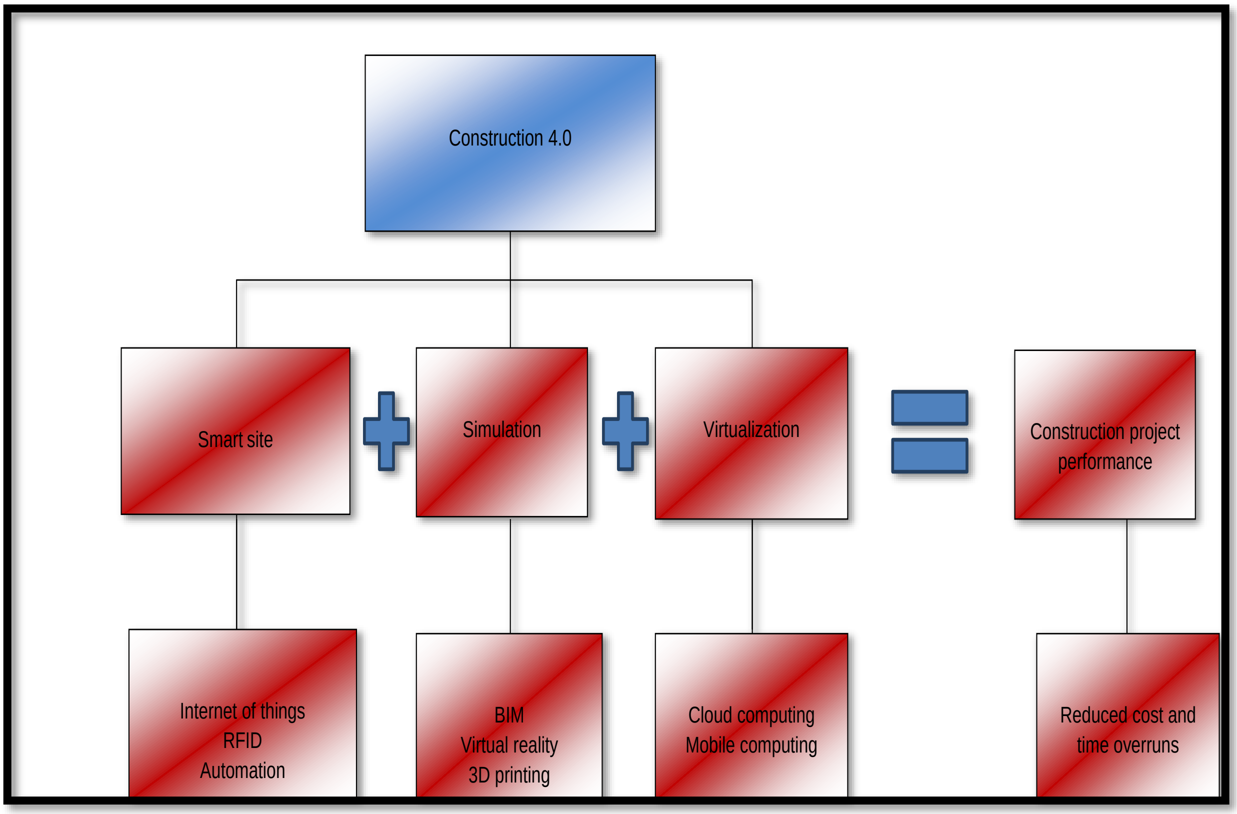

Figure 4: A Conceptual Framework for Construction 4.0

Source: Osunsanmi, Aigbavboa, Clinton, Oke and Ayodeji (2018: 208)

2.3.2.1 Understanding the Concept of Cyber-Physical Systems

According to Shi, Wan, Yan, and Suo (2011: 1), Cyber-Physical Systems (CPS) is an effective two-dimensional integration of computational resources through physical processes. Cyber-Physical Systems (CPS) are material systems where operation is monitored, integrated, controlled and coordinated into a computer and communication environment (Rajkumar, Lee, Sha and Stankovic, 2010: 731).

The most obvious use of computers and software is to process information that people will consume (Lee and Seshia, 2010: 1). These computers together with their software are called embedded systems or software (Lee and Seshia, 2010: 1). By definition, CPS includes a high level of integration between computing (virtual) and physical systems, supported by the CPS system (Yuan, Anumba and Parfitt, 2015).

Recent advances in information technology have led to the emergence of Cyber-Physical Systems (CPS), which provide a promising and effective way of recognizing temporary structures, such as scaffolding, during project implementation. execution (Yuan, Anumba and Parfitt, 2014).

In this day and age, there is evidence of the use of cyber-physical systems in sectors such as aviation engineering, automotive, chemical developments, public infrastructure, electricity power, health care, entertainment, consumer gadgets and manufacturing (Wu and Li, 2011: 291). A common feature of the cyber-physical system is the integration of the computer and physical systems (Wu and Li, 2011: 291). Figure 5 shows three key parts involved in a CPS.

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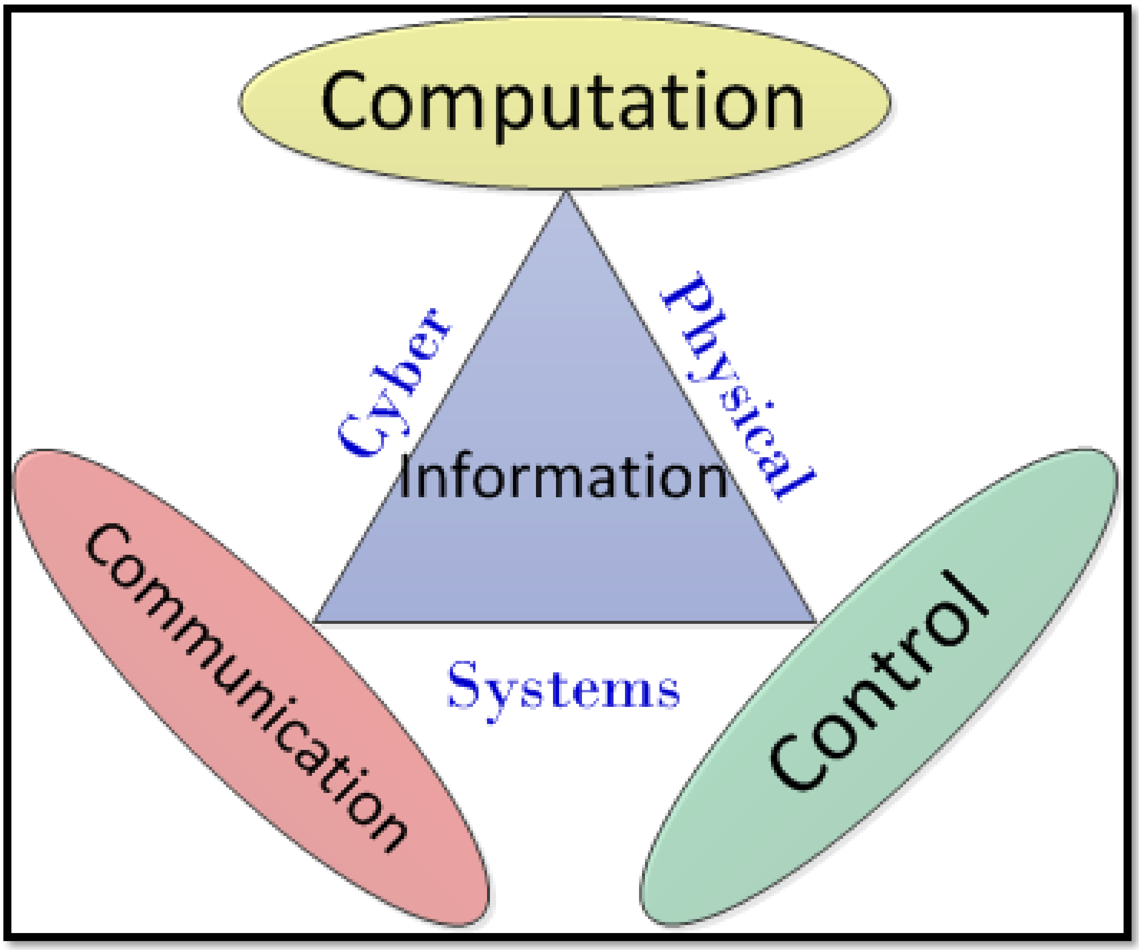

Figure 5: Three Key Functional Parts in the CPS

Source: Wu and Li (2011: 292)

CPS provides a viable solution to automated and flexible systems in a number of sectors such as automotive systems, distributed robots, and emerging semiconductor systems. CPS can deal with problems such as operational delays and equipment failures in the manufacturing industry and have been implemented in many industry sectors. In the manufacturing industry, CPS has been used to help manage dynamic changes in production. In the manufacturing sector, CPS has been used to help maintain dynamic changes in production (Laroque, Himmelspach, Pasupathy, Rose, Uhrmacher, Kaihara, Yao, and Nada, 2012: 2062). Gong and Li (2013: 82) state that CPS has been implemented in the transportation industry to promote the development of intelligent traffic systems in complex infrastructure projects. The healthcare sector is increasingly banking on CPS for effective network deployments and health information databases (Shi *et al.,* 2011: 3).

Yuan, Anumba and Parfitt (2015: 29) claim that the initial efforts to apply CPS applications in various fields such as transport, healthcare, and manufacturing given recognition to the importance of CPS in the construction industry. CPS performance and potential benefits have been explored in various fields of the construction industry, including the project delivery process (Yuan, Anumba and Parfitt, 2015: 26). Based on this research, CPS has been identified as a major strength in the construction industry, especially in solving those problems that require a dual link between the natural systems and their perceived representation.

2.3.2.2 An Overview of the Impact of Internet of Things (IoT) in the Construction Sector

One of the growing developments nowadays is the IoT. Competing industries around the world strive to maximize profits through the use of the internet and increase the level of production within the planned budget and time. IoT simply connects any "objects" via the Internet to transmit, collect and exchange data between them without any human contact. The term "Internet of Things" (IoT) was first used to describe RFID with an internet connection to improve the supply chain (Ranta, 2018: 2).

Chui, Loffler and Roberts (2010: 1) describe the Internet of Things as "sensors and actuators embedded in physical objects from roadways to pacemakers connected by wired and wireless networks, often using Internet Protocol (IP), the same that connects the Internet ".

According to Raheem and Tchantchane (2019: 53), the IoT is an innovation in communication technology. It is the nexus that electronically connects the planet with both living and non-living things, with a view towards making the process of human existence much easier (Raheem and Tchantchane, 2019: 69).

Oesterreich and Teuteberg (2016: 12), state that IoT is an integration of sensors like RFID, cloud applications, Enterprise Resource Planning (ERP) combination, and business intelligence technology. Kagermann (2015: 32-33) describes the Internet of Things (IoT) and Internet of Things (IoS) as part of the manufacturing process that sparked the 4th industrial revolution. IoT combines "objects" and "things" such as radio-frequency identification sensors (RFID) that will transmit storage information, processing, and analysis, and with smartphones and interact with intelligent components (William, 2014: 1-2).

Construction sites are regarded as the most dangerous workplaces for workers. According to Selvamalathi,(2018: 30), the death toll from the construction industry is more than double that of all sectors: construction sites are a nightmare for health and safety. Recently, safety systems in construction sites have been integrated with the use of the Internet of Things (IoT). These systems adopt various technological features such as sensors, drones, robots, laser scanning, and data analysis and management (LI, 2017: 305-306).

According to Bughin, Chui and Manyika (2015: 93), the use of the IoT technologies on construction sites, mines, and oil and gas extraction sites has enhanced the operations in monitoring the soundness of machinery and improvement of health and safety issues. The IoT is rapidly evolving into a major technology platform that can provide sustainable benefits for construction sites in terms of safety and productivity. These competitive and sustainable benefits include low cost, safer site staff, high quality production results and intelligent design processes (Manyika *et al.,* 2015: 9).

According to a report by Manyika *et al.* (2015: 7), it is estimated that by 2025, the annual global economic impact of IoT for smart worksites setting will be between US$160 billion to US$930 billion, most of which would be directed to operations optimisation, equipment maintenance, health and safety.

A large amount of potential economic value may also be due to condition-based and forecasting maintenance, which allows for significantly reduced cost in routine maintenance practices, thus reducing issues of breakdowns and increasing productivity and extending the useful life of equipment or machinery (Piron, 2018: 8).

Some examples of IoT implementation in the construction industry are the combined sensors on physical objects such as vehicles, robotics, and building components that are capable of connecting to the internet (Oesterreich and Teuteberg, 2016: 132). Machineries such as cranes, dozers and loaders that are equipped with sensors will transfer performance data via the internet to an engineer to be analysed. According to received data, engineers can predict the upcoming failures in vehicles and fix them beforehand (Oesterreich and Teuteberg, 2016: 131).

2.3.2.3 An Overview of Radio-Frequency Identification as an Element of 4IR

The RFID technology is a wireless sensor based on the detection of electromagnetic signals. (McCarthy, Nguyen, Rashid and Soroczak, 2002: 38). According to Jaselskis and El-Misalami (2003: 680), RFID is part of a network of automated diagnostic technology, which uses radio waves to capture and transmit data for successful production. RFID is a combination of radio frequency and microchip capable of working to facilitate seamless integration of any type of document, which is readable and reviewed remotely (Narayanan, Singh and Somasekharan, 2005: 271).

The standard RFID system consists of three main components: reader, tag and antenna (Ren, Sha and Hassan, 2007: 402). There is a radio signal output, which establishes the connection between the tag and the transmitter responsible for the data acquisition. The antenna is usually encased with a transceiver and decoder to be a reader. The reader can be configured as a holder or as a fixed mounting device. There is a radiation output from the reader in the form of up to 30 meters or more, depending on the output power and the radio waves used (Domdouzis, Kumar and Anumba, 2007: 350). The antenna allows the chip to transmit the identified information to the reader. The reader generates or listens to and converts radio waves from tags to digital data which can be transmitted to computers (Ren, Sha and Hassan, 2007: 402). Radio frequency identification technology involves the use of markers/tags or transponders that can collect data and manage it on a portable, flexible database within the marker/tag; communicate with route guidelines and other mechanical control requirements to machinery; and which can withstand severe environments (Jaselskis and El-Misalami, 2003: 680). Figure 6 displays a view of a simple RFID tag.

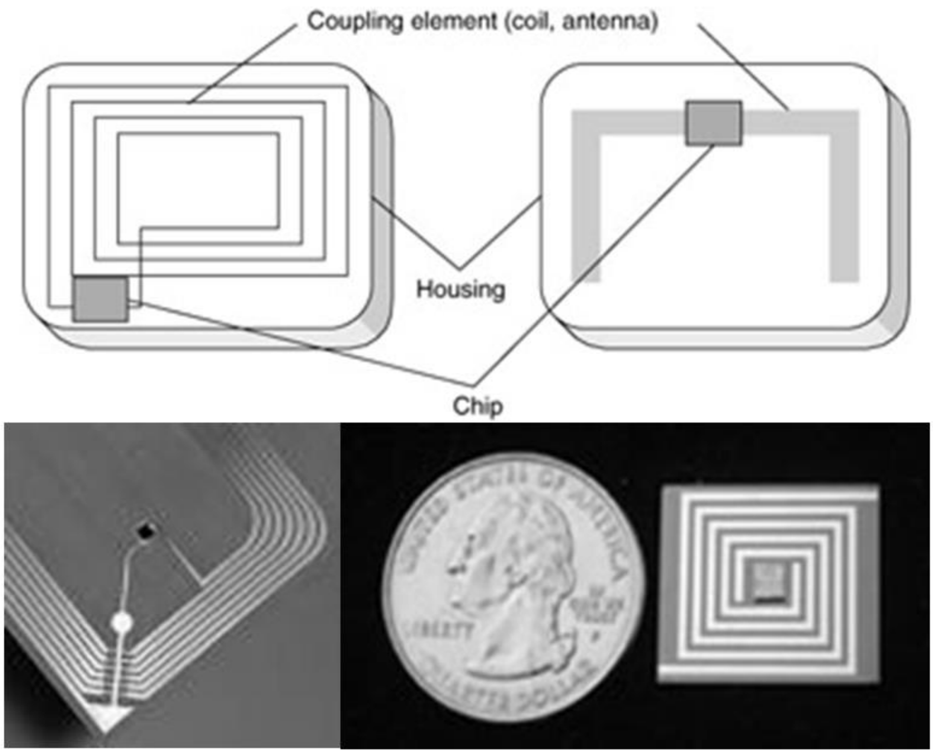

Figure 6: The Structure View of RFID Tag

Source: Wu and Li (2011: 292)

Tags can be differentiated by their energy source as passive, active, or semi-passive:

- Passive Tags: used without a separate external power source and get the performance generated by the reader (Ren, Sha and Hassan, 2007: 402). They are without a built-in power supply, so they require radio frequency energy (electromagnetic waves) from the RFID reader (Wu and Li, 2011)., Due to their lack of power supply, passive RFID and their reader systems cannot match the demand of Cyber-Physical System (CPS) utilisation. Because of their simplicity, flexibility, and durability in severe environments, passive tags have gained entry into various industries.
- Active Tags: are powered by an internal battery, used to control the microchip's electronics and to televise a signal to the reader (Ilie-Zudor, Kemeny, Egri, and Monostori, 2006: 30).
- Semi Passive tags, also called Battery Assisted Passive (BAP) tags, have a small battery to function an inside timer or random access memory. Semi Passive tags, also called Battery Assisted Passive (BAP) tags, have a small battery to function an inside timer or random access memory (Wu and Li, 2011:

292-293). They employ a battery to control memory in the tag or power the electronics that empower the tags to modulate the reflected signal. (Ilie-Zudor *et al.,* 2006: 30). However, the power supply does not actively connect with a reader until it is asked. When it is requested, it employs the radio wave power to disseminate the information to the reader, which is the same as that of a passive tag. The semi passive tag communicates in the same method as the other passive tags (Ilie-Zudor *et al.,* 2006; Wu and Li, 2011: 293).

The following table summarises each type of RFID tag:

Table 2: Classification of RFID tags

	Passive	**Active**	**Semi-Passive**	**Reference Source**
Cost	Cheaper	More expensive	Fair	(Jaselskis and El-Misalami, 2003: 681)
Read Range	4 – 5m	Over 100m about several km	Up to 100m	(Narayanan, Singh and Somasekharan, 2005: 276)
Typical RF	860 MHz – 930 MHz	433 MHz – 956 MHz	433 MHz – 864 MHz	(Domdouzis, Kumar and Anumba, 2007: 352)
Power Source	RF from reader	Internal battery	Internal battery	(Domdouzis, Kumar and Anumba, 2007: 352)
Life time	Unlimited	Up to 10years	Over 6years	(Jaselskis and El-Misalami, 2003: 680)

2.3.3 General Overview of Smart Procurement Approach within the Construction Industry

Laryea *et al.* (2014: 3) describe the acquisition of building materials as a process that involves a series of activities and steps in which customers receive specific products and services related to engineering and construction work over a specified period of time, costs and terms agreed upon. Sobhani *et al.* (2014: 250) adds that procurement in sustainable building construction has changed over the years to reduce production costs, enhance building construction quality and improve procurement efficiency.

Procurement is the process of creating, managing and fulfilling contracts relating to the supply of goods, and construction or disposal services and any combination thereof (Watermeyer, 2012: 1). According to Watermeyer (2012: 1), procurement is a main process for the delivery and maintenance of a construction project based on the needs and satisfaction of the client.

Emuze, Smallwood and Shakantu (2011: 756-757) emphasise that the overall goal of the project manager is to make product development decisions and value for money in the successful procurement phase; and meet the objectives of the project. As a result, the procurement strategy used by a project manager is likely to have a significant impact on the cost, quality, duration and sustainability of the building (Emuze, Smallwood and Shakantu, 2011).

Laryea *et al.* (2014: 3) claim that prior to the advent of electronic systems, the purchase of construction materials was often paper-based which was time-consuming and complex compared to modern purchasing operations. This is because paper-based operations not only waste time but also make one work harder, accelerating high costs linked to data management (i.e. storage, capturing, retrieval, reproduction and transfer) as well as producing unnecessary liability claims and low productivity (Laryea *et al.,* 2014: 3).

Kong *et al.* (2004: 262) describe conventional procurement as a systematic and specialized procurement process, which is a paper-based procurement process during construction. The procurement process involves the production, copying and distribution of various contractual documents such as requisition documents, quotations, purchase orders, etc.

Figure 7 shows a standard paper-based document practice of a procurement worksheet during the post-contract phase. In this technique, the site office prepares the requisition of materials needed and submits them to the procurement department (Kong, Li and Love, 2001: 45). The procurement department then develops the purchase order. The purchase order is then sent to the chosen supplier and the site office, the accounts department and the procurement department keep a record of all copies. The site office keeps delivery notes and invoices issued by the supplier when materials arrive at the site. The invoice is then compared with the purchase order by the purchasing department and after verification, passed to the accounts department for payments (Kong, Li and Love, 2001: 45).

Figure 8 details the tasks and their sequences in the normal procurement process. Once the tender document is received, the enterprise commences with pricing by sending enquiries to their selected suppliers for quotation. When quotations are received from suppliers, the enterprise will then choose a reasonable quotation and complete the tender documents (Kong, Li and Love, 2001: 44). If the contract is awarded to the contractor, the purchaser will reaffirm the supplier's original quotation received and confirm the validity of the original quote. The negotiation for a revised price will commence if needed. Once a suitable supplier has been identified, the next step in the purchasing process is to raise and issue a purchase order (PO) to the supplier, which will constitute a legal contract when the supplier accepts or acknowledges receipt of the order (Kong, Li and Love, 2001: 44). In a sense, the purchasing order becomes a binding contract to accept and pay for goods under an agreed set of terms and conditions. Purchasing orders will be tracked until materials are delivered and confirmed on site (Kong, Li and Love, 2001: 44).

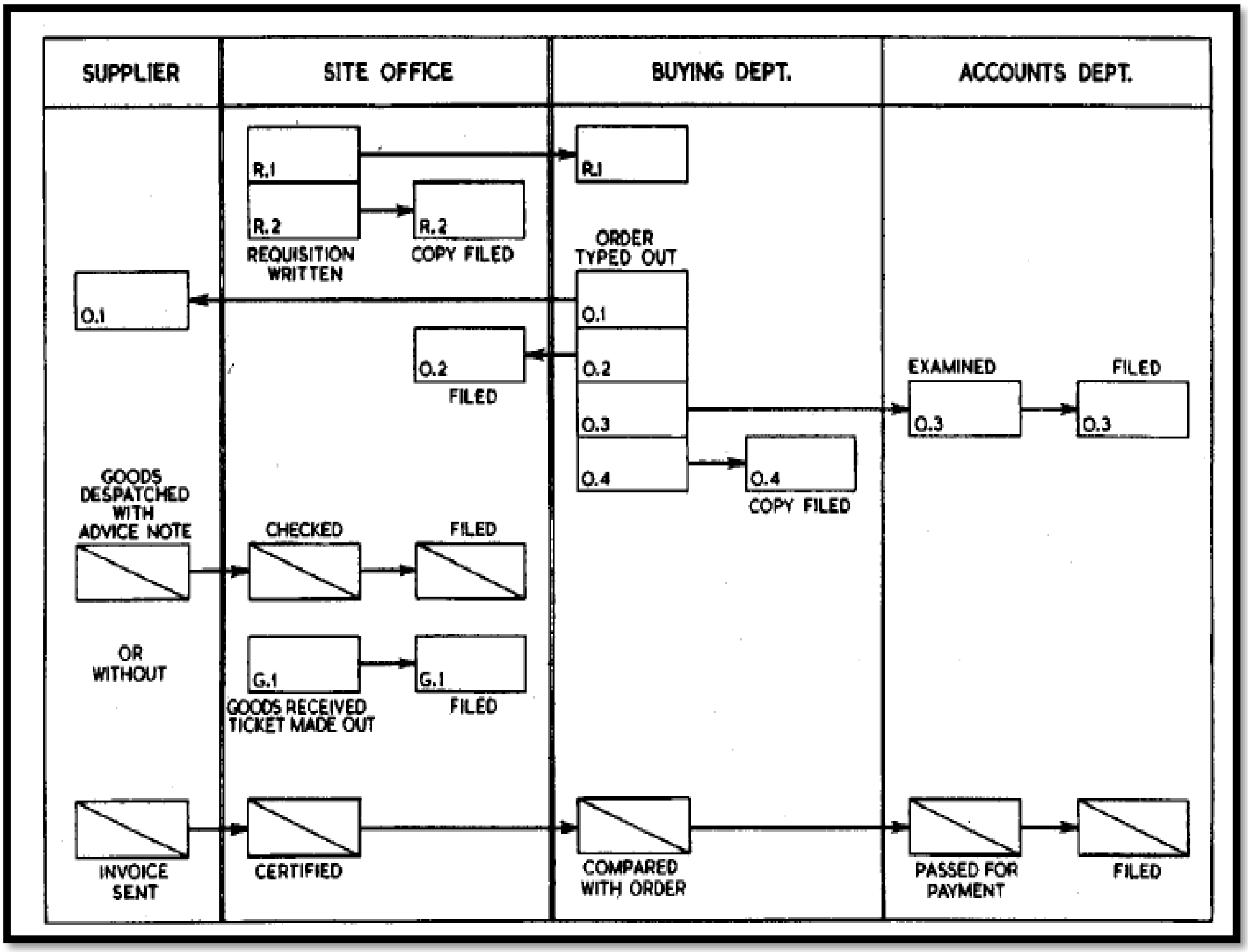

Figure 7: Typical Paper Work Cycle in Traditional Materials Procurement

Source: Kong, Li and Love (2001: 45)

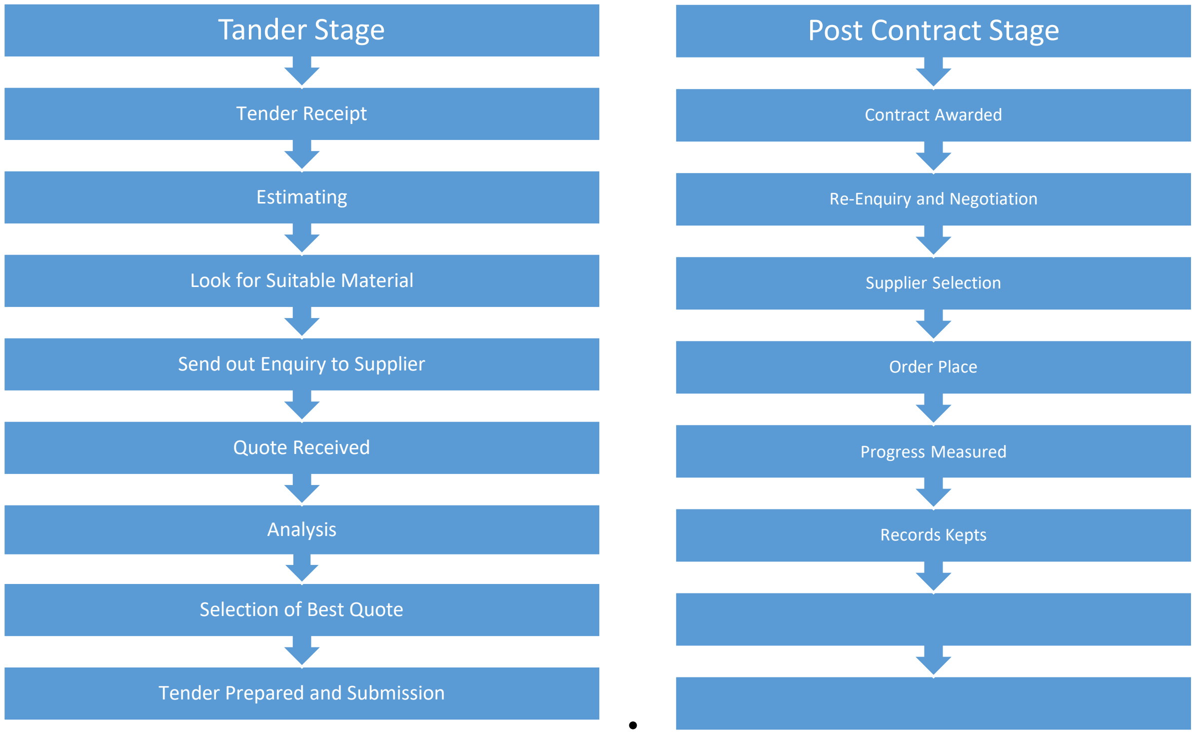

Figure 8: Typical Traditional Materials Procurement Process

Source: Kong, Li and Love (2001: 44)

2.3.3.1 An Overview of E-procurement for Construction Materials and Process

According to Bauasa, Kourtidis, Liljemo, Loozen, Rodrigues, and Snaprud (2014: 5), E-procurement is the process of using ICT, which promotes transactional processes to procure goods and tenders for construction activities. In recent years, electronic procurement has been used as a cost-cutting measure, as it allows for volume purchases, enables a wider choice of buyers and suppliers, delivers better quality, improves delivery, lessens the need of paperwork and reduces administrative costs (Swamy, Nanjundeswaraswamy, Rashmi, and Nalini, 2014: 32).

The use of digital technologies (DTs) as electronic tools for operating business transactions, which includes manufacturing and marketing of outputs and purchase of goods and services, is now broadly endorsed, and this process has advanced significantly in various modern sectors in the past forty years (Ibem and Laryea, 2014: 113-114).

Ibem and Laryea (2014: 11) state that the construction industry tends to be somehow slow in adopting DTs, when compared to other sectors such as manufacturing, banking and automation. Anumba and Ruikar (2002: 265), note that the use of electronic means to reinforce the implementation of construction projects acknowledges the need to better develop the traditional business process in construction and to increase its productivity and competitiveness. The current implementation shows that existing electronic procurement systems help to address paper-based related techniques such as scanning, storage, processing, and effective retrieval of data (Anumba and Ruikar, 2002: 267).

In this modern day, according to Nawari (2012: 107), there are a number of electronic programs and applications used to support the purchase of construction materials. This consists of web-enabled software packages such as BIM technology applied in the production of building drawings to provide detailed specifications and bill of quantities (BOQ) (Nawari, 2012: 107). However, there are also network technologies such as electronic data interchange (EDI), which is used to create automated connections between consumers and suppliers to transfer orders, receipts and electronic payments (Kong, Li and Love, 2001: 46). Thus, the electronic data interexchange (EDI) such as-email, wireless technologies, electronic marketplace and web 2.0 are significant for the exchange of project data and information (Laryea and Ibem, 2014: 111). E-procurement gives an equal win-win situation for both consumers and suppliers, as they can both benefit from the data and information exchange, customer contacts and knowledge management.

The e-procurement approach will save a lot of time and money, increase customer satisfaction and improve internal and external communication and collaboration (Klinc, Dolenc and Turk, 2008: online). In addition, Luzzini *et al.* (2015: 22) claim that the adoption of e-procurement for building materials procurement activities would improve the communication process between project participants. Electronic procurement has the potential to promote accurate, efficient and timely exchange of information between various procurement participants and stakeholders in the construction industry (Luzzini *et al.,* 2015: 22). The ripple effect towards the adoption of the electronic procurement system reflects in better management of materials information over time during construction phases.

2.3.4 Perspective of Smart Supply Chain in the Construction Industry

Benton and McHenry (2010: 130-131) define Supply Chain Management (SCM) as a system for continuously integrating a variety of business functions and processes across a range of value-added customer needs, with the aim of improving performance. According to Benton and McHenry (2010: 138-139), the Construction Supply Chain Management (CSCM) is a key management tool to manage the flow of business information, tasks, activities, and processes involving various networks of private organizations and communications. It produces an improved value that is delivered to customers in the form of a completed project (Benton and McHenry, 2010: 142-143).

The construction sector has a flexible and uncontrollable environment, where tracking and accessing information related to components/materials, plant and equipment can be a major challenge (Ergen and Akinci, 2007: 1). Thus, traditional methods of managing materials and equipment require more workers in terms of data collection methods for construction processes and their components (Ergen, Akinci and Sacks, 2007: 361). Many of the current field processes on construction sites still rely on manual processes for asset tracking and information management (Jang and Skibniewski, 2009: 221). Thus, construction data collected using manual methods often has errors and is unreliable or has incomplete results due to its dependence on motivation and human skills (workers in general) (Ergen, Akinci and Sacks, 2007: 357).

According to Ergen, Akinci and Sacks (2007: 357), data collected by traditional methods is often transmitted and stored in a paper-based format, difficult to locate and access at a glance, and which makes the processing of useful information expensive and unreliable. Therefore, part of the information ends up being not readily available to the people involved, who need to access the information in time to make effective decisions.

Thus, failure to successfully track building materials and information related to machinery and equipment during planning and construction work may result in project delays and increased labour costs (Ergen and Akinci, 2007: 1; Sardroud, 2012: 381-382). Therefore, successful supply chain management is essential for effective competition in today's global markets (Papadopoulos, Zamer, Gayialis and Tatsiopoulos, 2016: 529). In addition, the advent of advanced information technology and sensor solutions has created an understanding of some shortcomings of the manual process (Grau, Caldas, Haas, Goodrum and Gong, 2009: 905). Papadopoulos *et al.* (2016: 533), state that one of the best ways to improve CSCM is to adopt and use information technology (IT). This approach will improve the supply chain operation, assist the supply chain performance, and enable supply chain integration. In a combined construction supply chain, information is shared and made available to members and thus improving the visibility of the supply chain, which avoids information delays and distortions (Liu and Chua, 2016: 11). The flow of information in current building settings may not work properly because most of the information goes through an inefficient and unorganised system (Liu and Chua, 2016: 11). According to Araszkiewicz and Tryfon-Bojarska (2017: 37), the use of digital tools could greatly enhance the preparation and execution of building projects. Therefore, digitalisation is much needed to improve the flow of information, regarded as the lifeblood of the construction supply chain (Liu and Chua, 2016: 11).

The construction sites are very vigorous as building materials, which could arrive daily, are staged in different locations and their locations might change several times before being placed in their final locations within the facility (Ergen and Akinci, 2007: 1). Unlike factory industries, construction sites have unregulated areas, where pieces of equipment do not follow prearranged routes when moving or do not operate in a predetermined manner (Ergen and Akinci, 2007: 1). In addition, construction production takes place in the open, in difficult conditions such as rain and dust. In such volatile and harsh situations, it is clear that the current manual and paper-based method of tracking construction materials and components would be ineffective and would not work well in the 21st century business environment (Ergen and Akinci, 2007: 1). Thus, there is an imperative need for an automation resource tracking system in a construction production site that has the potential to work well in dynamic and challenging environments as seen in the construction industry (Ergen and Akinci, 2007: 1) However, one of the challenges in the construction industry is that there are many odd components that need to be tracked differently, which requires management strategies and methods of installation. The person in charge of the building materials/components on the site often searches paperwork for important handling and installation instructions. This results in time-wasting manual search methods to find related building materials/component information. Therefore, a variety of automated diagnostic technologies, such as barcodes, dual barcodes, RFID, visual character recognition, and contact memories are the best options for tracking resources and information related to construction planning, monitoring, control and maintenance (Wang, Love, Kim, Park, Sing and Hou, 2013: 40-43).

RFID is an alluring technology that addresses the challenges associated with tracking resources on construction sites. Radio Frequency Identification (RFID) technology has been widely used in various fields such as marketing, e-commerce, asset management and supply chain management, scientific research, security, etc., (Lu, Huang and Li, 2011: 101). According to Jaselskis and El-Misalami (2003: 680), the utilisation of RFID technology in the construction industry can enhance the operation of a construction project.

2.3.5 An Overview of Building Information Model in the Planning and Procurement of a Construction Project

According to Ren, Sha and Hassan (2007: 401), the dynamics of the construction industry in terms of its planning and operation and resource management within the construction site are critical to project development in terms of both time and cost-effectiveness. Timely and efficient waste disposal in construction production would have a significant impact on the competitiveness of the construction industry through Building Information Modelling (Saieg, Sotelino, Nascimento, and Caiado, 2018: 799). Building Information Modelling (BIM) is one of the most widely used tools in modern building projects (Eastman, Teicholz, Sacks and Liston, 2011: 289).

BIM is the latest generation of Object Oriented Computer Aided Design (OOCAD) that contains all the information about the elements that make up a building (Howell and Batcheler, 2005: 2). In theory, BIM bestows a single, consistent, logical source of all information related to the building (Howell and Batcheler, 2005: 2).

BIM provides the proficiency to monitor actual time construction progress, transfer retrieved data and compare it with database information. This BIM method monitors construction progress and makes future decisions in advance, based on project history information (Oskouie, Gerber, Alves and Becerik-Gerber, 2012: 113). BIM simplifies easy selection and facilitates access to facility manager's information during operation and maintenance (Meadati, Irizarry and Akhnoukh, 2010: 570). Building Information Modeling addresses the integration and challenges of managing information effectively throughout the institutional life cycle (Meadati, Irizarry and Akhnoukh, 2010: 571). Accessing information utilizing BIM is a two-step process. The first step is to choose the structure and the second step involves retrieving the corresponding object information from the virtual model. Currently, the first step is done manually (Meadati, Irizarry and Akhnoukh, 2010: 571). The second step comprises transferring and translating the updated data into a BIM model, that is powered by cloud computing and a global data sharing system to speed up data flow within a building project (Jardim-Goncalves and Grilo, 2010: 397).

The use of BIM in planning and acquiring a construction project will benefit all stages of the institution life cycle. Some benefits of BIM in different stages of the institutional life cycle are shown in Table 3 (Meadati, Irizarry and Akhnoukh, 2010: 572).

Table 3: Benefits of using BIM

Life cycle phase	**Benefits of BIM implementation in Construction**
Planning	• Provides some easy and fast analysis • Assists in power analysis modelling • Provides easy value and cost estimates • Facilitates details development
Design	• Improves collaboration • Provides easy data exchange • Provides automatic checking of codes • Facilitates tracking of design changes
Construction	• Reduces explanation problems • Enhances coordination among different trades • Lowers Request for Information (RFI) • Material waste are reduced • Reduces buildability issues • Facilitates proper tool selection • Gives more safe work environment
Operation and Maintenance	• Lower down time • Facilitate easy access to maintenance records, warranties, installation and operation manuals • Lowers rework and wastage • Resolves space management issues • Assist emergency evacuation planning

Source: Meadati, Irizarry and Akhnoukh (2010: 572)

2.3.6 Understanding the Concept of Construction 3D Printing: Emerging Construction Technologies

According to Tay, Panda, Paul, Noor-Mohamed, Tan and Leong (2017: 261), three-dimensional (3D) printing, also known as complementary production, is an advanced production process that can automatically generate complex geometric shapes from a computer-based 3D model without any tooling. It dies and fixtures. 3D printing in the construction industry is still in its inception (Wu, Wang and Wang, 2016: 2). According to Attaran (2017: 2), the name “additive manufacturing” refers to the technology or process of adding layers of material over one another, producing a final three-dimensional product.

The first 3D printer was introduced in 1984 and, in recent decades, 3D printing has become one of the fastest growing technologies. Initially, 3D technology was expensive and unaffordable in the entire global market (Attaran, 2017: 1). Over the years, however, 3D printing has developed rapidly and has become widely adopted in the manufacturing sector for decades. Thus, 3D technological aspects have been progressively introduced into the construction industry (Wu, Wang and Wang, 2016: 21). Many breakthroughs have been achieved in the medical, automotive, and aerospace industries. Thanks to open source programs, prototyping for innovative products as well as new 3D printing programs in different fields is available to everyone (Hager, Golonka and Putanowicz, 2016: 293). According to Hager, Golonka and Putanowicz (2016) the development of printing materials and 3D technology has become the goal of certain construction companies in various sectors around the world. Hager, Golonka and Putanowicz (2016: 293), went on to say that the real change in the construction industry began in 2014, with the printing of the first house: this brought a new passage in building technology worldwide.

The 3D manufacturing process has a significant competitive edge over the conventional production method of construction, especially if there are more complex pieces to be produced in smaller batches (Henke and Treml, 2013: 139). According to Henke and Treml (2013: 139), 3D manufacturing promises to be more suitable for construction production applications where it can be used in form design to improve structures or tailor-make building envelopes. Novakova-Marcincinova and Kuric (2012: 24), pointed out that the rapid prototyping of the physical component, known as solid free-form production, desktop production or layer production technology, represents a new phase in the prototyping of building construction.

Rapid prototyping (RP) is a new manufacturing system that can help customers to construct physical form layer-by layer from computer-aid design (CAD) data within a short period of time (Vaezi and Chua, 2011: 275). 3D printers utilise supplementary production systems and a variety of technologies to construct layers that create the final object. Soluble or softening materials are used to produce layers (Attaran, 2017: 2). 3D technology can bring significant benefits to the construction industry, in terms of increasing customization, cutting down construction time, reducing labour and building costs (Wu, Wang and Wang, 2016: 1).

2.3.7 An Overview of the Concept of Robotics Techniques in Construction Processes

Automation is defined as a motorized process executed by using programmable machines to perform a series of activities (Rajgor, 2013: 79). According to Pan *et al.* (2018: 3), there are no internationally accepted definitions of the terms “construction automation” and “construction robots”. Construction automation refers to the engineering or operation of any construction process, on-site or off-site, using telephone equipment and computation controls. Construction robots refer to advanced building equipment that demonstrate any level of skill related to telecommunications, sensor data collection and processing, computation control, or independent operation (Pan *et al.* 2018: 3). The idea of robots was first introduced in the production of components of industrialized buildings and modular houses. Later, autonomous robots were developed to carry out special construction activities on site (Bock, 2007: 1).

Construction automation and robotic efforts were launched around 1980 in the International Symposium on Automation, Control and Robotics (ISACR) and the International Association for Automation and Robotics in Construction (IAARC), promising major advances in technological advances in the 21st century (Hasegawa, 2006: 565). Robots in the construction industry are a new and rapidly growing field that integrates different fields (Balaguer and Abderrahim, 2008: 2-5). Applications and robotic tasks and automation in the construction industry began in the early 1990's, aimed at improving the performance of construction equipment, enhancing safety, heightening the vision of the workplace and ensuring a quality environment for occupants (Elattar, 2008: 21).

According to Momin, Patil and Nale (2015: 978), the construction industry requires a lot of labour and is done in hazardous conditions and, therefore, the importance of construction robots has grown exponentially. Modern construction projects are characterized by shorter design and construction times, growing quality requirements and lower cost. These problems can be automatically brought to the forefront using a computer-based robot that assists in planning, engineering and managing the construction of infrastructure projects. Particularly in countries with high operating costs, automated construction technology and robots can compensate for the growing demand for construction projects (Yaghoubi, 2013: 19). These automations and robotics are presented in Figure 9 and Figure 10.

2.3.7.1 Concept of Robotics and Automation on Construction Concrete Works

Applications for automation in concrete construction projects include placing concrete on the post-laying level, surface water removal, and final floor finishing (Elattar, 2008: 22). These robots were designed mainly for floor concrete work and they are used in many building construction sites by many general contractors and workers released from manual operations (Hasegawa, 2006: 565).

Figure 9: Concrete Horizontal Distributor

Source: Elattar (2008: 23)

Figure 10: Concrete Floor Finishing Robot

Source: Elattar (2008: 23)

2.3.7.2 Understanding the Competitive Edge of the Automotive Approach to Road Construction Infrastructure

Automation is very important because of the simplicity associated with it, it ability to do duplication, given the large amount of work involved in road construction (Deb, 2013: 44; Momin, Patil and Nale, 2015: 978). Thus, the introduction of robotic machinery in road construction infrastructure would result in better operation and health conditions, as well as reduced maintenance duration that would enhance the cost-benefit analysis of the construction project (Deb, 2013: 45). In addition to any solid financial benefits, the expected benefit of automated road construction equipment is to improve the safety and health of construction sites. In some cases, workers will be completely removed from the work loop so that they are protected from a working machine or other vehicle. In other cases, health risks associated with employees' exposure to cancer-causing agents may be reduced (Deb, 2013: 45; Momin, Patil and Nale, 2015: 979).

In the field of road construction, a number of projects have been launched over the past decade which focus on the development of a new generation of semi-autonomous road pavers and asphalt compactors (Balaguer, 2004: 2). According to Peyret *et al.* (2000: 448), the European Union (EU) Computer Integrated Road Construction (CIRC) projects adopted several machines including a project sensor-based compactor (see Figure 11) to improve productivity so as to achieve project objectives. The project sensor-based compactor is the new generation of semi-autonomous road pavers and asphalt compactors (Rajgor, 2013: 80).The effectiveness and efficiency of the CIRC lies in its Global Positioning System (GPS) and laser data, semi-autonomous guidance and quality control of pavers and roller systems in the form of speed control, temperature, layer thickness, travel distance, etc.

Figure 11: Project Sensor Based Compactor

Source: Deb (2013: 45)

2.3.8 Concept of Virtual Reality (VR) for a Construction Project

Messner *et al.* (2003: 2), describe virtual reality (VR) as an experience in which a person is "surrounded by a three-dimensional computer image, and is able to navigate the visible world and, see, access, capture and recreate images at different angles". Virtual Reality (VR) or immersive environment can provide enriching information to users by mimicking real world locations especially in building protocols (Froehlich and Azhar, 2016). VR has achieved more popularity in the gaming market, utilizing VR headsets, and army training, which gave it one of the first rooted VR apps. For example, soldiers can train infantry in urban combat tactics by transporting them to a virtual city full of computer enemies and friendly soldiers. Training in the virtual world is a good balance between the usual options for classroom-based training and physical-world training exercises. VR training offers an unparalleled level of reality in the classroom, as well as high flexibility and reduced costs compared to real-world workouts. Recently, the accomplishment of VR military training has led to the adoption of VR technology in other forms of training, especially in the medical field (Bowman and McMahan, 2007: 37).

According to Bouchlaghem and Liyanage (1996: 1), VR has gradually spread in the construction industry. There is a significant potential for virtual reality in construction, which includes design analysis and co-ordination (Mandeville *et al.,* 1995: 8); as well as construction integration and construction scheduling processes (Heesom and Mahdjoubi, 2002: 3).

Sonu Wasu (2019: online) stated that the production of construction drawings with multiple pages would soon be out of date. The Quick Response (QR) codes are now used in some construction production processes through a set up scan device machine that utilises a smart phone. Virtual reality gives a completely new perspective to the finished project in 3D while it is still under construction. This means one is able to see the complete building while it is still under construction. Hence the errors are detected in time. This is a lot more efficient and has been done to deliver projects on time and under budget (Sonu Wasu, 2019: online).

Virtual Reality provides has the potential to enhance construction site tasks and greatly assist in the construction planning phase. In addition, virtual reality has the capacity to enhance the scheduling usage of site space, logistics and initial layout prior to project work commencement (Heesom and Mahdjoubi, 2002: 31), Thus, with VR, the issues of conflicts between material positions can be detected and resolved seamlessly with regard to the project schedule (Heesom and Mahdjoubi, 2002: 41).

3 CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes the research methodology used in this study. It presents and discusses the overview of the research process, data collection methods, and questionnaire design and data analysis strategies.

3.2 Research Outline

This research is made up of five main chapters, as seen in Figure 12. Chapter 1 is the introduction, which consists of the problem setting, research problem formulation, research problem statement, research hypothesis, research aim and objectives, research questions, scope of research, importance of the study and research area. Chapter 2 is a literature review, which provides an historic background to 4IR, the concept of the 4IR and applications and techniques within the construction sector. Chapter 3 t outlines the structure of research in an effort to highlight the methods and techniques taken by the researcher to achieve the objectives. Chapter 4 presents data, and discusses the findings in relation to literature and the methodology adopted. Chapter 5 concludes by summarising the research results and makes recommendations for future research work.

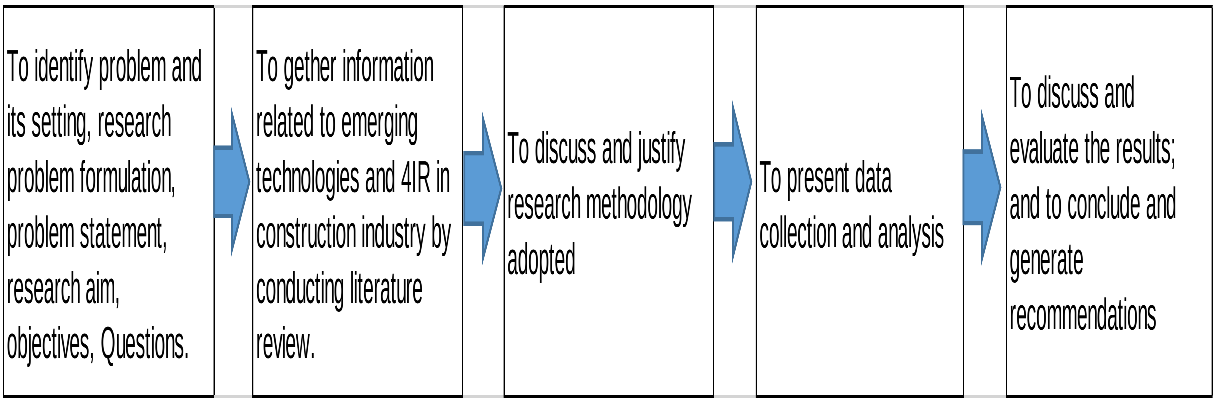

Figure 12: Research Procedure Outline

3.3 Brief Concept of Research Methodology

Leedy and Ormrod (2005: 2), define research as a process in which information is collected, analysed, and interpreted in a systematical way in order to better understand events that intrigue a researcher with proven facts. Research is a process of inquiring and investigating literature in a systematic and methodological manner (Leedy and Ormrod, 2005: 2).

Kinash (2008: 3), states that research methods are the techniques and principles used to conduct scientific research. The body of knowledge that uses these methods is called the methodology. Research methods are part of a process used to collect and analyse data systematically, while new knowledge is being developed. Creswell and Clark (2007: 5) claim that the choice of research methodology and approaches in discipline management and social science is influenced by the researcher's views on the state of the social world, the complexity of the research, and his or her knowledge of the subject. However, in the area of advanced research, the two main types of methods in research are qualitative and quantitative methods. A combination of these two methods in one study is called “mixed research method”(Creswell and Clark, 2007: 5).

3.4 Research Design/ Strategies

The research design encompasses the entire set of considerations, from the application of specific research methods to the storage and analysis of data (Cassim, 2014: 53). The purpose of the research and the research questions are the basics used in developing the research design because they provide important indications about the problem the researcher intends to explore (Wahyuni, 2012: 72). The research design gives the researcher the ability to choose a research method that is relevant to the type of research required by a particular study (Schensul, 2008: 516). However, Leedy and Ormrod (2013: 74), also explain that the design of the study provides a possible solution to the identified research problem by providing the researcher with a clear strategy. The problem identified in this study (refer section 1.3) is that: “The construction industry is resistant to ICT changes, yet the fourth industrial revolution is developing rapidly? This situation creates both a disruptive atmosphere of uncertainty and a window of opportunity for South African construction organisations to adopt and implement ICT technologies in design, procurement, and construction delivery as well as the operation and maintenance of built environment infrastructure projects. The research design describes the data gathering and analysis/treatment of data to answer the research questions asked, which will then provide a clear framework for conducting research (Dainty, 2008: 3). Hughes (2008: 196) adds that the value of any research method will be assessed and verified in accordance with its validity in the case of the questions being asked and the sensitivity of the methods should be in line with the research question.

3.5 Research Method

In order to achieve the research objectives outlined in Chapter 1, it is important to explore possible ways of achieving these goals. There are two different types of research methods, namely: quantitative and qualitative research methods.

3.5.1.1 Quantitative research method

The quantitative or direct approach to research is based on a philosophical paradigm known as logical positivism (Welman, Kruger and Mitchell, 2005: 6). The quantitative method analyses data with features that can be measured more or less accurately (Walliman, 2004: 139). According to Welman, Kruger and Mitchell (2005: 8), the quantitative method comes down to measurements or a certain type of magnitude that is usually expressed in numbers and ranges from very simple mathematical processes such as percentages to sophisticated or complex statistical tests or mathematical models. Roberts and Priest (2006: 42), posit that quantitative research is the study of numbers primarily using numerical methods. Henn, Weinstein and Foard (2009: 16), explain that quantitative methods are often related to theory and seek to collect factual data and study the relationship between facts and how the facts and relationships relate to the ideas and findings of any study (or literature) previously done.

According to Hancock and Algozzine (2016: 7), when the time and resources are limited, a quantitative method may be more appropriate.

Based on the above definitions, a quantitative approach was deemed relevant to this study in order to answer the research questions and affirm or disprove the research hypothesis.

3.5.1.2 Qualitative research method

Qualitative data cannot be measured and calculated accurately and it is usually expressed in words rather than in numbers (Walliman, 2004: 141). The qualitative method uses research instruments such as individual interviews, focus groups, reviews, reviews of existing documents, or a number of these. While these may lead to a wealth of rich information, more time and resources are needed to represent the study environment (Hancock and Algozzine, 2016: 7).

Qualitative study cannot be associated with the concept of translation in social research but rather aims to understand human behaviour (Henn, Weinstein and Foard, 2009: 17). Qualitative study often uses test methods and generates text data rather than numbers or ratings (Roberts and Priest, 2006: 42).

3.5.1.3 Research method adopted for this research and its justification

Based on the explanations above in relation to quantitative and qualitative research methods, the quantitative method was seen as appropriate for this research.

The nature of the research problem, namely “the reluctance of the construction industry to adopt and implement ICTs, and the fourth industrial revolution in general requires a quantitative research approach because study sought to assess and quantify the actual depth of utilisation and impact of the Fourth Industrial Revolution and emerging ICT technologies among construction companies in Durban with specific focus on how the companies can utilise ICTs in project design, procurement, construction, delivery, operation and maintenance. Thus, adopting of quantitative research method enabled the researcher to use statistical tools such as Statistical Package for the Social Sciences (SPSS) to quantify data and assess some of the construction organisations' levels of awareness and understanding of concept of the Fourth Industrial Revolution and emerging ICTs. The package also helped the researcher to assess perceptions on an actual benefits of implementing emerging ICTs and the 4th industrial revolution as well as ascertain the companies' level of readiness to take advantage of the 4th industrial revolution in their project design, procurement and construction in relation to a project cost, time, quality and environmental safety.

Quantitative design was deemed most appropriate for answering the research questions and resolving the research problem of this study. Thus, the study adopted a cross-sectional and survey-based method. The research used a survey/ questionnaire research design, which is quantitative in nature, as a data collection tool. A questionnaire survey tends to be systematic, making it easier to measure and analyse construction firms' responses in relation to elements of the 4th industrial revolution (Wagner, Kawulich and Garner, 2012: 1).

3.6 Research Paradigm

The word "paradigm" can be used to describe an approach or design. The research adopts a positivist paradigm. Positivists often utilise experimental, quantitative methods that allow for the testing of hypotheses. The paradigm ensures competency through a rigorous specification process, definition as well as application of pilot experiments. The research study follows a logical positivist paradigm that has no context to match the requirements of logical empirical inference (Wagner, Kawulich & Garner, 2012: 52). As stated by Wagner, Kawulich and Garner (2012: 53), positivism argues that there is no other way to find truth and honesty of purpose than the scientific method.

In conducting any research, it is important to make sure that the data-gathering instruments measure what is supposed to be measured and measured in a consistent manner. In any of incomplete data and wrong data, a data clearing method will be utilised in to compensate for the misplaced data. Since this study is quantitative, reliability and validity of the data-gathering instruments ensured data quality (Struwig, Struwig and Stead, 2001: 130). Statistical analysis was utilised to analyse the gathered data. Descriptive and inferential statistical instruments used in for statistical analysis and analysis included percentages, mean scores, and standard deviations, using the 27.0 Statistical Package for Social Sciences (SPSS) version.

3.7 The Data: Primary and Secondary data

Primary data can be gathered by observation, personal interview, telephone interview, submission of questionnaire through emails and other methods (Harrell and Bradley, 2009: 10). In this study, primary data was gathered using survey questionnaires.The data gathering instrument comprised an online survey using Google form-online based questionnaires as well as normal paper-based questionnaires through mail and hand delivery, whilst secondary data are sourced from literature, books and academic journals.

3.7.1 Data Collection Techniques

According to Chaleunvong (2009: 3), data gathering techniques allow the researcher to systematically gather knowledge about his or her study material (people, objects, events), and the settings in which it occurs. In data collection, the researchers should be organised. If data is collected randomly, it will be difficult to answer the research questions in a comprehensive way (Chaleunvong, 2009: 3).

The researcher administered research questionnaires through an online survey using the Google form-online based approach as well as normal paper-based questionnaires through mail and hand delivery. The questionnaire was distributed among Durban construction contractors in grades 4 to 9 (as respondents) on the Construction Industry Development Board (CIDB) Register of Contractors (RoC), within civil and general building in the eThekwini region (See Table 4).

The responses were recorded as yes or no, as well as on a Likert-type 5-point scale, in which 1 represents total disagreement and 5 total agreement, and reliability and validity issues were also assessed.

$$MIS = \frac{1n1 + 2n2 + 3n3 + 4n4 + 5n5}{\sum N}$$

Where;

n1 = number of respondents for strongly disagree

n2 = number of respondents for disagree

n3 = number of respondents for neutral

n4 = number of respondents for agree

n5 = number of respondents for strongly agree

N = Total number of respondents

3.7.2 Justification of Chosen Research Population and its Sampling Techniques

The target population for this study comprised construction contractors in grades 4 to 9 on the Construction Industry Development Board (CIDB) Register of Contractors (RoC), within civil engineering and general building in Durban, eThekwini region. According to Churchill and Lewis (1983: 22), the five stages for business growth and competitiveness can be summed up in a systematic way as follows:

(i) presence;
(ii) endurance;
(iii) achievement;
(iv) development/progression; and
(v) re-establishment or decline stages.

Scott and Bruce (1987: 78), claim that the extent of an enterprise (contractor) can be measured by the combination of internal and external aspects, related to its strengths; such as sales, service delivery, total goods, and number of employees, crop status, management capacity, and industrial structure and technological changes.

- However, the size of the company is not treated unconditionally, but as something different for each business. It is a concept that is important here. Based on the purpose of the study and the South African context, the study classifies contractors according to the CIDB categories (see Table 4) for the five levels of business growth, as follows:
- Level I- stage 1;
- Level II- stage 2-3;
- Level III- stage 4-5,
- Level IV- stage 6-7; and
- Level V- stage 8- 9 contractors.

The researcher conducted a comparative study to assess the entrepreneurial spirit levels and innovativeness of construction companies in terms of adopting new changes such as emerging technologies in the business environment. According to Cadden and Lueder, (2012: 3) and Churchill and Lewis (1983: 34), organisations (contractors) in stage III (Achievement) have shown themselves to be economically healthy, competitive and successful in the market, whilst organisations/contractors in stage IV (Development/Progression) are highly competitive and economically sustainable, with an increasingly complex business structure and organisations/contractors in stage V (Re-establishment/Decline Stages) have appeared to be very competitive and economically viable in the long run and achieved a high level of competitiveness.

Churchill and Lewis (1983:6) claim that any organization/stage V contractor who does not have the creativity and entrepreneurship in making business decisions to adapt to new changes will ossify (the inability of the business to continue to grow in the market). For this reason, radical change in the environment (such as aspects of the fourth industrial revolution) could cause some of the large organizations to strive for greater competitiveness and greater profits if they ignore innovation changes (Churchill and Lewis, 1983: 6). Furthermore, McCabe (2010: 76) confirms that contractors at any stage of business development must constantly strive to achieve and improve their competitiveness and economic viability through flexibility and innovativeness in embracing change in the business environment.

Table 4: The Durban CIDB Register of Contractors

Contractors Grading Designation	Maximum Tender Value (R)	Total Contractor (Active - Currently in Durban)	Proportion (%)	Size
1	R200 000.00	7141	89.34	Small
2	R500 000 to R1000 000	404	5.05	Small
3	R1000 000 to R3000 000	198	2.48	Small
4	R3000 000 to R6000 000	102	1.28	Medium
5	R6000 000 to R10 000 000	53	0.66	Medium
6	R10 000 000 to R20 000 000	39	0.49	Medium
7	R20 000 000 to R60 000 000	33	0.41	Large
8	R60 000 000 to R200 000 000	20	0.25	Large
9	R200 000 000 to No limit	3	0.04	Large
Grand Total		**8118**	**100.00**	
Overall Sample size for this study				
1	Medium	131	73	Medium
2	Large	49	27	Large
Grand Total		**180**	**100**	

Source: CIDB (2020: Online)

Grade 1-3= small contractors; Grade 4-6= medium contractors & 7-9= Large contractors.

3.7.2.1 Sampling size

During the proposal stage, the estimated population was 194 (medium contractors) and 56 (large contractors), as per CIDB provision (see Table 4). According to Israel (1992: 2), there are a variety of methods that can be determined by sample size and these include: utilising a small population census, simulation of the sample size of similar previous studies, use of published tables, use of formulas, among other methods. Israel (1992) also pointed out that the size of the sample is influenced by the purpose of the study, the size of the population, the cost and the time needed (Israel, 1992: 2).

Based on the estimated population provided by the Construction Industry Development Board (CIDB), which is 194 (medium contractors) and 56 (large contractors), the researcher used Slovin's formula with a margin of error of ±5%, and the confidence level of 95%. The calculated sample size was as follows:

$$n = \frac{N}{1 + N(e^2)}$$

Where n = sample size, N = number of target population, e^2 = error of margin.

According to the CIDB register of contractors' site, there are 194 contractors listed under CIDB level 4 to 6 for GB and CE classes.

Based on the above formula, therefore, the population is:

$$n = \frac{194}{1 + 194(0.05^2)}$$

$$n = 130.6$$

Say = 131 contractors (Sample size of medium contractors)

According to the CIDB register of contractors' site, there are 56 contractors listed under CIDB level 7 to 9 for GB and CE classes

n=	56
	1 + 56(0.05²)
	n = 49.1

Say = 49 contractors (Sample size of large contractors)

The research questionnaire was distributed randomly among selected research respondents (grade 4-9 contractors), based on the sample size through two main strategies, namely: online (survey monkey), emailing and when necessary, direct drop-offs.

3.7.2.2 Sampling techniques

The sampling technique used for this research was the probability random sampling method. Sampling probability is a gold standard in the sampling process and ensures the fulfilment of the targeted population in research results (Acharya, Prakash, Saxena and Nigam, 2013: 330). In probability sampling, each human being in the population has an equal-opportunity of being chosen for the study(Miller, 2003: 268). The advantages of this method are that less population knowledge is required, internal and external validity is higher and it is easier to analyse the data (Acharya *et al.,* 2013: 331).

3.7.3 Validity and reliability of the research Data be consistent with upper and lower case. Choose one and stick to it!

Validity defines the degree to which an instrument accurately measures a concept it alleges to measure (Roberts and Priest, 2006; Washington, 2010: 99). Reliability, on the other hand, can be defined as the similarity or the extent to which the research tool measures a given variable consistently (Yilmaz, 2013: 317). A scale or experiment is declared to be reliable if repeated measurements made by it under constant situations will give the same result (Taherdoost, 2016: 33). To ensure validity or trustworthiness, the participants in the survey must all be entities that have been involved in the overall project delivery in terms of project design, procurement, construction, delivery, operation and maintenance. The result of this will be to ensure that the research is not only reliable but also effective on the basis of accuracy and precision According to Taherdoost (2016: 33), reliability testing is vital as it refers to the consistency across the components of a measuring tool. Thus, the tool used should therefore be able to produce the same results whenever it is used later, which means that the findings of the study should be the same when another researcher seeks to analyse the findings from the same study. Cronbach's alpha was adopted to measure the reliability of this data collection instrument. Cronbach's alpha serves as a tool for measuring the reliability of the scale using internal consistency.

3.7.4 Data Analysis Techniques

Statistical instruments used for data setting and analysis include mean score, standard deviation, ranking each question and Chi-square goodness-of-fit-test. Chi-square tests were used in the segment variance to assess whether there were any of the response options chosen more/less often than others. Under the null hypothesis, it is assumed that all responses are selected equally.

3.8 Research Ethics Considerations

Ethical considerations are defined as one of the most crucial components of the study (Fellows and Liu, 2015: 247). According to Fellows and Liu (2015: 247), and Bryman and Bell (2007: 71), the following ten points represent very important issues associated with ethical considerations and are identified in this study as follows:

- Study participants should not be exposed to harm in any way.
- Respect for the dignity of the study participants should be paramount.
- Full approval should be obtained from the participants prior to the study.
- The protection of the privacy of the study participants has to be confirmed.
- Adequate level of confidentiality of the research data should be confirmed.
- Anonymity of individuals and organisations participating in the research has to be confirmed.
- Any fraud or exaggeration regarding research objectives should be avoided.
- Affiliations in any forms, sources of funding, and any conflicts of interests must be declared.

- Any form of communication in relation to the study must be done honestly and openly.
- Any kind of misleading information and misrepresentation of key data acquisitions should be avoided.

Likewise, the voluntary participation of respondents in the study is vital. Therefore, participants have the right to withdraw from the study at any stage if they wish to do so. The researcher will therefore look at an informed consent principle, in which researchers will provide adequate information about the nature of the study and assurances that participation in the study is voluntary and without the use of pressure or coercion. In addition, this study was conducted in accordance with the guidelines of the DUT Institutional Research Ethics Committee (IREC).

3.9 Concluding Remarks

This chapter outlined the research approach process that was followed in this research. In particular, it reflected the research methodology, strategy, and approach adopted and its relevance to the topic. In addition, it highlighted the data gathering and analysis instruments used to obtain information and infer findings.

4 CHAPTER FOUR: DATA ANALYSIS AND FINDINGS

4.1 Introduction

This chapter discusses the results of this study in detail. The list of questions is analysed and aligned with the numerical tabulations. Data is analysed using percentages, mean score, standard deviations, and each question ranked with the support of the SPSS statistical package. In addition, the data is represented on pie charts and bar graphs.

4.2 Response to Questionnaires and Data Analysis

This section presents the data attained from the participating companies as well as analysis the results. It analyses two sections of the questionnaire, namely section A which covers the personal and company details, and section B which covers various statements.

4.2.1 Response Rate for the Overall Questionnaires Distributed

Table 5: Grade 4-6 Medium Contractors

Contractors Grading Designation	Sample size (No.)	Questionnaire received (No.)	Response rate (%)
4	55	40	72.73
5	35	29	82.86
6	41	36	87.80
Total	**131**	**105**	**80.15**

Questionnaire success rate = Questionnaires received ÷ questionnaires administered $\times$ 100

Questionnaire success rate = 105 ÷ 131 $\times$ 100 = 80.15%

Table 5 shows a total of 131 questionnaires distributed, and 105 responses received. There were 40 (72.73%) respondents from the Grade 4, 29 (82.86%) from Grade 5 and 36 (87.80%) from Grade 6. The overall response rate was significantly high at 80.15%, given that construction industry workers are usually busy and find little spare time to respond to surveys.

Table 6: Grade 7-9 Large Contractors

Contractors Grading Designation	Sample size (No.)	Questionnaire received (No.)	Response rate (%)
7	28	23	82.14
8	18	14	77.78
9	3	3	100.00
Total	**49**	**40**	**81.63**

Questionnaire success rate = Questionnaires received ÷ questionnaires administered $\times$ 100

Questionnaire success rate = 40 ÷ 49 $\times$ 100 = 81.63%

Table 6 shows a total of 49 questionnaires distributed, and 40 responses received. There were 23 (82.14%) respondents from the Grade 7, 14 (77.78%) from Grade 8 and 3 (100%) from the Grade 9. The overall response rate was 81.63%. There were marginally more respondents from large contractors (81.63%) compared to medium contractors (80.15%). This was most likely because large contractors understood the importance of the study better.

4.2.2 Questionnaire Section A: Analysis of Respondents' Demographics Profiles

This section analyses the demographic profiles of the respondents such as gender, their designation, organisation CIDB grade, years of experience in the construction industry, highest educational qualification and professional membership and their role/ responsibility in the respective organisations.

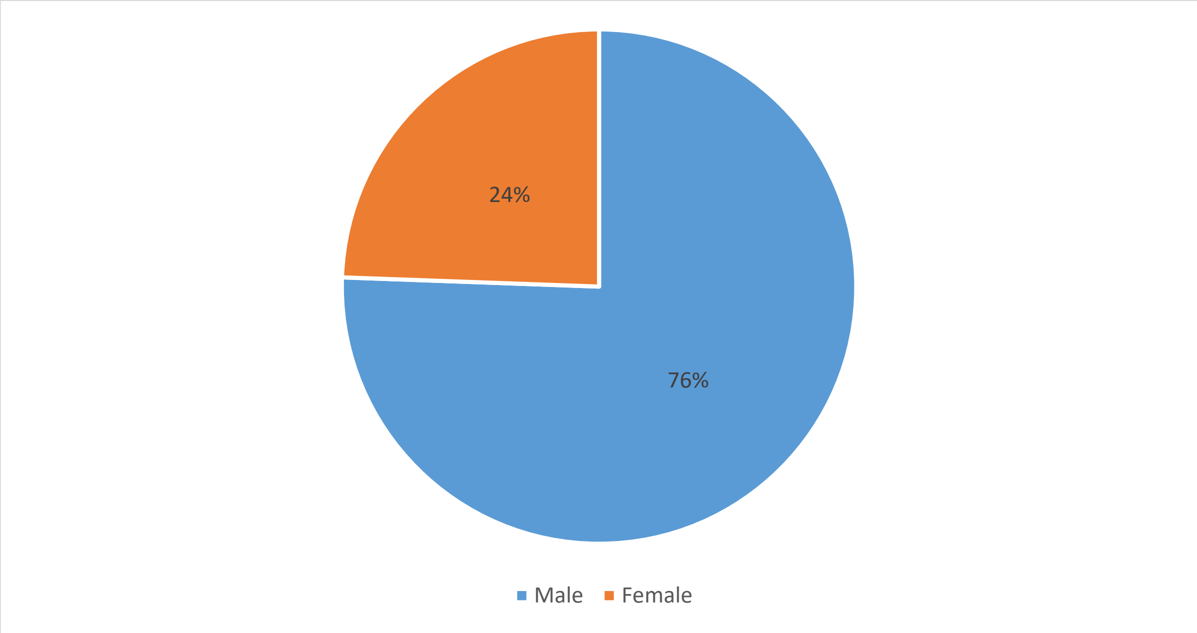

Figure 13: Gender

Figure 13 shows that the construction industry in Durban is highly male dominated. The graph indicates that males (76%) are the majority compared to females (24%) respondents. It was found that from the medium contractors 78.6% were males compared to large contractors who had 72.5% males. Females from the medium contractors were 21.4% compared to large contractors who had 27.5%. It is evident from this study that the construction industry remains male dominated.

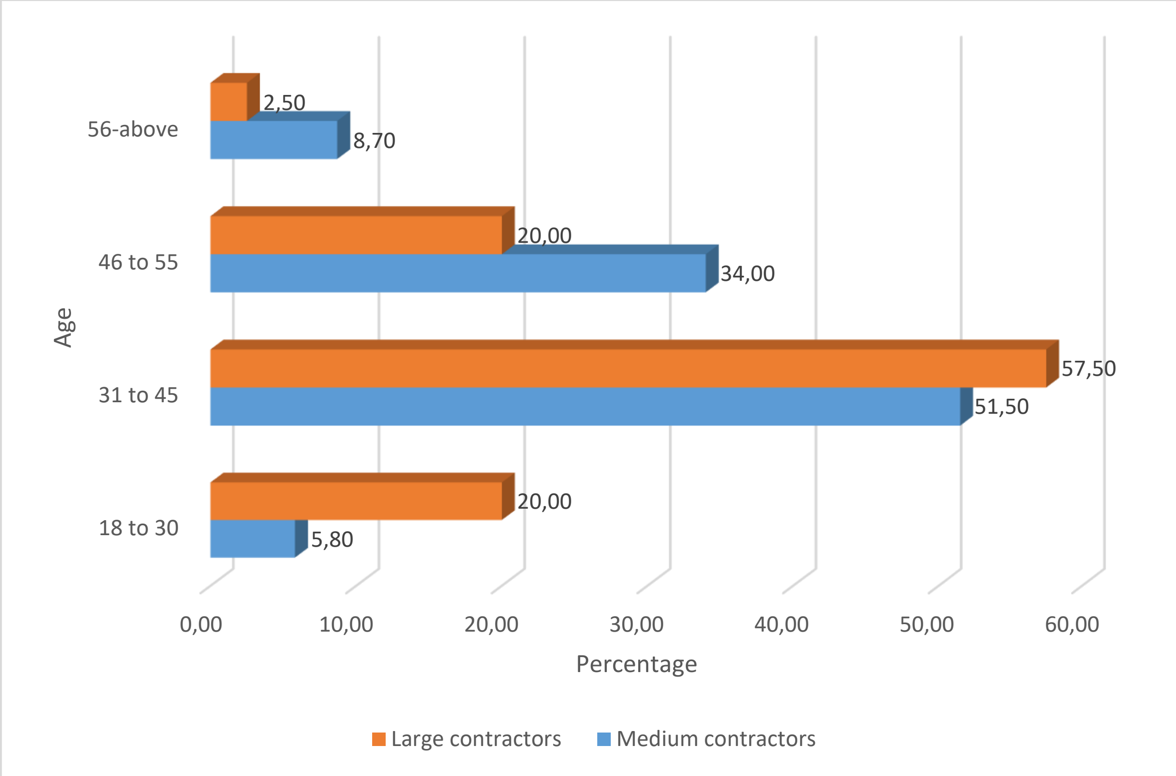

Figure 14: Age Distribution of Respondents

Figure 14 shows that respondents from the medium contractors between 18 to 30 years of age were 5.8% while respondents from the large contractors were 20.0%. Respondents from medium contractors between 31 to 45 years of age were 51.5% while respondents from large contractors were 57.5%. Respondents medium contractors aged between 46 to 55 years were 34.0% and 20.0% from large contractors. Respondents from medium contractors aged 56 and above were 8.7% and 2.5% from large contractors.

It evident that respondents between ages of 31 to 45 years dominated strategic positions in the industry, as the sample indicated 51.5% from medium contractors and 57.5% from large contractors, followed by those aged between 46 to 55 years at 34.0% from medium contractors and 20.0% from large contractors. It can therefore be concluded that the respondents who participated in the survey were mature and had a high possibility of having a vast wealth of experience in the construction industry.

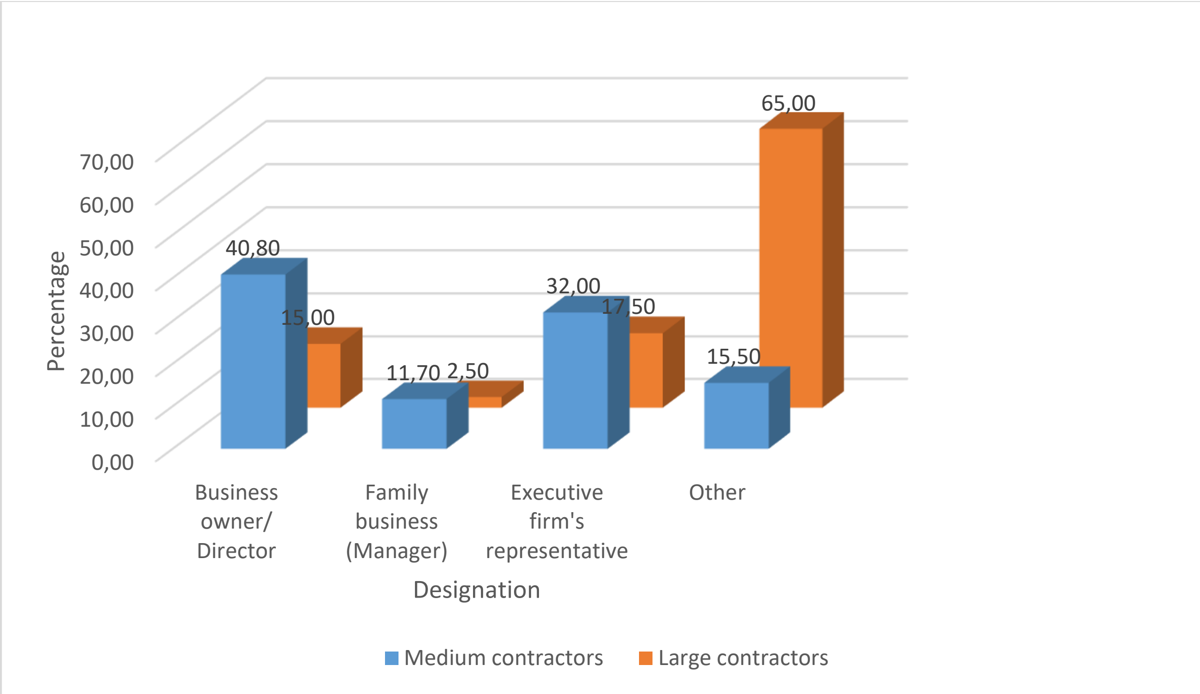

Figure 15: Designation of Respondents in their Organisation

Figure 15 shows the designation of respondents in their respective organisations. It shows that 40.8% of respondents from medium contractors and 15.0% from large contractors were business owners/ directors, whilst 11.7% respondents from medium contractors and 2.5% from large contractors were in strategic job positions as managers. In addition, 32.0% of respondents from medium contractors and 17.5% from large contractors were in an executive firm's representative position, whilst 15.5% from medium contractors and 65% from large contractors were noted as other designations.

The results show that medium contractors in their everyday work are managed by owners/ directors, whereas the opposite applies to the large contractors where the majority of the respondents were employees. This makes sense because large contractors are capable of handling large-scale projects as per their grade than medium-size contractors.

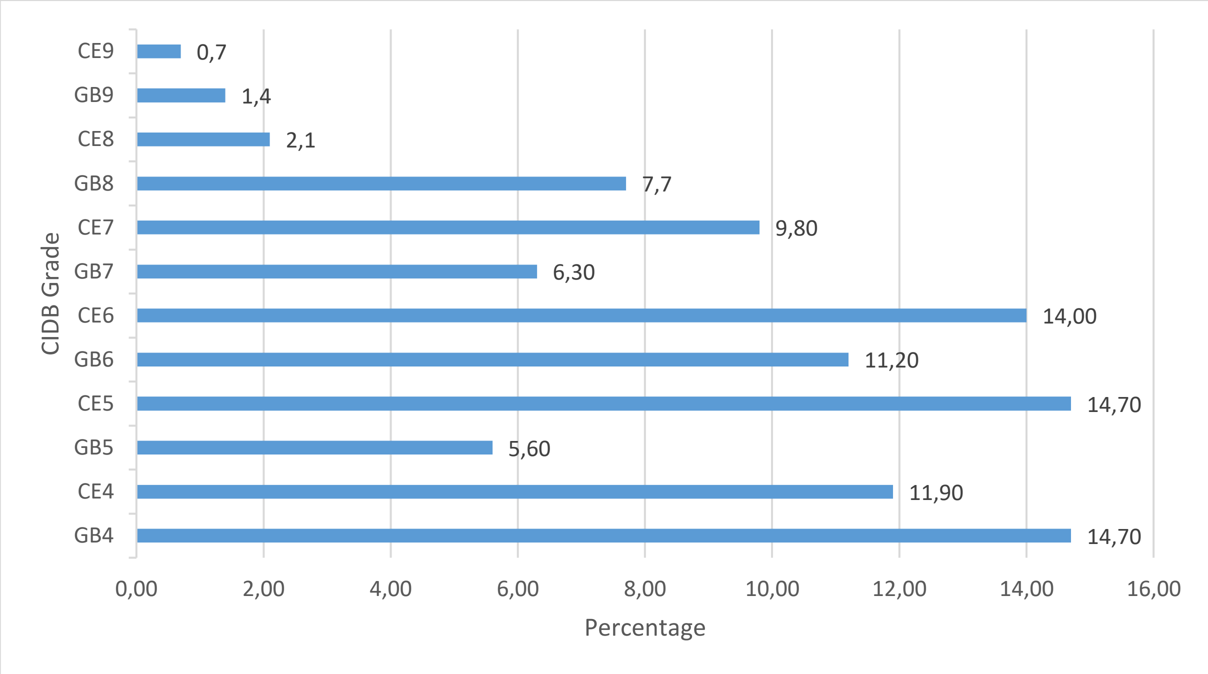

Figure 16: CIDB grade

Figure 16 represents the contractors' classes/grades from which the data was acquired. The graph above shows that the data were collected from construction contractors in grades 4 to 9 within civil engineering and general building works. It is notable that grade 1 to 3 are not featured here. The reason is that they are deemed to be small contractors and might not have a stable financial capability, strategic resources, adequate work experience and track record of project delivery compared to their peers, who are medium (grade 4 to 6) and large contractors (grade 7 to 9). Small contractors might also not have the potential and access to opportunities to seamlessly integrate the new and emerging ICT technologies that would enhance their project delivery. The results show that General Building (GB) stage 4 and Civil Engineering (CE) stage 5 were dominant within the medium-size, both sitting at 14.7%, followed by civil engineering (CE) stage 6 (14.0%), civil engineering (CE) stage 4 (11.9%), general building (GB) stage 6 (11.2%) and general building (GB) stage 5 (5.6%). Civil engineering (CE) stage 7 (9.8%) were dominant within large contractors, followed by general building (GB) stage 8 (7.7%), general building (GB) stage 7 (6.3%), civil engineering (CE) stage 8 (2.1%), general building (GB) stage 9 (1.4%) and civil engineering (CE) stage 9 (0.7%)

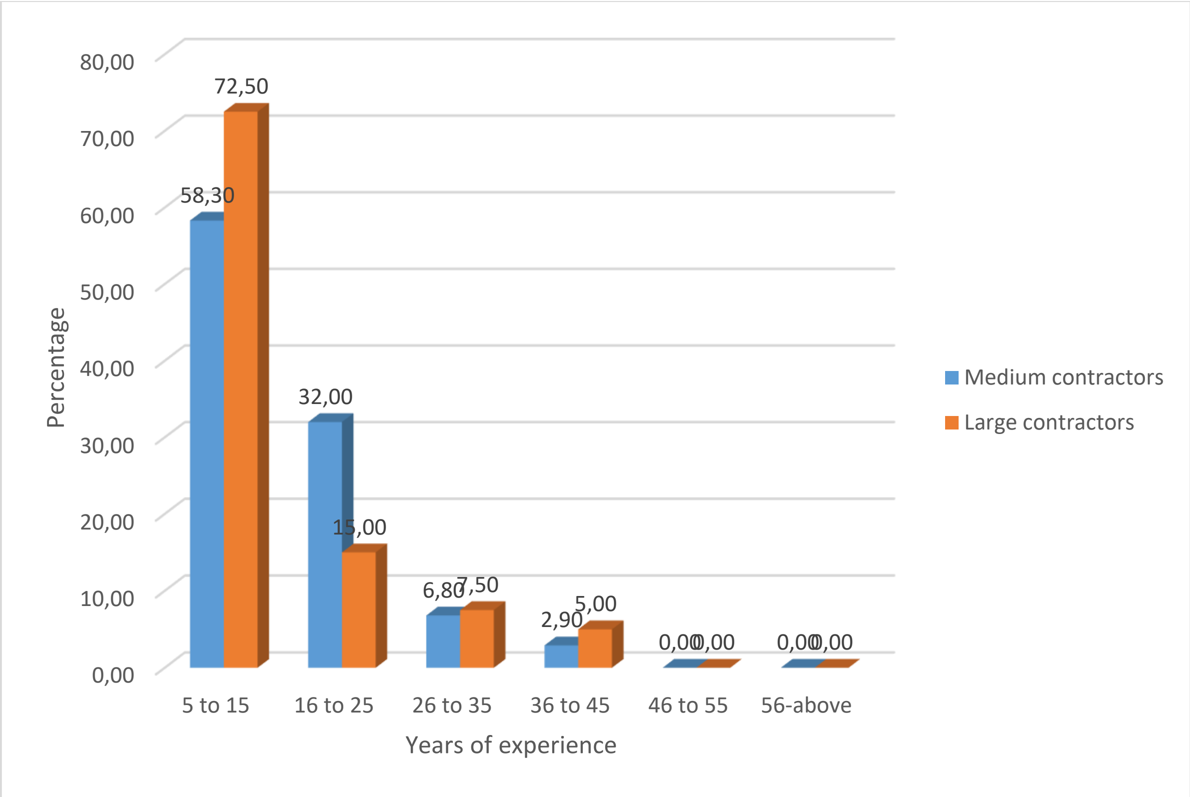

Figure 17: Respondent's Years of Experience in Construction Industry

Figure 17 shows the experiences of respondents within the construction industry. 58.3% of respondents from medium contractors and 72.5% from large contractors had between 5 to 15 years of experience, 32.0% from medium contractors and 15.0% from large contractors had between 16 to 25 years of experience, 6.8% from medium contractors and 7.5% from large contractors had 26 to 35 years of experience, while 2.9% from medium contractors and 5.0% from large contractors had 36 to 45 years of experience. Those with 0% experience from both medium and large contractors were between 46 to 55 and 56 above. The results show that the respondents from large contractors were slightly more experienced when compared to respondents from medium contractors. Looking at the 26 to 35 and 36 to 45 age group and their years of experience as show in the graph above, it is evident that respondents from large contractors were marginally more experienced than respondents from medium contractors.

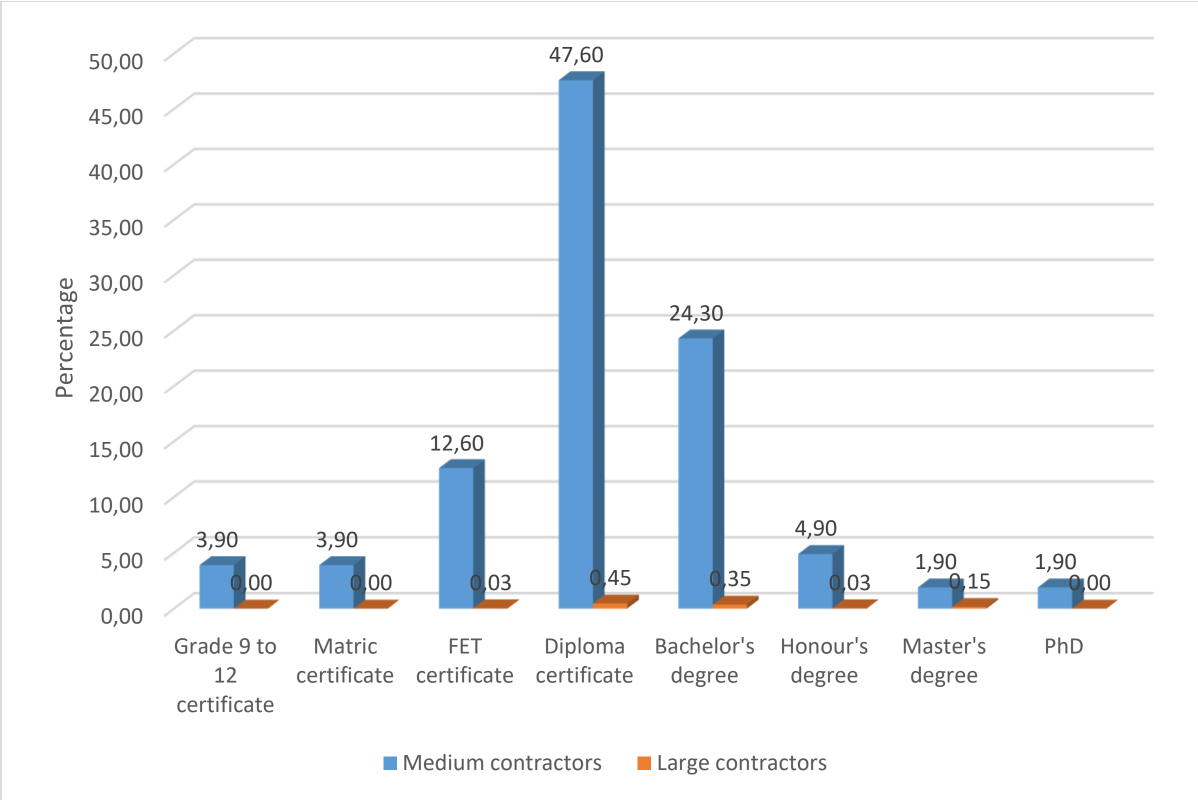

Figure 18: Respondent's Highest Educational Qualification

Figure 18 shows the highest educational qualifications of the respondents. 3.9% of respondents from medium contractors and 0% from large contractors had Grade 9 to 12 certificates; 3.9% from medium contractors and 0% from large contractors had matric certificates; 12.6% from medium contractors and 2.5% from large contractors had FET certificates; 47.6% from medium contractors and 45.0% from large contractors had diploma certificates; 24.3% from medium contractors and 35.0% from large contractors had bachelor's degrees; 4.9% from medium contractors and 2.5% from large contractors had honours degrees; 1.9% from medium contractors and 15.0% from large contractors had master's degrees and 1.0% from medium contractors and 0% from large contractors had doctoral degrees. The results show that the majority of respondents' highest educational qualifications were diplomas from both medium (47.6%) and large (45.0%) contractors, followed by bachelor's degrees from both medium (24.3%) and large (35.0%) contractors. The majority of respondents from large contractors were master's degrees (15%) and FET certificate holders (12.6%) from medium contractors. This indicates that the majority of respondents were well-informed and may have provided accurate information.

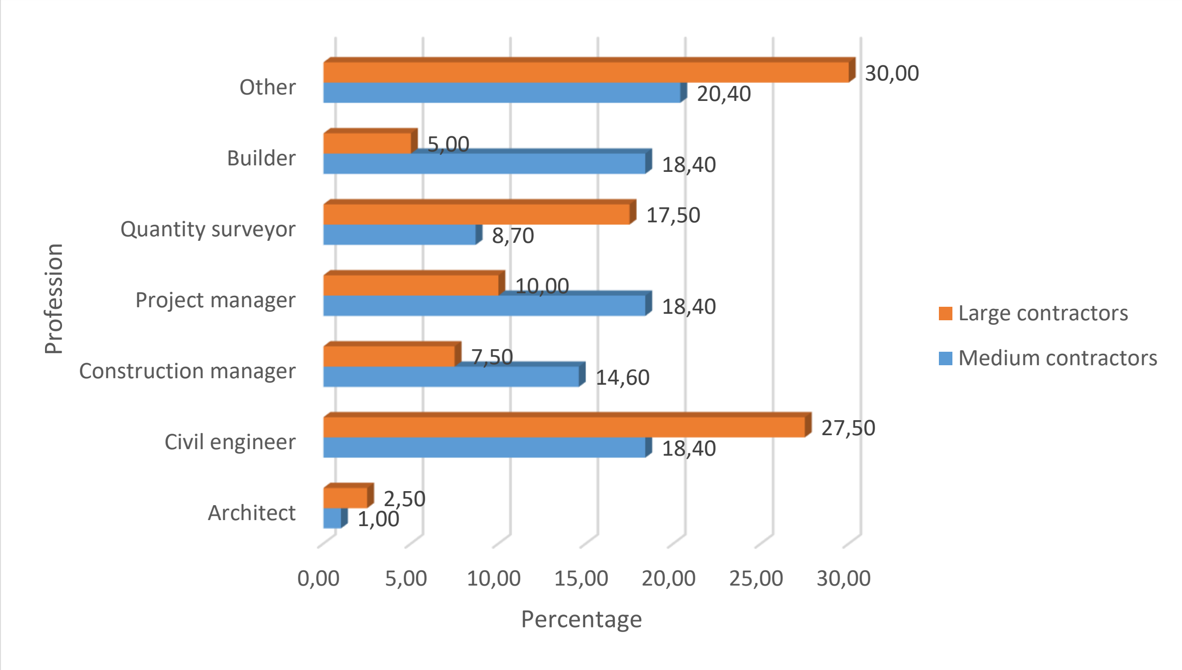

Figure 19: Respondent's Category of Profession

Figure 19 shows the professions of the respondents who participated in this study. It shows that 1.0% of respondents from medium contractors and 2.5% from large contractors were architects, 18.4% from medium contractors and 27.5% from large contractors were civil engineers, 14.6% from medium contractors and 7.5 from large contractors were construction managers, 18.4% from medium contractors and 10.0% from large contractors were project managers, 8.7% from medium contractors and 17.5% from large contractors were quantity surveyors, 18.4% from medium contractors and 5.0% from large contractors were builders and 20.4% from medium contractors and 30% from large contractors had other professions. The results show that other professions were dominant especially among the large contractors. It is also notable that civil engineers were dominant in both medium and large contractors groups, followed by builders, quantity surveyors, project managers and architects, who were least represented. The reason for this could be that architects usually work as r consultants rather than for contractors.

4.2.3 Analysis Questionnaire Section B

This section analyses responses from the main questionnaire survey's ranked statements and discusses the findings. This section covers 3 statements:

4.2.3.1 The level of awareness, understanding and knowledge of new emerging technologies presently linked to the Fourth Industrial Revolution (4IR).

Research participants were asked to respond "YES" or "NO" or "UNSURE" to a set of 14 items related to the level of awareness, understanding and knowledge of new emerging technologies presently linked to the Fourth Industrial Revolution (4IR). The frequencies of their responses, broken down by size of contractors, are summarised as follows:

Question 1.1: Does your organisation make use of Building Information Modelling (BIM) in planning and procuring construction projects in all phases of the facility's life cycle?

Table 7: Analysis question 1.1

Size	Medium Contractors				Large Contractors			
Q1.1	Yes	No	Unsure	**Total**	Yes	No	Unsure	**Total**
Frequency	9	87	7	**103**	10	25	5	**40**
Percent	8.7	84.5	6.8	**100**	25	62.5	12.5	**100**
Value	8.626a							
Df	2							
p-value	0.013							

Table 7 above shows the responses of participants to the question regarding the usage of BIM in planning and procuring construction projects in all stages of the facility's life cycle.

The medium contractors' table above shows that 8.7% of respondents were aware of the use of BIM, 84.5% are not aware of the use BIM and 6.8% were not sure whether the organisation used BIM, meaning that they were not aware of BIM. The large contractors' table above shows that 25% were aware of the use of BIM, 62.5% were not aware of use BIM and 12.5% were not sure whether the organisation used BIM, which could mean that they were not aware of BIM.

Findings from the analysis using chi-square goodness-of-fit-test show that a significant number of medium contractors (84.5%) did not use BIM in planning and procuring construction projects in all stages of the facility's life cycle, compared to large contractors (62.5%). The observation between medium versus large contractors p=.013; Table 7. These findings show that the knowledge of BIM among construction companies in Durban is sub-optimal. This could be attributed to lack of skills, education and knowledge on BIM, which is the major obstacle to the full adoption of BIM in South Africa (Kekana, Aigbavboa and Thwala, 2015: 1).

Question 1.2: Does your organisation use Three-Dimensional (3D) technology to increase production, minimise construction time, reduce labour and construction costs?

Table 8: Analysis question 1.2

Size	**Medium Contractors**				**Large Contractors**			
Q1.2	Yes	No	Unsure	**Total**	Yes	No	Unsure	**Total**
Frequency	11	87	5	**103**	2	31	7	**40**
Percent	10.7	84.5	4.9	**100**	5	77.5	17.5	**100**
Value	6.682a							
Df	2							
p-value	0.035							

Table 8 above represents the responses to the question regarding the use of 3D technology to increase production, minimise construction period, reduced labour and construction expenditure. The medium contractors' table above shows that 10.7% were aware of the 3D technology, 84.5% were not aware of 3D technology and 4.9% were not sure whether their organisation used 3D technology, meaning they were not aware of 3D technology**,** whereas the large contractors' table above shows that 5% were aware of the 3D technology, 77.5% were not aware of 3D technology and 17.5% were not sure whether the organisation used 3D technology, meaning they were not aware of 3D technology.

The analysis using chi-square goodness-of-fit-test shows that a significant number of medium-size contractors (84.5%) did not use Three-Dimensional (3D) technology to increase production, reduce construction period, reduce labour and construction expenditure compared to large contractors (77.5%). The observation shows that there was a significantly higher proportion of medium (84.5%) vs large (77.5%) contractors, p=.035; Table 8. These findings were in agreement with Aghimien, Aigbavboa and Matabane (2020: 3) who stated that 3D printing in South African construction delivery was almost non-existent.

Question 1.3: Does your company use electronic procurement (e-procurement), which is the process of utilising the electronic communication technologies (ICT) that foster transaction processes to buy services, goods, and works or conduct tendering for construction works?

Table 9: Analysis question 1.3

Size	Medium Contractors				Large Contractors			
Q1.3	Yes	No	Unsure	**Total**	Yes	No	Unsure	**Total**
Frequency	55	42	6	**103**	33	5	2	**40**
Percent	53.4	40.8	5.8	**100**	82.5	12.5	5.0	**100**
Value	11.009a							
Df	2							
p-value	0.004							

Table 9 above represents the responses to the question regarding the use of electronic procurement (e-procurement), which is the process of utilising electronic communication technologies (ICT) to buy services, goods, and works or conduct tendering for construction works.

The medium contractors' table above shows that 53.4% were aware of e-procurement, 40.8% were not aware of e-procurement and 5.8% were not sure whether the organisation used e-procurement, meaning they were not aware of e-procurement; whereas**,** the large contractors' table above shows that 82.5% were aware of e-procurement, 12.5% were not aware of e-procurement and 5.0% were not sure whether the organisation used e-procurement, meaning they were not aware of e-procurement.

Findings from the analysis using chi-square goodness-of-fit-test show that a significant number of large contractors (82.5%) used electronic procurement (e-procurement), which is the process of utilising electronic communication technologies (ICT) to buy services, goods, and works or conduct tendering for construction works, compared to medium contractors (53.4%), p=.004. These findings were in disagreement with Ibem and Laryea (2014: 11), who stated that the construction sector is often slow in adopting digital technologies (DTs) compared to other industries such as manufacturing, finance and transportation.

Question 1.4: Does your organisation use robotic technology to generate higher output at a lower unit cost, with better quality product?

Table 10: Analysis question 1.4

Size	**Medium Contractors**				**Large Contractors**			
Q1.4	Yes	No	Unsure	**Total**	Yes	No	Unsure	**Total**
Frequency	2	97	4	**103**	0	30	2	**40**
Percent	1.9	94.2	3.9	**100**	0	95.0	5.0	**100**
Value	0.864a							
Df	2							
p-value	0.649							

Table 10 above represents the responses to the question regarding the use of robotic technology to produce high quality products at low cost, with the highest quality product. The medium contractors' table above shows that 1.9% were aware of the robotic technology, 94.2% were not aware of robotic technology and 3.9% were not sure whether the organisation used robotic technology, meaning they were not aware of robotic technology. In addition, the large contractors' table above shows that 0% were aware of robotic technology, 95% were not aware of robotic technology and 5.0% were not sure whether the organisation used the robotic technology, meaning they were not aware of robotic technology.

Findings from the analysis using chi-square goodness-of-fit-test show that a significant number of large contractors (95%) did not use robotic technology to generate higher output at a lower unit cost, with better quality product, compared to medium contractors (94.2%), p >.05. These findings were in agreement with Liu, Lu and Niu (2018: 2), who pointed out that robotics could make construction second among high technology industries.

Question 1.5: Does your organisation make use of Virtual Reality (VR) to improve construction site activities as well as to assist significantly in the construction planning stage?

Table 11: Analysis question 1.5

Size	Medium Contractors				Large Contractors			
Q1.5	Yes	No	Unsure	**Total**	Yes	No	Unsure	**Total**
Frequency	6	90	7	**103**	2	32	6	**40**
Percent	5.8	87.4	6.8	**100**	5.0	80.0	15.0	**100**
Value	2.352a							
Df	2							
p-value	0.309							

Table 11 above represents the responses to the question regarding the use of Virtual Reality (VR) to improve construction site activities as well as to assist significantly in the construction planning stage. Thus, the medium contractors' table presented above shows that 5.8% were aware of VR, 87.4% were not aware of VR and 6.8% were not sure whether the organisation used VR, meaning they were not aware of VR; whereas, the large contractors' table as presented above shows that 5.0% were aware of VR, 80.0% were not aware of VR and 15.0% were not sure whether the organisation used VR, meaning they were not aware of VR. Findings from the analysis using chi-square goodness-of-fit-test show that a significant number of medium contractors (87.4%) did not make use of Virtual Reality (VR) to improve construction site activities as well as to assist significantly in the construction planning stage, compared to large contractors (80.0%), $p > .05$.

The use of Virtual Reality (VR) to improve construction site activities as well as to assist significantly in the construction planning stage in medium contractors was rated 5.8% and 5.0% in large contractors, despite its potential to improve construction site activities as well as to assist significantly in the construction planning stage. The findings reveal that the usage of VR in both medium and large contractors was significantly low.

Findings were in agreement with Bouchlaghem and Liyanage (1996: 1), who stated that VR has gradually spread in the construction industry, no matter there is a significant potential for virtual reality in construction, which includes design analysis and co-ordination or not (Mandeville *et al.,* 1995: 8). This applies as well to construction integration and the construction scheduling process (Heesom and Mahdjoubi, 2002: 3).

Question 1.6: Does your organisation apply safety systems in construction sites using the Internet of Things (IoT)?

Table 12: Analysis question 1.6

Size	Medium Contractors				Large Contractors			
Q1.6	Yes	No	Unsure	**Total**	Yes	No	Unsure	**Total**
Frequency	10	88	5	**103**	4	29	7	**40**
Percent	9.7	85.4	4.9	**100**	10.0	72.5	17.5	**100**
Value	6.082a							
Df	2							
p-value	0.048							

Table 12 above represents the response to the question regarding the application of safety systems in construction sites using the Internet of Things (IoT). The medium contractors' table as presented above shows that 9.7% were aware of the IoT, 85.4% were not aware of IoT and 4.9% were not sure whether the organisation used the IoT, meaning they were not aware of IoT. On the other hand, the large contractors' table as presented above shows that 10.0% were aware of the IoT, 72.5% were not aware of IoT and 17.5% were not sure whether the organisation used the IoT, meaning they were not aware of IoT. Thus, the findings from the analysis using chi-square goodness-of-fit-test show that a significant number of medium contractors (85.4%) did not use the Internet of Things (IoT), compared to large contractors (72.5%), p=.05.The application of safety systems in medium contractors 'construction sites using the Internet of Things (IoT) was rated 9.7% compared to 10.0% for large contractors. It is evident that the usage of IoT was significantly low, even if it has been proven to enhance operations by monitoring the soundness of machinery and improving health and safety issues (Bughin, Chui and Manyika, 2015: 93).

Question 1.7: Does your organisation apply Radio Frequency Identification (RFID) technology to address the challenges associated with tracking resources on construction sites?

Table 13: Analysis question 1.7

Size	**Medium Contractors**				**Large Contractors**			
Q1.7	Yes	No	Unsure	**Total**	Yes	No	Unsure	**Total**
Frequency	4	92	5	**103**	4	26	10	**40**
Percent	3.9	91.3	4.9	**100**	10.0	65.0	25.0	**100**
Value	15.442a							
Df	2							
p-value	0.000							

Table 13 above represents the responses to the question regarding the application of Radio Frequency Identification (RFID) technology to address the challenges associated with tracking resources on construction sites.

The medium contractors' table as presented above shows that 3.9% were aware of the RFID, 91.3% were not aware of RFID and 4.9% were not sure whether the organisation used RFID, meaning they were not aware of RFID. However, the large contractors' table above shows that 10.0% were aware of the RFID, whereas 65.0% were not aware of RFID and 25.0% were not sure whether the organisation used RFID, meaning they were not aware of RFID. Thus, the above findings, from the analysis using chi-square goodness-of-fit-test, show that a significant number of medium contractors (91.3%) did not use the Radio Frequency Identification (RFID) technology to address the challenges associated with tracking resources on construction sites, compared to large contractors (65.0%), $p<.001$. The application of Radio Frequency Identification (RFID) technology to address the challenges associated with tracking resources on construction sites in medium contractors was rated 3.9%, compared to 10.0% for large contractors. This shows that the use of RFID among small to medium contactors was significantly low.

Findings as indicated in Table 13 were in agreement with Lu, Huang and Li (2011: 101), who pointed out that RFID technology has been widely used in various fields such as retail, electronics trading, supply chain management and procurement, scientific research, security, etc. but has not yet gained popularity in the construction industry.

Question 1.8: Does your organisation make use of the Cyber Physical System (CPS) system operations for monitoring (plant and equipment), coordinating, progress tracking, construction process control, and as-built documentation?

Table 14: Analysis question 1.8

Size	Medium Contractors				Large Contractors			
Q1.8	Yes	No	Unsure	**Total**	Yes	No	Unsure	**Total**
Frequency	3	89	11	**103**	3	24	13	**40**
Percent	2.9	86.4	10.7	**100**	7.5	60.0	32.5	**100**
Value	12.161a							
Df	2							
p-value	0.002							

Table 14 above represents the responses to the question regarding the use of the Cyber Physical System (CPS) system operations for monitoring plant and equipment, coordinating, progress tracking, construction process control, and as-built documentation. Accordingly, the medium contractors' table above shows that 2.9% were aware of the CPS, 86.4% were not aware of CPS and 10.7% were not sure whether the organisation used the CPS, meaning they were not aware of CPS; whilst the large contractors' table shows that 7.5% were aware of the CPS, 60.0% were not aware of CPS and 32.5% were not sure whether the organisation used the CPS, meaning they were not aware of CPS.

Findings from the analysis using chi-square goodness-of-fit-test show that a significant number of medium contractors (86.4%) did not use the Cyber Physical System (CPS) system operations for monitoring (plant and equipment), coordinating, progress tracking, construction process control, and as-built documentation, compared to large contractors (60.0%), p=.002.

The use of Cyber Physical System (CPS) system operations for monitoring (plant and equipment), coordinating, progress tracking, construction process control, and as-built documentation, in medium contractors was rated 2.9% and 7.9% in large contractors despite its potential to improve construction site activities as well as to assist significantly in the construction planning stage (Kan, Anumba and Messner, 2017: 140)., The findings reveal that the use of CPS in both medium and large contractors was at a very low level.

Question 1.9: Are drones used to survey construction sites, scan sites in order to create 3D models of structures and for health and safety monitoring?

Table 15: Analysis question 1.9

Size	**Medium Contractors**				**Large Contractors**			
Q1.9	Yes	No	Unsure	**Total**	Yes	No	Unsure	**Total**
Frequency	17	77	9	**103**	14	23	3	**40**
Percent	16.5	74.8	8.7	**100**	35.0	57.5	7.5	**100**
Value	5.826a							
Df	2							
p-value	0.054							

Table 15 above represents the response to the question regarding the use of Drones to survey construction sites, scan sites in order to create 3D models of structures, and for health and safety monitoring. Accordingly, the medium contractors' table above shows that 16.5% were aware of drones, 74.8% were not aware of drones and 8.7% were not sure whether the organisation used drones, meaning they were not aware of drones. In addition, large contractors' data in Table 15 shows that 35.0% were aware of drones, 57.5% were not aware of drones and 7.5% were not sure whether the organisation used drones, meaning they were not aware of drones. Thus, the findings from the analysis using chi-square goodness-of-fit-test shows that a significant number of medium contractors (74.8%) do not use drones to survey construction sites, for site scanning and to create 3D models of structures as well as for health and safety monitoring, compared to large contractors (57.5%), p=.054. These findings were in agreement with Li and Liu (2019: 401) who stated that the construction sector has been slow to embrace of novel technology. The use of Drones to survey construction sites, scan site in order to create 3D models of structures, and health and safety monitoring (Li and Liu, 2019: 406) in medium contractors was rated 16.5% compared to 35.0% in large contractors which shows that low to medium usage of Drones was significantly low.

Question 1.10: Does your company have a website?

Table 16: Analysis question 1.10

Size	**Medium Contractors**				**Large Contractors**			
Q1.10	Yes	No	Unsure	**Total**	Yes	No	Unsure	**Total**
Frequency	54	48	1	**103**	32	7	1	**40**
Percent	52.4	46.6	1.0	**100**	80.0	17.5	2.5	**100**
Value	10.468a							
Df	2							
p-value	0.005							

Table 16 above represent table the responses to the question regarding whether the company had a website.

The medium contractors' table above shows that 52.4% were aware of the website, 46.6% were not aware of a website and 1.0% were not sure whether the organisation had a website, meaning they were not aware of a website. The large contractors' table shows that 80.0% were aware of the website, 17.5% were not aware of a website and 2.5% were not sure whether the organisation used a website, meaning they were not aware of a website.

Findings from the analysis using chi-square goodness-of-fit-test reveal that a significant number of large contractors (80.0%) and medium contractors (52.4%) did have a website, p=.005. This shows that ownership of a website among companies in Durban (Ibem and Laryea, 2015: 364), was significantly higher among medium contractors compared to large contractors. Ibem and Laryea's (2015: 364) study implies that construction firms in South Africa predominantly use e-mails and websites to support the execution of the pre-award phase of construction procurement.

Question 1.11: Do you use cloud computing, the practice of using a network of remote servers hosted on the internet to store, manage, and process data, rather than a local server or a personal computer?

Table 17: Analysis question 1.11

Size	Medium Contractors				Large Contractors			
Q1.11	Yes	No	Unsure	**Total**	Yes	No	Unsure	**Total**
Frequency	49	49	5	**103**	30	7	3	**40**
Percent	47.6	47.6	4.9	**100**	75.0	17.5	7.5	**100**
Value	10.937a							
Df	2							
p-value	0.004							

Table 17 above represents the responses to the question regarding the use of cloud computing in the practice of using a network of remote servers hosted on the internet to store, manage, and process data, rather than a local server or a personal computer. Accordingly, the medium contractors' table shows that 47.6% were aware of cloud computing, 47.6% were not aware of cloud computing and 4.9% were not sure whether the organisation used cloud computing, meaning they were not aware of cloud computing. In addition, the large contractors' table shows that 75.0% were aware of cloud computing, 17.5% were not aware of cloud computing and 7.5% were not sure whether the organisation used cloud computing, meaning they were not aware of cloud computing. Thus, the findings from the analysis using chi-square goodness-of-fit-test show that a significant number of large contractors (75.0%) did use cloud computing in the practice of using a network of remote servers hosted on the internet to store, manage, and process data, rather than a local server or a personal computer (Chong, Wong and Wang, 2014: 3-4), compared to medium contractors (47.6%), p=.004. The significant usage of cloud computing may be attributed to its flexibility and the fact that the services it provides are fault-tolerant and highly available (Chong, Wong and Wang, 2014: 6-7).

Question 1.12: Does your firm use electronic communication systems or tools to conduct tendering and submission of proposals, tenders or bids?

Table 18: Analysis question 1.12

Size	**Medium Contractors**				**Large Contractors**			
Q1.12	Yes	No	Unsure	**Total**	Yes	No	Unsure	**Total**
Frequency	84	17	2	**103**	37	3	0	**40**
Percent	81.6	16.5	1.9	**100**	92.5	7.5	0	**100**
Value	2.855a							
Df	2							
p-value	0.240							

Table 18 above represent the responses to the question regarding the use of electronic communication systems or tools to conduct tendering and submission of proposals, tenders or bids. The medium contractors' table above shows that 81.6% were aware of electronic communication, 16.5% were not aware of electronic communication and 1.9% were not sure whether the organisation used electronic communication, meaning they were not aware of electronic communication. The large contractors' table above shows that 92.5% were aware of electronic communication, 7.5% were not aware of electronic communication and 0% were not sure whether the organisation used electronic communication, meaning they were not aware of electronic communication.

Findings from the analysis using chi-square goodness-of-fit-test show that a significant number of large contractors (92.5%) did use electronic communication system or tools to conduct tendering and submission of proposals, tenders or bids (Ibem and Laryea, 2017: 310), compared to medium contractors (81.6%), p >.05. These findings were in disagreement with Ibem and Laryea (2017: 310) who found that the usage of electronic communication tools were relatively low,due to barriers such as slow Internet connection; resilience to change and costly internet services.

Question 1.13: Does your firm use electronic payment (e-payment) system or tools to do payments for goods or services on the internet?

Table 19: Analysis question 1.13

Size	Medium Contractors				Large Contractors			
Q1.13	Yes	No	Unsure	**Total**	Yes	No	Unsure	**Total**
Frequency	95	7	1	**103**	40	0	0	**40**
Percent	92.2	6.8	1.0	**100**	100	0	0	**100**
Value	3.291a							
Df	2							
p-value	0.193							

Table 19 above represents the responses to the question regarding the use of electronic payment (e-payment) system or tools to do payments for goods or services on the internet.

Accordingly, the medium contractors' table above shows that 92.2% were aware of e-payment, 6.8% were not aware of e-payment and 1.0% were not sure whether the organisation used e-payment, meaning they were not aware of e-payment; whereas the large contractors' table as above shows that 100% were aware of e-payment, 0% were not aware of e-payment and 0% were not sure whether the organisation used e-payment, meaning they were not aware of e-payment.

Findings from the analysis using chi-square goodness-of-fit-test show that a significant number of large contractors (100.0%) did use electronic payment (e-payment) system or tools to do payments for goods or services on the internet (Ayegba *et al.*, 2018: 226), compared to medium contractors (92.2%), $p > .05$. This finding is contrary to Ayegba *et al.* (2018: 224), who reported that the adoption and implementation of an electronic payment tool is relatively low within the South African construction industry.

Question 1.14: Does your firm use electronic invoicing (e-invoicing) systems or tools in the exchange of invoice documents?

Table 20: Analysis question 1.14

Size	Medium Contractors				Large Contractors			
Q1.14	Yes	No	Unsure	**Total**	Yes	No	Unsure	**Total**
Frequency	57	35	11	**103**	35	2	3	**40**
Percent	55.3	34.0	10.7	**100**	87.5	5.0	7.5	**100**
Value	14.281a							
Df	2							
p-value	0.001							

Table 20 above represent the responses to the question regarding the use of electronic invoicing (e-invoicing) system or tools in the exchange of invoice documents. Accordingly, the medium contractors' table above shows that 55.3% were aware of e-invoicing, 34.0% were not aware of e-invoicing and 10.7% were not sure whether the organisation used e-invoicing, meaning they were not aware of e-invoicing. In addition, the large contractors' table as presented above shows that 87.5% were aware of e-invoicing, 5.0% were not aware of e-invoicing and 7.5% were not sure whether the organisation used e-invoicing, meaning they were not aware of e-invoicing.

Findings from the analysis using chi-square goodness-of-fit-test show that a significant number of large contractors (87.5%) used electronic invoicing (e-invoicing) system or tools in the exchange of invoice documents (Ibem and Laryea, 2014: 11), compared to medium contractors (55.3%), p=.001.

The study findings reveal that t medium and large construction companies operating in Durban were aware of and use the new emerging technologies in their office-related business operations. However, that was not the case on construction site operations, which is the main area of project delivery where emerging ICT technologies and elements of fourth industrial revolution are most needed in order to significantly improve overall quality delivery of construction projects in terms of construction cost, time, quality, and environmental health and safety. The items for which "YES" was selected by a significant number of the sample (1.3, 1.10, 1.11, 1.12, 1.13 and 1.14), are all office-based technologies. However, the "NO" items were also selected by a significant number of the sample (1.1, 1.2, 1.4, 1.5, 1.6, 1.7, 1.8 and 1.9). These are all site-based technologies. It is evident in accordance with the Test of the Hypothesis H1a: The Knowledge and in-depth understanding of the concept of the fourth industrial revolution among construction companies in Durban is at a basic level.

The analysis was used to compare medium-size and large-size organisations using the Mann Whitney test. The analysis shows a level of agreement that construction companies' awareness and usage of new emerging technologies within the office space was significantly higher for large contractors compared to medium contractors. However, awareness and usage of new emerging technologies on site was significantly higher among large contractors than among medium contractors.

4.2.3.2 The Potential and Actual Benefits of the Implementation of Smart Technology within Construction Sites and Offices with Elements of Fourth Industrial Revolution (4IR).

Questionnaires were used in the collection of data. These featured a 5-point rating scale where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. These were used to measure the perceived and actual benefits of the implementation of smart technology amongst medium and large construction firms in Durban.

Tables 21 and 22 show the respondents' ranking on the perceived and actual benefits of the implementation of smart technology within construction sites and offices. The implementation of ICTs in project design, procurement and construction delivery were ranked as follows (Comparison between medium and large contractors):

4.2.3.2.1 Medium Contractors' Responses

The results in Table 21 were obtained from respondents' rankings of the variables using a five-point Likert scale where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. The rankings were used to measure the perceived and actual benefits of the implementation of smart technology and elements of the Fourth Industrial Revolution (4IR) on construction sites and in offices of medium construction firms in Durban. The use of "electronic procurement (e-procurement)"in conducting business operations was ranked first with a mean score of 4.41 and standard deviation (SD) of 0.910. The view that the use of Building Information Modelling (BIM) among medium contractors to plan and procure construction projects would be most beneficial in all phases of the facility's life cycle ranked second with a mean score of 3.98 and standard deviation (SD) of 1.036. The hypotheses that the implementation of "robotic technology", and "Three-dimensional (3D) technology" would advance construction delivery and operations were ranked third with a mean of 3.90 and standard deviation (SD) of 0.890; and fourth with a mean score of 3.86 and standard deviation (SD) of 1.051; respectively. The "application of Virtual Reality (VR)" was ranked fifth with a mean score of 3.76 and standard deviation (SD) = 1.089. The use of the Internet of Things (IoT) and the Cyber Physical System (CPS) system operations to monitor (plant and equipment) were ranked sixth, with a mean score of 3.63 and standard deviation of 1.018 and seventh, with mean score of 3.49 and standard deviation of 1.040 respectively. However, the use of Radio Frequency Identification (RFID) technology to address the potential and actual challenges associated with tracking resources on construction sites was ranked eighth with mean score of 3.46 and standard deviation of 1.174

Table 21: Response Analysis from Medium Contractors on Benefits of Implementing ICT Technologies within Construction Sites and Offices: Medium Contractors' Perspectives

Questions	Mean Score	Std. Dev	Asymp. Sig (2-sided)	Rank
Q2.3: Electronic procurement (e-procurement) utilising the electronic communication technologies (ICT), is used in transaction processes to buy services and goods and works to improve delivery, reduce paperwork and lower administrative costs	4.41	0.91	0.000	1
Q2.1: The use of Building Information Modelling (BIM) in planning and procuring construction projects is benefiting all phases of the facility's life cycle.	3.98	1.04	0.000	2
Q2.4: Implementation of Robotic technology has the capability to generate higher output at a lower unit cost, with better quality products.	3.9	0.89	0.000	3
Q2.2: Implementing Three-Dimensional (3D) technology brings significant benefits to the organisation, in terms of increased customisation, reduced construction time, reduced manpower and construction cost.	3.86	1.05	0.000	4
Q2.5: Application of Virtual Reality (VR) allows costly mistakes to be identified and rectified before they occur and easy	3.76	1.09	0.000	5

communication among site staff and office staff.				
Q2.6: Safety systems in construction sites have integrated the usage of the Internet of Things (IoT).	3.63	1.02	0.000	6
Q2.8: Cyber Physical System (CPS) system operations are used for monitoring (plant and equipment), coordinating, progress tracking, construction process control, and as-built documentation.	3.49	1.04	0.002	7
Q2.7: Radio Frequency Identification (RFID) technology is used to address the challenges associated with tracking resources on construction sites.	3.46	1.17	0.003	8

Based on the ranking (R), using the computer calculated standard deviation (SD) and mean score ($\bar{X}$) for the actual benefits of implementing smart technology as an element of the Fourth Industrial Revolution (4IR) within construction sites and offices of construction companies in the eThekwini District Municipality of KwaZulu-Natal, the following results were revealed:

Electronic procurement (e-procurement) utilising electronic communication technologies (ICT), is used in transaction processes to buy services, goods, and works so as to improves delivery, reduce paperwork and lower administrative costs.

Electronic procurement was the most utilised technology and was ranked first ($\bar{X}$=4.41; SD=0.910; R=1) among medium contractors. There was a significant agreement that electronic procurement was the most utilised technology among medium contractors, $p<.001$. These findings were in disagreement with Ibem and Laryea (2017: 374-375) who found that there was low usage of electronic procurement systems and applications to support the execution of construction procurement activities in South Africa.

The use of Building Information Modelling (BIM) in planning and procuring a construction project benefits all phases of the facility's life cycle.

The use of Building Information Modelling (BIM) in planning and procuring construction projects could benefit all stages of the facility's life cycle among medium contractors was ranked second ($\bar{X}$=3.98; SD=1.036; R=2). The respondents significantly agreed that the use of Building Information Modelling (BIM) in planning and procuring a construction project could benefit all phases of the facility's life cycle among medium contractors, $p<.001$. These findings were in agreement with Kekana, Aigbavboa and Thwala (2015: 3), who stated that the benefits of BIM vary across the various stages of the project, from planning to up to the maintenance of a completed project.

Implementation of Robotic technology has the capability to generate higher outputs at a lower unit cost, with better quality products.

The implementation of robotic technology among medium contractors was ranked third ($\bar{X}$=3.90; SD=0.890; R=3). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that the implementation of robotic technology has the capability to generate higher outputs at a lower unit cost, with better quality products among medium contractors, $p<.001$. These findings were in line with Yaghoubi (2013: 19) who stated that the introduction of automation and robotics technologies in construction has the potential to improve the industry in terms of productivity, safety and quality.

Implementing Three-Dimensional (3D) technology brings significant benefits to the organisation, in terms of increased customisation, reduced construction time, reduced manpower and construction cost.

Implementing Three-Dimensional (3D) technology among medium contractors was ranked fourth ($\bar{X}$=3.86; SD=1.051; R=4). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement among medium contractors, $p<.001$ that implementing of Three-Dimensional (3D) technology could bring significant benefits to their organisations, reduce construction time, manpower and construction costs. These findings were in agreement with Wu, Wang and Wang (2016: 1), who stated that 3D technology could bring significant improvement to the construction sector, in terms of increased customisation, minimised construction periods, reduced labour force and construction expenditure.

Application of Virtual Reality (VR) allows costly mistakes to be identified and rectified before they occur and fosters easy communication among site and office staff.

Application of Virtual Reality (VR) among medium contractors was ranked fifth ($\bar{X}$=3.76; SD=1.089; R=5). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that the application of Virtual Reality (VR) allowed costly mistakes to be identified and rectified before they occurred and fostered easy communication among site and office staff among medium contractors, p<.001. These findings were concurred with Bouchlaghem and Liyanage (1996: 4) who stated that VR allows a person to move around a building observing the characteristics of its behaviour and matching the effects of that behaviour as quickly as possible.

Safety systems in construction sites have integrated the usage of the Internet of Things (IoT).

The use of the Internet of Things (IoT) among medium contractors was ranked sixth ($\bar{X}$=3.63; SD=1.018; R=6). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that safety systems in construction sites had integrated the use of the Internet of Things (IoT) among medium contractors, p<.001. These findings were in agreement with LI 2017: (305-306) who stated that safety systems in construction sites incorporate Internet of Things (IoT) systems by adopting different technological features such as sensors, drones, robots, laser scanning and data analysis and management.

Cyber Physical System (CPS) operations are used for monitoring (plant and equipment), coordinating, progress tracking, construction process control, and as-built documentation.

The utilisation of Cyber Physical System (CPS) operations to monitor plant and equipment among medium contractors was rated seventh ($\bar{X}$=3.49; SD=1.040; R=7). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement on utilisation of Cyber Physical System (CPS) operations in monitoring plant and equipment, coordinating, progress tracking, construction process control, and as-built document among medium contractors, p=.002. These findings were in agreement with Yuan, Anumba and Parfitt (2015: 32), who claimed that the use of CPS and its potential benefits have been explored in different fields of the construction industry, including the project delivery process.

Radio Frequency Identification (RFID) technology is used to address the challenges associated with tracking resources on construction sites.

The use of Radio Frequency Identification (RFID) technology to address the challenges associated with tracking resources on construction sites among medium contractors was ranked eighth ($\bar{X}$=3.46; SD=1.174; R=8). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that the use of Radio Frequency Identification (RFID) technology could address the challenges associated with tracking resources on construction sites among medium contractors, p=.003. These findings were in agreement with Lu, Huang and Li (2011: 101) who claimed that RFID is an attractive technology that has potential to address the challenges associated with tracking resources on construction sites.

4.2.3.2.2 Large Contractors Responses

The results presented in Table 21 were obtained from respondents' rankings of the variables using a five-point Likert scale where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. The rankings were used to measure the perceived and actual benefits of implementing smart technology as an element of the Fourth Industrial Revolution (4IR) within construction sites and offices of large construction firms in Durban. The result revealed that the use of "electronic procurement (e-procurement)" i.e. electronic communication technologies (ICT) in conducting construction business operations was most beneficial and it was ranked first with a mean score of 4.51 and standard deviation (SD) of 0.644. However, the results also showed that the implementation of robotic technology and utilisation of Building Information Modelling (BIM) in planning and procuring a construction project would be most beneficial in the current era of industry revolution as they were ranked second with a mean of 4.13 and standard deviation (SD) = 0.741 and third with mean score of 4.09 and standard deviation (SD) = 0.919 respectively. Thus, the general perception was that the implementation of Three-Dimensional (3D) technology and application of Virtual Reality (VR) would significantly enhance construction delivery as they were ranked fourth with mean score of 3.97 and standard deviation (SD) of 0.890 and fifth with mean score of 3.93 and standard deviation (SD) of 0.842 respectively. The use of Radio Frequency Identification (RFID) technology to address the challenges associated with tracking resources on construction sites among large contractors was ranked sixth, with mean score of 3.90 and standard deviation of 0.860. In addition, results of the study show that the use of the Internet of Things (IoT), and Cyber Physical System (CPS) operations to monitor (plant and equipment) has significant potential to advance construction delivery as they were ranked sixth with a mean score of 3.90 and standard deviation of 0.772; and seventh with a mean score of 3.87 and standard deviation of 0.548 respectively.

Table 22: Response Analysis from Large Contractors on Benefits of Implementing of ICT technologies within Construction Sites and Offices: Large Contractors' Perspectives

Questions	Mean Score	Std. Dev	Asymp. Sig (2-sided)	Rank
Q2.3: Electronic procurement (e-procurement) utilising the electronic communication technologies (ICT), is used in transaction processes to buy services, goods and works so as to improve delivery, reduce paperwork and lower administrative costs	4.41	0.91	0.000	1
Q2.4: Implementation of robotic technology has the capability to generate higher output at a lower unit cost with better quality product.	4.13	0.74	0.000	2
Q2.1: The use of Building Information Modelling (BIM) in planning and procuring a construction project benefits all phases of the facility's life cycle.	4.09	0.92	0.000	3
Q2.2: Implementing Three-Dimensional (3D) technology brings significant benefits to the organisation, in terms of increased customisation, reduced construction time, reduced manpower and construction cost.	3.97	0.89	0.000	4
Q2.5: Application of Virtual Reality (VR) allows costly mistakes to be identified and rectified before they occur and	3.93	0.84	0.000	5

fosters easy communication among site staff and office staff.				
Q2.6: Safety systems in construction sites have integrated the usage of the Internet of Things (IoT).	3.9	0.77	0.000	6
Q2.8: Cyber Physical System (CPS) system operations are used for monitoring (plant and equipment), coordinating, progress tracking, construction process control, and as-built documentation.	3.87	0.55	0.000	7
Q2.7: Radio Frequency Identification (RFID) technology is used to address the challenges associated with tracking resources on construction sites.	3.9	0.86	0.000	8

Based on the ranking (R), using the computer calculated standard deviation (SD) and mean score ($\bar{X}$) for the actual benefits of implementing smart technology as an element of the Fourth Industrial Revolution (4IR) within construction sites and offices of construction companies in the eThekwini District Municipality of KwaZulu Natal, the following findings emerged:

Electronic procurement (e-procurement), which utilises electronic communication technologies (ICT), is used in transaction processes to buy services, goods, and works so as to improve delivery, reduce paperwork and lower administrative costs.

Electronic procurement is the most utilised technology among large contractors ($\bar{X}$=4.51; SD=0.644; R=1). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that electronic procurement is the most utilised technology among large contractors, $p<.001$.

The implementation of robotic technology has the potential to generate higher outputs at a lower unit cost, with better quality products.

The implementation of robotic technology among large contractors had a mean score of 4.13 and standard deviation (SD) of 0.741; R=2. Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that the implementation of robotic technology has the capability to generate higher outputs at a lower unit cost, with better quality products among large contractors, $p<.001$.

The use of Building Information Modelling (BIM) in planning and procuring a construction project benefits all phases of the facility's life cycle.

The use of Building Information Modelling (BIM) in planning and procuring a construction project benefits all phases of the facility's life cycle among large contractors ($\bar{X}$=4.09; SD=0.919; R=3). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that the use of Building Information Modelling (BIM) in planning and procuring a construction project is beneficial to all phases of the facility's life cycle among large contractors, p<.001.

Implementing Three-Dimensional (3D) technology brings significant benefits to the organisation, in terms of increased customisation, reduced construction time, reduced manpower and construction cost.

Implementing Three-Dimensional (3D) technology among large contractors had a mean score of 3.97 and standard deviation (SD) of 0.890; R=4. Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that the implementation of Three-Dimensional (3D) technology could bring significant benefits to the organisation, reduce construction time, manpower and construction cost among large contractors, p<.001.

Application of Virtual Reality (VR) allows costly mistakes to be identified and rectified before they occur and allows easy communication among site and office staff.

Application of Virtual Reality (VR) among large contractors had a mean score ($\bar{X}$) of 3.93 and standard deviation (SD) of 0.842; R=5. Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that the application of Virtual Reality (VR) allowed costly mistakes to be identified and rectified before they occurred and facilitated easy communication between site staff and office staff of large contractors, p<.001.

Safety systems in construction sites have integrated the use of the Internet of Things (IoT).

The use of the Internet of Things (IoT) among large contractors had a mean score ($\bar{x}$) of 3.90 and a standard deviation (SD) of 0.772; R=6. Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that safety systems in construction sites have integrated the use of the Internet of Things (IoT) among large contractors, $p<.001$.

Cyber Physical System (CPS) operations are used for monitoring (plant and equipment), coordinating, progress tracking, construction process control, and as-built documentation.

The use of Cyber Physical System (CPS) operations to monitor (plant and equipment) among large contractors had a mean score ($\bar{x}$) of 3.87 and a standard deviation (SD) of 0.548; R=7. Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that the use of Cyber Physical System (CPS) operations were used for monitoring (plant and equipment), coordinating, progress tracking, construction process control, and as-built document among large contractors, $p<.001$. These findings were in agreement with Yuan, Anumba and Parfitt (2015: 32) who claimed that the use of CPS and its potential benefits have been explored in different fields of the construction industry, including the project delivery process.

Radio Frequency Identification (RFID) technology is used to address the challenges associated with tracking resources on construction sites.

The use of Radio Frequency Identification (RFID) technology to address the challenges associated with tracking resources on construction sites among large contractors had a mean score ($\bar{x}$) of 3.90 and a standard deviation (SD) of 0.860; R=6. Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that Radio Frequency Identification (RFID) technology was used to address the challenges associated with tracking resources on construction sites among large contractors, $p<.001$. These findings were in agreement with Lu, Huang and Li (2011: 101) who claimed that RFID is an attractive technology that has potential to address the challenges associated with tracking resources on construction sites.

4.2.3.2.3 Merged Findings from both Medium and Large contractors as shown in Tables 21 and 22.

Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that the use of Building Information Modelling (BIM) in planning and procuring construction projects was more beneficial to all phases of the facility's life cycle among medium contractors than among large contractors, p<.001. in addition, findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that the implementation of Three-Dimensional (3D) technology would bring significant benefits such as reducing construction time, manpower and construction cost to large contractors compared to medium contractors, p<.001. In addition, the findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that electronic procurement was the most utilised technology among large contractors compared to medium contractors, p<.001, whilst there was also significant agreement that the implementation of robotic technology had the capability to generate higher outputs at a lower unit cost, with better quality product among large contractors compared to medium contractors, p<.001.

Moreover, the findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that the application of Virtual Reality (VR) allowed costly mistakes to be identified and rectified before they occurred and facilitated easy communication among site and office staff among large contractors compared to medium contractors, p<.001, whereas there was significant agreement that safety systems in construction sites among large contractors had integrated the use of the Internet of Things (IoT) more than medium contractors, p<.001. In addition, findings from the analysis using chi-square goodness of-fit-test indicated that there was significant agreement that large contractors used of Radio Frequency Identification (RFID) technology to address the challenges associated with tracking resources on construction sites more than medium contractors, p=.003. There was also significant agreement that the use of Cyber Physical System (CPS) operations for monitoring (plant and equipment), coordinating, progress tracking, construction process control, and as-built document was higher among large contractors compared to medium contractors, p=.002.

The Wilcoxon rank sum test is a nonparametric test that was used to assess whether the distribution of observations obtained from two separate groups on a dependent variable are systematically different. Non-parametric tests, also called distribution-free tests, were employed in order to compare the opinions of the respondents in relation to the objectives of this section. This study adopted the Wilcoxon rank sum test and Mann-Whitney U non-parametric test to analyse the retrieved data.

Table 23: Cronbach's Alpha Score

Implementing of new technologies within construction site and office	Medium	Large
No. of Items	8	8
Cronbach's Alpha Score	0.907	0.840

A combination of these 8 items obtained by averaging agreement scores across all items yielded a reliable composite measure for benefit of implementation (BOI) for each group. Reliability was confirmed using Cronbach's alpha. Alpha = .907 (medium) and .840 (large). For this section, the Cronbach's alpha value ranged between 0.840 and 0.907 as indicated in Table 23, which shows that the data collection instrument was reliable and the responses obtained from it are reliable and valid.

Table 24: Analysis of Implementation using Wilcoxon Rank Sum Test

Implementing of new technologies within construction site and office	Median	Asymp. Sig (2-sided)
Medium size contractors	4.00	0.001
Large size contractors	4.25	0.001

Table 24 presents the Wilcoxon rank sum test. The analysis of this composite measure shows that there was significant agreement that smart technology was implemented within construction sites and offices of medium and large contractors, (median = 4.00), p<.001 for medium group and (median = 4.25), p<.001 for large group.

Table 25: Analysis of Implementation using Mann Whitney Test

Implementing of new technologies within construction site and office as an element of 4IR	Mean	Mann-Whitney test	Asymp. Sig (2-sided)
Medium size contractors	3.765	-6.525	0.000
Large size contractors	4.066	-5.245	0.000

Table 25 presents the analysis across groups using the Mann Whitney test. The analysis shows that the level of agreement on the implementation of smart technology was significantly higher among large contractors than medium contractors, p=.034. However, based on the results that emanated from the study, it is evident that a significant number of respondents were of the opinion that the implementation of smart technology would benefit construction sites and office operations. Sig. observed significant often called the p-value. It is the basis for deciding whether or not to reject the null hypothesis. If the observed significance is small enough usually less than 0.05 or 0.01 the null hypothesis is rejected (Creedy*,* 2018: 98). The test of the H2o is rejected and alternative H2a: The implementation of emerging ICT technologies in project design, procurement and delivery of construction projects in Durban is at an average level.

4.2.3.3 The Appreciation of the Advantages of New Emerging Technologies Presently Linked to the Fourth Industrial Revolution

Questionnaires were used in the collection of data. A 5 point rating scale where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree was used to measure the actual levels of commitment to advance new emerging technologies. Tables 26 and 27 present the respondents' rankings of the appreciation of the advantages of new emerging technologies presently linked to Fourth Industrial Revolution (4IR). The respondents' rankings of the advantages of new emerging technologies in relation to project design, procurement, construction, cost, time, quality, and environmental health and safety and delivery were as follows:

4.2.3.3.1 Medium Contractors' Responses

The results in Table 26 were obtained from Medium contractors' rankings of the variables using a five-point Likert scale where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. The rankings were used to measure the construction organisation's "management dedication" to promote the use of new technology to improve performance in project design, procurement, construction, cost, time, quality, and environmental health and safety and Delivery. Medium contractors ranked first with mean score of 4.29 and standard deviation (SD) = 0.779. The propositions “top management support and promotion of the new emerging technology” to ensure increased “control of environmental health” and “safety of workers and project” and “top management support and promotion” of the new emerging technologies aligned with its “organisational strategy” were ranked second with a mean score of 4.21 and standard deviation (SD) = 0.793, and third with mean score of 4.20 and standard deviation (SD) = 0.878 respectively. Thus, the results of the study reveal that “management motivation of employees to upskill” in areas of the Fourth Industrial Revolution to “enhance competencies” on the latest construction technologies and to ensure overall competitiveness of the organisation’s skillset were ranked fourth with a mean score of 4.19 and standard deviation (SD) of 0.782; whereas “management’s understanding of the benefits and impact” of using emerging technologies to enhance construction project delivery was ranked fifth with a mean score of 4.18 and standard deviation (SD) of 0.889.

In addition, the findings reveal that “organisational culture and participation in the use of new technologies to ensure success of project delivery” was ranked sixth with a mean score of 4.05 and standard deviation (SD) of 0.891. The “organisation’s financial capacity” had a significant impact on integration and successful implementation of new technologies to enhance overall project delivery in term of site management and reduction of cost and time and was ranked seventh with a mean score of 3.96 and standard deviation (SD) of 0.884. The results of the study also reveal that “organisational financial capacity” had a significant impact on the integration and successful implementation of new technologies to enhance overall project delivery in terms of site management and reduction of health and safety challenges” as it was ranked eighth with mean score of 3.93 and standard deviation (SD) of 1.067. The findings further reveal that “management investment in the latest technologies such as Internet of Things (IoT), 3D Printing, Virtual Reality (VR), Building Information Modelling (BIM), robotics and wireless sensor technology would enhance the organisations’ business operations as it was ranked ninth, with a mean score of 3.34 and standard deviation (SD) of 0.888. The finding that “employees in the organisation were not experiencing emotional stress and fear of losing jobs to automation” and other elements of fourth industrial revolution was ranked tenth with a mean score of 2.26 and standard deviation (SD) of 0.930;

Table 26: Response Analysis from Medium Contractors on Commitment to Advance New Emerging Technologies: Medium Contractors' Perspectives

Questions	Mean Score	Std. Dev	Asymp. Sig (2-sided)	Rank
Q3.1: Management promotes the use of new technology to improve performance in your organisation	4.29	0.779	0.000	1
Q3.6: Top management support and promote new emerging technology in order to ensure increased control of environmental health and safety of workers and project	4.21	0.891	0.000	2
Q3.4: Top management support and promote new emerging technology that is aligned with its organisational strategy	4.20	0.782	0.000	3
Q3.7: Management motivate employees to upskilling training in areas of fourth industrial revolution in order to enhance their competencies on the latest construction technologies, and to ensure overall competitiveness of the organisation's skillset	4.19	0.884	0.000	4
Q3.2: Management understands the benefit and impact of using emerging technology to enhance construction project delivery	4.18	0.783	0.000	5
Q3.5: Your organisation's culture towards the new technology has been shown to have significant influence on the success of project delivery	4.05	0.889	0.000	6
Q3.10: Your organisation's financial capacity has a significant impact on integration and successful implementation of new technologies in order to enhance overall project delivery in terms of site management and reduction of cost and time reduction	3.96	0.930	0.000	7
Q3.9: Your organisation's financial capacity has a significant impact on integration and successful implementation of new technologies in order to enhance overall project	3.93	0.888	0.000	8

delivery in terms of site management and reduction of health and safety challenges				
Q3.3: Management invests in the latest technology such as Internet of Things (IoT), 3D Printing, Virtual Reality (VR), Building Information Modelling (BIM), robotics and wireless sensor technology	3.34	0.878	0.000	9
Q3.8: Employees in your organisation are not experiencing emotional stress fearing job loss to automation and elements of fourth industrial revolution	2.26	1.067	0.000	10

Based on the ranking (R) using the computer calculated standard deviation (SD) and mean score ($\bar{X}$) of the appreciation of the advantages of new emerging technologies presently linked to Fourth Industrial Revolution (4IR), the following results emerged from the data:

Management promotes the use of new technology to improve performance in the organisation.

Management's commitment to the promotion of new technologies to improve performance was ranked first among the medium contractors ($\bar{X}$=4.29; SD=0.779; R=1). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that management was committed to promote the use of new technologies to improve performance among medium contractors, $p<.001$.

Top management support and promote new emerging technology in order to ensure increased control of environmental health and safety of workers and the project

Top management support and promotion of the new emerging technologies to ensure increased control of environmental health and safety of workers and the project among medium contractors was ranked second: ($\bar{X}$=4.21; SD=0.783; R=2). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement among medium contractors that top management supported and promoted the use new emerging technologies to ensure increased control of environmental health and safety of workers and the project, $p<.001$.

Top management support and promote new emerging technology that is aligned with its organisational strategy

Among medium contractors, top management support and promotion of new emerging technologies aligned with organisational strategy was ranked third ($\bar{X}$=4.20; SD=0.878; R=3). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that top management supported and promoted the use of new emerging technologies that were aligned with organisational strategy $p<.001$.

Management motivate employees to upskill training in areas of Fourth Industrial Revolution to enhance competencies in the latest construction technologies and to ensure overall competitiveness of the organisation's skillset

Among medium contractors, management's motivation of employees to upskill in areas of the Fourth Industrial Revolution to enhance competencies in the latest construction technologies and to ensure overall competitiveness of the organisation's skillset was ranked fourth ($\bar{X}$=4.19; SD=0.782; R=4). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that management motivated employees to upskill in areas of the Fourth Industrial Revolution to enhance competencies in latest construction technologies and to ensure overall competitiveness of the organisation's skillset $p<.001$.

Management understands the benefits and impact of using emerging technology to enhance construction project delivery

Management's understanding of the benefits and impact of using emerging technology to enhance construction project delivery among medium contractors was ranked fifth ($\bar{X}$=4.18; SD=0.889; R=5). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that management understood the benefits and impact of using emerging technology to enhance construction project delivery among medium contractors, $p<.001$.

Your organisation's culture towards the new technology has been shown to have a significant influence on the success of project delivery.

The influence of organisational culture on uptake new technology to enhance the success of project delivery among medium contractors was ranked sixth ($\bar{X}$=4.05; SD=0.891; R=6). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that organisational culture towards new technology participation has influence on the success of project delivery among medium contractors, $p<.001$.

Your organisation's financial capacity has a significant impact on the integration and successful implementation of new technologies to enhance overall project delivery in terms of site management and reduction of cost and time.

The organisation's financial capacity and its impact on the integration and successful implementation of new technologies to enhance overall project delivery in terms of site management and reduction of cost and time among medium contractors was ranked seventh ($\bar{X}$=3.96; SD=0.884; R=7). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that the organisation's financial capacity has a significant impact the integration and successful implementation of new technologies to enhance overall project delivery in terms of site management and reduction of cost and time among medium contractors, $p<.001$.

Your organisation's financial capacity has a significant impact on the integration and successful implementation of new technologies to enhance overall project delivery in term of site management and reduction of health and safety challenges.

The organisation's financial capacity and its impact on the integration and successful implementation of new technologies to enhance overall project delivery in terms of site management and reduction of health and safety challenges among medium contractors was ranked eighth ($\bar{X}$=3.93; SD=1.067; R=8). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that the organisation's financial capacity has a significant impact on the integration and successful implementation of new technologies to enhance overall project delivery in terms of site management and reduction of health and safety challenges among medium contractors, $p<.001$.

Management Investment in the Latest Technology, such as Internet of Things (IoT), 3D Printing, Virtual Reality (VR), Building Information Modelling (BIM), Robotics and Wireless Sensor Technology.

Management investment in the latest technologies such as Internet of Things (IoT), 3D Printing, Virtual Reality (VR), Building Information Modelling (BIM), Robotics and wireless sensor technology among medium contractors was ranked ninth ($\bar{X}$=3.34; SD=0.888; R=9). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that management invested in latest technologies such as Internet of Things (IoT), 3D Printing, Virtual Reality (VR), Building Information Modelling (BIM), Robotics and wireless sensor technology, in medium contractors, $p=.001$. Brewer and Gajendram (2011: 638) suggested that management were reluctant to wholeheartedly invest their time and effort in latest technology.

Employees in your organisation are not experiencing emotional stress fearing job loss to automation and elements of the Fourth Industrial Revolution.

The finding that employees in the organisation were not experiencing emotional stress fearing job loss to automation and elements of the Fourth Industrial Revolution among medium contractors was ranked tenth ($\bar{X}$=2.26; SD=0.930; R=10). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that employees were not experiencing emotional stress fearing job loss to automation and elements of the Fourth Industrial Revolution among medium contractors, $p<.001$.

In brief, the relative high mean score from Table 26, in terms of commitment from management makes it clear that the participants believed that management promoted the use of new technology to improve performance in their organisations. It also shows that top management supported and promoted new emerging technologies to ensure increased control of environmental health and safety of workers and projects. Top management also supported and promoted new emerging technologies that were aligned with organisational strategy and motivate employees towards upskilling in areas of the Fourth Industrial Revolution to enhance competencies in the latest construction technologies and to ensure overall competitiveness of the organisation's skillset. Management also understood the benefits and impact of using emerging technology to enhance construction project delivery and they were committed to advance new emerging technologies presently linked to fourth industrial revolution. These findings are in agreement with Fouche, Smallwood and Emuze (2011: 10) who found that firms tend to ensure that management embrace and enhance the overall level of technology in the firm.

It can also be interpreted from the above table that management invested in the latest technologies such as Internet of Things (IoT), 3D Printing, Virtual Reality (VR), Building Information Modelling (BIM), Robotics and wireless sensor technology and employees were not experiencing emotional stress fearing job loss to automation and elements of the Fourth Industrial Revolution. As a result these were the least factor that aided commitment to advance new emerging technologies presently linked to the Fourth Industrial Revolution. The average mean score could be caused by management's reluctance to wholeheartedly invest time and effort in new technologies due to cultural issues rooted in attitudes and behaviour (Fouche, Smallwood and Emuze, 2011: 10).

4.2.3.3.2 Large Contractors' Responses

The results presented in Table 27 were obtained from respondents' rankings of the variables using a five-point Likert scale where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. The rankings were used to measure an organisation's commitment to advancing new emerging technologies in construction operations amongst large construction firms in Durban. The results of the findings revealed that "management's dedication to promote" the use of new technology to improve performance was ranked first with a mean score of 4.31 and standard deviation (SD) = 0.694, whereas there was a perception that the "organisation's financial capacity has a significant impact on the integration and successful implementation of new technologies to enhance overall project delivery" in terms of "site management and reduction of cost" and "time reduction" and this was ranked second, with a mean score of 4.26 and standard deviation (SD) = 0.191. the finding that the organisation's financial capacity had a significant impact on the integration and successful implementation of new technologies to enhance overall project delivery in terms of site management and reduction of health and safety challenges was ranked third, with a mean score of 4.21 and standard deviation (SD) = 0.923.

In addition, the findings revealed that “management’s understanding of the benefits and impact” of using emerging technology to enhance construction project delivery was ranked fourth, with a mean score of 4.08 and standard deviation (SD) = 0.839; and “top management support and promotion” of the new emerging technology “aligned with its organisational strategy” was ranked fifth, with a mean score of 4.05 and standard deviation (SD) = 0.647; whereas “management motivation of employees to upskill training” in areas of the Fourth Industrial Revolution to enhance their competencies in the latest construction technologies to ensure overall competitiveness of the organisation’s skillset was ranked sixth, with mean score of 4.00 and standard deviation (SD) = 0.688.

Moreover, the findings showed that “top management support and promotion of the new emerging technologies to ensure increased control of environmental health and safety of workers and projects was ranked seventh, with a mean score of 3.95 and standard deviation (SD) = 0.724; and “effect of organisational culture towards uptake of new technology” to ensure success of project delivery was ranked eighth, with a mean score of 3.82 and standard deviation (SD) = 0.766. On the other hand, “management’s investment in the latest technology”, such as Internet of Things (IoT), 3D Printing, Virtual Reality (VR), Building Information Modelling (BIM), Robotics and wireless sensor technology was ranked ninth, with a mean score of 3.33 and standard deviation (SD) = 0.890. Thus, the findings further revealed that “employees in the organisations were not experiencing emotional stress” fearing job loss to automation and elements of the Fourth Industrial Revolution was ranked tenth, with a mean score of 2.21 and standard deviation (SD) = 1.082.

Table 27: Response Analysis from Large Contractors on Commitment to Advance New Emerging Technologies

Questions`	**Mean**	**Std. Dev**	**Asymp. Sig (2-sided)**	**Rank**
Q3.1: Management promotes the use of new technology to improve performance in your organisation	4.31	0.694	0.000	1

Q3.4: Top management support and promote new emerging technology that is aligned with its organisational strategy	4.26	0.191	0.000	2
Q3.9: Your organisation's financial capacity has a significant impact integration and successful implementation of new technologies in order to enhance overall project delivery in terms of site management and reduction of health and safety challenges	4.21	0.923	0.000	3
Q3.5: Your organisation's culture towards the new technology has been shown to have a significant influence on the success of project delivery	4.08	0.839	0.000	4
Q3.8: Employees in your organisation are not experiencing emotional stress fearing job loss to automation and elements of fourth industrial revolution	4.05	0.647	0.000	5
Q3.7: Management motivate employees to upskilling training in areas of fourth industrial revolution in order to enhance their competencies in the latest construction technologies, and to ensure overall competitiveness of the organisation's skillset	4.00	0.688	0.000	6
Q3.6: Management understands the benefit and impact of using emerging technology to enhance construction project delivery	3.95	0.724	0.000	7
Q3.10: Your organisation's financial capacity has a significant impact integration and successful implementation of new technologies in order to enhance overall project delivery in terms of site management and reduction of cost and time reduction.	3.82	0.766	0.000	8
Q3.3: Management invest in the latest technology, such as Internet of Things (IoT), 3D Printing, Virtual Reality (VR), Building Information Modelling (BIM), Robotics and wireless sensor technology.	3.33	0.890	0.000	9
Q3.2: Management understand the benefit and impact of using emerging technology to enhance construction project delivery	2.21	1.082	0.000	10

Based on the ranking (R) using the computer calculated standard deviation (SD) and mean score ($\bar{X}$) for the appreciation of the advantages of new emerging technologies presently linked to the Fourth Industrial Revolution (4IR), the following results emerged from the data:

Management promotes the use of new technology to improve performance in your organisation

Management's commitment to the promotion of new technologies to improve performance among the large contractors had mean score ($\bar{x}$) of 4.31; and a standard deviation (SD) of 0.694; R=1. Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that management was committed to the promotion of new technology to improve performance among large contractors, $p<.001$.

Top management support and promote new emerging technology that is aligned with its organisational strategy

Top management support and promotion of new emerging technology that is aligned with its organisational strategy in large contractors had a mean score ($\bar{x}$) of 4.26 and a standard deviation (SD) of 0.191; R=2. Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that top management supported and promoted new emerging technologies aligned with its organisational strategy among large contractors, $p<.001$.

Your organisation's financial capacity has a significant impact integration and successful implementation of new technologies in order to enhance overall project delivery in terms of site management and reduction of health and safety challenges

The organisation's financial capacity and its impact on the integration and successful implementation of new technologies to enhance overall project delivery in terms of site management and reduction of health and safety challenges in large contractors had a mean score and standard deviation of ($\bar{x}$=4.21; SD=0.923; R=3). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that the organisation's financial capacity has a significant impact on the integration and successful implementation of new technologies to enhance overall project delivery in terms of site management and reduction of health and safety challenges among large contractors, $p<.001$.

Your organisation's culture towards the new technology has been shown to have a significant influence on the success of project delivery

Organisational culture towards the new technology participation for the success of project delivery in large contractors had a mean score and standard deviation of ($\bar{X}$=4.08; SD=0.839; R=4). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that organisation culture towards the new technology participation influenced the success of project delivery among large contractors, $p<.001$.

Employees in your organisation are not experiencing emotional stress fearing job loss to automation and elements of Fourth Industrial Revolution

The finding that employees in the organisation are not experiencing emotional stress fearing job loss to automation and elements of fourth industrial revolution in large contractors had a mean score and a standard deviation of ($\bar{X}$=4.05; SD=0.647; R=5). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that employees were not experiencing emotional stress fearing job loss to automation and elements of the Fourth Industrial Revolution among large contractors, $p<.001$.

Management motivate employees to upskill in areas of the Fourth Industrial Revolution to enhance competencies in the latest construction technologies and to ensure overall competitiveness of the organisation's skillset

Management's motivation of employees to upskill in areas of Fourth Industrial Revolution to enhance competencies in the latest construction technologies and to ensure overall competitiveness of the organisation's skillset among large contractors had a mean score and a standard deviation of ($\bar{X}$=4.00; SD=0.688; R=6). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that management's motivation of employees to upskill in areas of the Fourth Industrial Revolution to enhance competencies on the latest construction technologies and to ensure overall competitiveness of the organisation's skillset among large contractors, $p<.001$.

Management understands the benefits and impact of using emerging technology to enhance construction project delivery

Management's understanding of the benefits and impact of using emerging technology to enhance construction project delivery in large contractors had a mean score and standard deviation of ($\bar{X}$=3.95; SD=0.724; R=7). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that management understood the benefits and impact of using emerging technology to enhance construction project delivery among large contractors $p<.001$.

Your organisation's financial capacity has a significant impact on the integration and successful implementation of new technologies to enhance overall project delivery in terms of site management and cost and time reduction

The finding that the organisation's financial capacity had a significant impact on the integration and successful implementation of new technologies to enhance overall project delivery in terms of site management and cost and time reduction among large contractors had a mean score and a standard deviation of ($\bar{X}$=3.82; SD=0.766; R=8). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that the organisation's financial capacity has a significant impact on the integration and successful implementation of new technologies to enhance overall project delivery in terms of site management and cost and time reduction among large contractors, $p<.001$.

Management investment on latest technology such as Internet of Things (IoT), 3D Printing, Virtual Reality (VR), Building Information Modelling (BIM), Robotics and wireless sensor technology

Management investment on latest technology such as Internet of Things (IoT), 3D Printing, Virtual Reality (VR), Building Information Modelling (BIM), Robotics and wireless sensor technology among large contractors had a mean score and a standard deviation of ($\bar{X}$=3.33; SD=0.890; R=9). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that management invested in the latest technologies such as Internet of Things (IoT), 3D Printing, Virtual

Reality (VR), Building Information Modelling (BIM), Robotics and wireless sensor technology among large contractors, $p<.001$.

Management understands the benefits and impact of using emerging technology to enhance construction project delivery

Management's understanding of the benefits and impact of using emerging technology to enhance construction project delivery among large contractors had a mean score and a standard deviation of ($\bar{X}$=2.21; SD=1.082; R=10). Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that management understood the benefits and impact of using emerging technology to enhance construction project delivery among large contractors, $p<.001$.

In brief, from the relatively high mean score from Table 27, in terms of commitment's commitment to new technologies shows that the participants believed that management promoted the use of new technology to improve performance in the organisation. Top management also supported and promoted new emerging technologies aligned with its organisational strategy and the organisation's financial capacity had a significant impact on the integration and successful implementation of new technologies to enhance overall project delivery in terms of site management and reduction of health and safety challenges. In addition, the organisation's culture towards the new technology has a significant influence on the success of project delivery and employees were not experiencing emotional stress fearing job loss to automation and elements of the Fourth Industrial Revolution.

It is also evident from the a table that management invested in the latest technology such as Internet of Things (IoT), 3D Printing, Virtual Reality (VR), Building Information Modelling (BIM), Robotics and wireless sensor technology and understood the benefits and impact of using emerging technology to enhance construction project delivery as this was the least noted factor that aided commitment to advance new emerging technologies. The average mean score could be attributed management's reluctance to wholeheartedly invest time and effort into new technology due to cultural issues rooted in attitudes and behaviour (Fouche, Smallwood and Emuze, 2011: 10). Furthermore it could be that management lacks an innovative and entrepreneurial spirit to make business decisions and adapt to new changes, leading to ossification (Churchill and Lewis, 1983: 6).

4.2.3.3.3 Merged Findings from both Medium and Large contractors as shown in the Tables 26 and 27

Findings from the analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that management's commitment to the use of new technology improve performance among large contractors compared to medium contractors, $p<.001$. In addition, the findings from the analysis using chi-square goodness-of-fit-test, indicate that there was significant agreement that management's understanding of the benefits and impact of using emerging technology to enhance construction project delivery was higher among medium contractors than large contractors, $p<.001$. Also, findings from the analysis using chi-square goodness-of-fit-test indicate that there was significant agreement that management investment in the latest technology, such as Internet of Things (IoT), 3D Printing, Virtual Reality (VR), Building Information Modelling (BIM), Robotics and wireless sensor technology was higher among medium contractors compared to large contractors, $p<.001$. The mean score was average, and the findings were similar to those of with Oesterreich and Teuteberg (2016: 122), who stated that lack of innovation and technological advances in the construction industry are accompanied by limited investment in research and development.

In addition, findings from the data analysis using chi-square goodness-of-fit-test confirmed that there was significant agreement that medium contractors' top management supported and promoted new emerging technology that was aligned with their organisational strategy more than large contractors, $p<.001$; whereas the findings from the collected data analysis using chi-square goodness-of-fit-test show that there was significant agreement that the organisational culture of medium contractors and attitude towards new technology had significant influence on the success of project delivery compared to the organisational culture of large contractors, $p<.001$. These findings corroborate those of Churchill and Lewis (1983:6) who state that any organisation/contractor at stage-V (mature/ large firm) that lacks an innovative and entrepreneurial spirit to make business decisions and adapt to new changes will grow into ossification (inability of a business to grow further in the market).

Thus, the findings from the data analysis using chi-square goodness-of-fit-test confirmed that there was significant agreement that top management among medium contractors supported and promoted new emerging technology to ensure increased control of environmental health and safety of workers and projects more than large contractors, $p<.001$. findings from the analysis using chi-square goodness-of-fit-test further also supported that there was significant agreement that management amont medium contractors motivated employees to upskill themselves in areas of the Fourth Industrial Revolution to enhance t competencies on the latest construction technologies and to ensure overall competitiveness of the organisation's skillset more than among, large contractors, $p<.001$. In addition, the findings from the data analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that employees from medium contractors were not experiencing emotional stress fearing job loss to automation and elements of the Fourth Industrial Revolution in compared to employees from large contractors, $p<.001$.

Furthermore, the findings emanating from the data analysis using chi-square goodness-of-fit-test indicated that there was significant agreement that an organisation's financial capacity among large contractors had a significant impact on the integration and successful implementation of new technologies to enhance overall project delivery in term of site management and reduction of health and safety challenges in compared to medium contractors, $p<.001$, Moreover, the findings from the analysis using chi-square goodness-of-fit-test validated that there was significant agreement that an organisation's financial capacity among large contractors had a significant impact on the integration and successful implementation of new technologies to enhance overall project delivery in terms of site management and cost and time reduction than among medium contractors, $p<.001$. Non-parametric tests, also called distribution-free tests, were employed to compare the opinions of the respondents in relation to the objectives of this section. Mann-Whitney U non-parametric test were used to analyse the retrieved data for this section.

Table 28: Reliability Confirmation of Commitment using Cronbach's Alpha Score

Commitment to advance with new emerging technologies	Medium	Large
No. of Items	10	10
Cronbach's Alpha Score	0.861	0.851

Average agreement scores across all questions yielded a reliable composite measure for commitment to advance new emerging technologies for each group. Thus, the reliability was confirmed using Cronbach's alpha: Alpha = .861 (medium) and .851 (large). For this section, the Cronbach's alpha value ranged between 0.851 and 0.861 as indicated in Table 28, which shows that the data collection instrument was reliable and the responses obtained from it was valid.

Table 29: Analysis of Commitment using Mann Whitney Test

Commitment to advance with new emerging technologies	Mean	Mann-Whitney test	Asymp. Sig (2-sided)
Medium size contractors	4.0382	-7.547	0.000
Large size contractors	3.9684	-5.041	0.000

Table 29 presents an analysis across groups using the Mann Whitney test. The analysis shows that the level of agreement on commitment to advance new emerging technologies was significantly higher among medium contractors than among large contractors, $p<.001$.

The test of the H3o is rejected and alternative H3a: The level of readiness for and appreciation of the benefits of the 4th industrial revolution in terms of design, construction, cost, time, quality, and environmental health and safety is at a basic level.

4.3 Conclusion

In this chapter, each question was analysed and data were presented in the form of tables and graphs. The findings were discussed in line with the research objectives.

5 CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This study consists of 5 chapters. Chapter 1 covered the current literature on the Fourth Industrial Revolution and the attendant emerging technologies. It provided a background to the study and a brief conceptual framework of digital transformation. Chapter 2 identified the key elements of Fourth Industrial Revolution and associated technologies as well as their indisputable impact on the transformation of entire systems across countries, companies, industries, and society as a whole. The chapter explored narratives about readiness of construction companies to embrace and implement Industry 4.0 technologies. Chapter 3 discussed the research methodology and the research methods adopted in the study as well as the data collection and sampling techniques. Chapter 4 presented and analysed data analysis in relation to literature and the adopted research methodologies as explained in Chapter 3.

This chapter presents the conclusions drawn from the in-depth data analysis. It provides recommendations for future research on emerging ICT technologies. The aim of the study was to assess the actual depth of utilisation and the impact of, the Fourth Industrial Revolution and emerging ICT technologies on construction companies in Durban, with specific focus on project design, procurement, construction, delivery, operation and maintenance.

5.2 Summary of findings

The findings of the study are summarised in line with the research objectives. The first objective was to assess the level of awareness and knowledge of the concept of the Fourth Industrial Revolution and emerging ICT technologies among construction companies in Durban in relation to project delivery. The second objective was to assess perceptions on the actual benefits of implementing emerging ICT technologies and the Fourth Industrial Revolution among construction companies in Durban in terms of t project design, procurement and construction delivery; and the third objective was to ascertain the level of readiness among construction companies in Durban to take advantage of the elements of the Fourth Industrial Revolution in their project design, procurement and construction in relation to project cost, time, quality and environmental safety.

The following are summaries of the findings aligned to objectives:

5.2.1 Objective 1

The descriptive statistics, frequencies and percentage analysis from the questionnaire revealed that medium and large construction companies in Durban were aware of, and used new emerging technologies for office business activities and not for construction site operations. However, a comparison between medium-size contractors and large-size contractors using the Mann Whitney test shows that the level of awareness and knowledge of new emerging technologies among construction companies within office operations was significantly higher for large contractors than for medium contractors. In addition, the analysis further indicated that the level of awareness and knowledge of new emerging technologies for and within construction sites was significantly higher amongst large contractors than among medium contractors.

5.2.2 Objective 2

Using the Wilcoxon rank sum test and analysis, the findings from the second statement indicate that there is significant agreement among medium and large contractors in Durban that if smart technologies are implemented within construction sites and office operations, they would enhance the project design, procurement and delivery of construction services in Durban. The Whitney test analysis shows that large contractors had a higher level of agreement compare to medium contractors that smart technologies can enhance the productivity of construction companies.

5.2.3 Objective 3

The findings from the questionnaires' third statement, using descriptive analysis, revealed that commitment to advance new emerging technologies of the Fourth Industrial Revolution was high in both medium and large-size contractors. However, the Whitney test analysis showed that the level of agreement to the view that that commitment to advance new emerging technologies of the Fourth Industrial Revolution was significantly higher among the medium contractors than among large contractors in the Durban construction market

5.3 Conclusions

The study drew conclusions based on contractors' perceptions of the actual benefits of the 4IR and ICT technologies, the level of awareness and depth of utilisation of ICT technologies in the construction industry and the impact of the Fourth Industrial Revolution and emerging technologies on construction companies in Durban in relation to project design, procurement, construction, delivery, operation and maintenance. The study revealed that there is a significant level of awareness and knowledge about the 4IR and its potential benefits to construction companies in Durban. Both medium and large contractors agreed that new emerging technologies such as e-procurement, e-invoicing, e-payment, cloud computing, electronical communication and website creation were beneficial to office operations. However, the study also revealed that some construction companies in Durban faced critical challenges such as lack of awareness and knowledge of new emerging technologies that can enhance construction site operations such as three-dimensional (3D) printing, robotics, Virtual Reality (VR), Internet of Things (IoT), Radio Frequency Identification (RFID), Cyber Physical System (CPS) and drones. Thus, construction projects that building contractors in KwaZulu-Natal undertake often experience delays, cost overruns and non- conformance to quality and exhibit overall poor performance.

In addition, the study revealed that a significant number of respondents believed that the implementation of emerging ICT technologies and Fourth Industrial Revolution applications can significantly improve productivity in terms of project design, procurement and construction delivery. In addition, the study concluded that there is a high level of commitment from management to take advantage of the emerging technologies and elements of the Fourth Industrial Revolution among construction companies in Durban. Thus, it is notable that the level of awareness, understanding and utilisation of new emerging technologies and elements of the Fourth Industrial Revolution is high within office operations low on construction site operations.

5.4 Recommendations

Literature shows that South African construction companies are behind in terms of the extent to which they utilise the new and emerging technologies. As a result they are not in a position to compete with their peers in other countries such as China (Pillay, Ori and Merkofer, 2017: 4). The results indicate that there is a low level of awareness and use of new emerging technologies on construction sites of construction companies in Durban. In light of these conclusions, the study makes the following recommendations:

- Construction companies in Durban need to enhance traditional business processes and improve levels of productivity and competitiveness by implementing new emerging technologies on construction sites.
- This study recommends that construction companies in Durban should adopt new emerging technologies to improve levels of performance in the sector.
- Finally, construction companies in Durban should invest in research work on how to adopt new technologies that enhance their ability to compete with other sectors such as manufacturing and the automobile sector, which have already entered into the future by adopting a full digital approach to their day-to-day business operations.

5.5 Limitations

This study focused on medium and large size-contractors registered with CIDB in KwwaZulu-Natal. Therefore, the findings can only be generalised to construction companies in KwaZulu-Natal, specifically the eThekwini region. Other organisations such as consultancy firms, were not part of this research. Due to Covid-19 regulations and restrictions, it was difficult for the researcher to distribute and collect questionnaires and this partially affected the results of the study.

5.6 Future research

Future studies should include small contractors and consultant firms, cover the entire KwaZulu-Natal province and compare results with the findings in this study.

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APPENDICES

Appendix A

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Durban, 4001

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Good Day Sir/Madam

I hope you are doing well.

I am a BTech qualification holder and I am currently doing my postgraduate master's degree in the Department of Construction Management and Quantity Surveying at the Durban University of Technology (DUT). I would like to invite you to participate in the research study.

Research is the systematic investigation into and study of materials and sources in order to establish facts and reach new conclusions.

You will be asked to answer/respond to a questionnaire survey about the study by rating/ranking various statements and remarks/questions. The questionnaire survey will either be sent through email, online-based survey or hand delivery to your offices, and because of the Covid-19 pandemic, all Covid-19 regulations will be strictly adhered to. Thus, the questionnaire survey will be used as a data collection instrument, which will involve statistical analysis and themes discussion with regard to your responses accordingly. The questionnaire survey will take about 15 to 25 minutes, to be completed by each research respondent.

There are no known risks or discomforts associated with this study. However, as you share your business time while responding to the questionnaire, it may slightly interrupt your time from work schedules. Please may I request that you complete the entire questionnaire as best as you can, as it will be beneficial for study analysis and findings, and I hereby guarantee that your identity/ your company's identification will be protected and treated in the most confidential manner.

Please be informed that your participation in this study should be voluntary and there will be no adverse consequences should you (research respondent) choose to withdraw at any given time during or prior to the interview.

It is envisaged that this research will result in creating awareness and knowledge on the elements of the fourth industrial revolution and emerging ICT technologies that are enhancing construction project delivery in term of projects' design, procurement processes, and construction delivery , as well as issues of project cost, time, quality and environmental safety. This will assist the construction firms in Durban and the South African construction industry's stakeholders to effectively deliver the projects. There will be no remuneration for this study.

The research respondents (you) will not incur any cost, and your response to the questionnaire survey will only take place online through email or online-based survey or/and manual (hardcopy). Thus, respondents (you) may incur cost in terms of time and internet data bundle.

In this study, your responses to the questionnaire survey will be coded and processed in a manner that ensures an adequate level of confidentiality and protection of the privacy of all the research respondents. Thus, anonymity of individuals and organisations participating in this research study is ensured, and data collected from this study will be protected by coding so that no trace can be linked to any individuals or organisations who voluntary participated in the study. The data to be collected will only be viewed by the principal investigator and authorised members of the research team at the Durban University of Technology. You should understand that the results of this study will be kept confidential unless you ask for a copy. The results of this study may be published in professional journals or presented at professional conferences, but your record or identity will not be revealed and I will use coded names. The information emanating from data collection will be filed and kept in a safe, password-secure hard drive. In this research, there will be no injury or exposure to risk.

The information will be filed and kept in a safe, password-secure hard drive and stored in a locker where it will be accessible to the main investigator and co-investigators. The data will be kept for a period of five years in accordance with the University's guidelines and will then be discarded accordingly.

Please contact the researcher (0737369367), my supervisor (0784784636) or the Institutional Research Ethics Administrator on 031 373 2375. Complaints can be reported to the Director: Research and Postgraduate Support Dr L Linganiso on 031 373 2577 or researchdirector@dut.ac.za.

You are assured that your participation is voluntary and the approximate number of participants to be included are disclosed. A copy of the information letter will be issued to participants.

Appendix B

LETTER OF INFORMATION

Title of the Research Study: Assessment of Emerging Technologies Enhancing Project Delivery among Medium and Large Construction firms in Durban

Principal Investigator/s/researcher: Mchunu Johannes S'thembiso - BTech. Construction Management

Co-Investigator/s/supervisor/s: Dr I. Anugwo (PhD)

I am a postgraduate master's degree candidate in the Department of Construction Management and Quantity Surveying at the Durban University of Technology (DUT). I am conducting research on **"Assessment of Emerging Technologies Enhancing Project Delivery among Medium and Large Construction firms in Durban".** I would like to invite you to participate in the research. This study will be using a research questionnaire survey that will require about 15-25 minutes to give your responses by ranking the various statements and remarks in the questionnaire survey. Thus, the study aims to assess the actual depth of utilisation, and impact of the fourth industrial revolution and emerging ICT technologies among Durban's construction companies in their project design, procurement, construction, delivery, operation and maintenance. This study will seek to have an in-depth assessment of emerging technologies that are enhancing construction project delivery in the Durban construction market. This study outcome would assist in enhancing awareness and knowledge of emerging ICT technologies and elements of fourth industrial revolution that are improving? Construction project performance and delivery.

Appendix C

DUT DURBAN UNIVERSITY OF TECHNOLOGY | FACULTY OF ENGINEERING & THE BUILT ENVIRONMENT | DEPARTMENT OF CONSTRUCTION MANAGEMENT AND QUANTITY SURVEYING

Department of Construction Management and Quantity Surveying
Faculty of Engineering and the Built Environment
Durban University of Technology
S3 Level 2, Room BS3 404 Steve Biko Campus,
Durban, 4001

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18th February 2021

To:

The Construction Industry Development Board (cidb)

428 Blinkbonnie Rd, Mayville,

Durban, 4000

Dear Sir/Madam

LETTER OF REQUEST TO CONDUCT RESEARCH

Mr Johannes S'thembiso Mchunu, with DUT student number 19750705, is a Master's student in the Department of Construction Management and Quantity Surveying, Durban University of Technology, Durban, South Africa. He is currently conducting a research study entitled "Assessment of Emerging Technologies Enhancing Project Delivery among Medium and Large Construction firms in Durban" under my supervision. The research required that he administer research questionnaires through online-based survey, or email or hand delivery among Durban's cidb- registered contractors from grade 4-6 and grade 7-9 contractors as medium and large construction firms in categories of general building contractor and civil engineering contractors respectively.

Mr Johannes research study is focus on the assessment of elements of fourth industrial revolution and emerging ICT technologies that would enhance construction project delivery within the eThekwini District Municipality of KwaZulu Natal. Thus, Mr

Johannes has identified construction contractors between grades 4 to 9 on the Construction Industry Development Board (CIDB) Register of Contractor (RoC), within civil engineering and general building contractors as targeted research respondents for his study. As his academic supervisor, I would like to kindly request your permission to provide us with a gatekeeper's approval letter for ethical purposes.

The letter should indicate that Mr. Johannes is a registered student, currently studying for his Master degree in Construction Management, and has been granted permission by the the Construction Industry Development Board (CIDB), Durban branch to conduct research among the construction contractors between grades 4 to 9 on the cidb register of contractor (RoC), within civil engineering and general building contractors. Participants are anonymous. There are no known risks, current or anticipated, to any participant in this research and all information received will be treated with utmost confidentiality.

With regards to any queries, please do not hesitate to contact mchunus425@gmail.com and IrukaA@dut.ac.za

Thank you in anticipation of your favourable consideration of this request.

Dr IC Anugwo

Supervisor and DRC Member,

Department of Construction Management & Quantity Surveying

Durban University of Technology, Durban, South Africa.

(+27) 031 373 2468

Appendix D

Research Instrument: Questionnaire

Master Candidate: Johannes S'thembiso MCHUNU (19750707)

Supervisor: Dr IC Anugwo

Department: Department of Construction Management & Quantity Surveying

Institution: Durban University of Technology

Research Title: Assessment of Emerging Technologies Enhancing Construction Project Delivery: The eThekwini District Construction Industry Perspective

Section A: Participant Personal Information *(Please indicate with an "X" where appropriate)*

1.1 Name of your organisation: ……………………………………………………

1.1.1 Your Head Office Location: ………………………………………………

1.2 Gender:

Male: ☐

Female: ☐

1.3 Age:

18-30: ☐

31-45: ☐

46–55: ☐

56-Above: ☐

1.4 Your designation/ position in this organisation:

Business Owner (Director/ Managing Director): ☐

Family Business (Manager): ☐

Executive Firm's Representative: ☐

Other: ……………

1.5 Your organization CIDB grade:

GB4: ☐

CE4: ☐

GB5: ☐

CE5: ☐

GB6: ☐

CE6: ☐

GB7: ☐

CE7: ☐

GB8: ☐

CE8: ☐

GB9: ☐

CE9: ☐

1.6 Your years of experience in the construction industry:

5-15: ☐

16-25: ☐

26-35: ☐

36-45: ☐

46-55: ☐

56-Above: ☐

1.7 Your highest educational qualification:

Grade 9- 12 Certificate: ☐

Matric Certificate: ☐

FET (Vocational) Certificate: ☐

Diploma Certificate: ☐

Bachelor's Degree: ☐

Honour's Degree: ☐

Masters' Degree: ☐

Doctor's Degree: ☐

1.8 Please indicate category of profession you belong to:

Architect: ☐

Civil Engineer: ☐

Construction Manager: ☐

Project Manager: ☐

Quantity Surveyor: ☐

Builder: ☐

Others (Please specify): ☐

Please describe your role in this organization ……………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

………………………………………………………………………………

Section B: Research Questionnaire

1. The following statement refer to the level of awareness, understanding and knowledge of new emerging technologies presently linked to Fourth Industrial Revolution (4IR). You are required to select your response by placing an 'x' in the selected box. **(Please note the 'unsure' option).**

1.1	Does your organization make use of Building Information Modelling (BIM) in planning and procuring construction project in all phases of the facility's life cycle?	Yes	
		No	
		Unsure	
1.2	Does your organization use Three-Dimensional (3D) technology to increased production, reduced construction time, reduced manpower and construction cost?	Yes	
		No	
		Unsure	
1.3	Does your company use electronic procurement (e-procurement) which is the process of utilising the electronic communication technologies (ICT), which foster transaction processes to buy services, goods, and works or conduct tendering for construction works?	Yes	
		No	
		Unsure	
1.4	Does your organization use Robotic technology to generate higher output at a lower unit cost, with better quality product?	Yes	
		No	
		Unsure	
1.5	Does your organization make use of Virtual Reality (VR) to improve construction site activities as well to assist significantly in the construction planning stage?	Yes	
		No	
		Unsure	
1.6	Does your organization apply safety systems in construction sites using the Internet of Things (IoT)?	Yes	
		No	
		Unsure	
1.7	Does your organization apply Radio Frequency Identification (RFID) technology to address the challenges associated with tracking resources on construction sites?	Yes	
		No	
		Unsure	

1.8	Does your organization make use of Cyber Physical System (CPS) system operations to monitor (plant and equipment), coordinating, progress tracking, construction process control, and as-built documentation?	Yes	
		No	
		Unsure	
1.9	Are drones used to survey construction sites, to scan sites in order to create 3D models of structures, and for health and safety monitoring?	Yes	
		No	
		Unsure	
1.10	Does your company have website?	Yes	
		No	
		Unsure	
1.11	Do you use cloud computing in the practice of using a network of remote servers hosted on the internet to store, manage, and process data, rather than a local server or a personal computer?	Yes	
		No	
		Unsure	
1.12	Does your firm use electronical communication system or tools to conduct tendering and submission of proposals, tenders or bids?	Yes	
		No	
		Unsure	
1.13	Does your firm use electronical payment (e-payment) system or tools to do payments for goods or services on the internet?	Yes	
		No	
		Unsure	
1.14	Does your firm use electronical invoicing (e-invoicing) system or tools in the exchange of invoice documents?	Yes	
		No	
		Unsure	

2. On a scale of 1**(Strongly Disagreed)** to 5 **(Strongly Agreed)** The following statements refer to actual levels of implementation of smart technology within construction site and office as element of Fourth Industrial Revolution (4IR). Please indicate to what extent do you agree or disagree with each statement on a 5 point rating scale where **1 = strongly disagree**, **2 = disagree**, **3 = neutral**, **4 = agree**, and **5 = strongly agree**. You are required to select your response by placing an 'x' in the selected box. **(Please note the 'unsure' option).**

	Statement: Implementing of new technologies within construction site and office	**Unsure**	**Strongly Disagree**	**...**	**...**		**Strongly Agree**
			1	**2**	**3**	**4**	**5**
2.1	The use of Building Information Modelling (BIM) in planning and procuring construction project is benefiting all phases of the facility's life cycle.						
2.2	Implementing Three-Dimensional (3D) technology bring significant benefits to the organization, in terms of increased customization, reduced construction time, reduced manpower and construction cost.						
2.3	Electronic procurement (e-procurement) which utilising the electronic communication technologies (ICT), is used in transaction processes to buy services, goods, and works so as to improves delivery, reduces paperwork and lowers administrative costs						
2.4	Implementing of Robotic technology have the capability to generate higher output at a lower unit cost, with better quality product.						
2.5	Application of Virtual Reality (VR) allows costly mistake to be identified and rectified before they occur and easy communication among site staff and office staff.						
2.6	Safety systems in construction sites has integrated the usage of the Internet of Things (IoT).						
2.7	Radio Frequency Identification (RFID) technology is used to address the challenges associated with tracking resources on construction sites.						

2.8	Cyber Physical System (CPS) system operations are used for monitor (plant and equipment), coordinating, progress tracking, construction process control, and as-built documentation.						

3. The following statements refer to the appreciation of advantageous nature of new emerging technologies presently linked to fourth industrial revolution in relation to project design, procurement, construction, cost, time, quality, and environmental health and safety, delivery. Please indicate the extent to which you agree or disagree with each statement on a 5 point rating scale where **1 = strongly disagree**, **2 = disagree, 3 = neutral**, **4 = agree**, and **5 = strongly agree**. You are required to select your response by placing an 'x' in the selected box. **(Please note the 'unsure' option).**

	Statement: Commitment to advance with new emerging technologies	**Unsure**	**Strongly Disagree**		**... …**		**Strongly Agree**
			1	**2**	**3**	**4**	**5**
3.1	Management promotes the use of new technology to improve performance in your organization						
3.2	Management understands the benefit and impact of using emerging technology to enhance construction project delivery						
3.3	Management invest on latest technology such as Internet of Things (IoT), 3D Printing, Virtual Reality (VR), Building Information Modelling (BIM), Robotics and wireless sensor technology						
3.4	Top management support and promotes new emerging technology that are aligned with its organisational strategy						
3.5	Your organization culture towards the new technology have been shown to significant influence on the success of project delivery						
3.6	Top management support and promotes new emerging technology in order to ensure increase control of						

	environmental health and safety of workers and project						
3.7	Management motivate employees to upskilling training in areas of fourth industrial revolution in order to enhance their competencies on the latest construction technologies, and to ensure overall competitiveness of the organisation's skillset						
3.8	Employees in your organisation are not experiencing emotional stress fearing job loss to automation and elements of fourth industrial revolution						
3.9	Your organisation's financial capacity has a significant impact integration and successful implementation of new technologies in order to enhance overall project delivery in term of site management and reduction of health and safety challenges						
3.10	Your organisation's financial capacity has a significant impact integration and successful implementation of new technologies in order to enhance overall project delivery in term of site management and reduction of cost and time reduction						