A Study into the Adoption of Internet of Things – IoT Technologies within Contractors in Dubai, United Arab Emirates

دراسة عن مدى تبني تكنولوجيا إنترنت الأشياء من قبل مقاولي الإنشاءات العاملين في إمارة دبي في دولة الإمارات العربية المتحدة

by

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Abstract

Purpose – The construction industry has remained conservative and lagged in the implementation of technology. Although the industry has a fragmented nature and plays a critical role in social and economic development, technology is adversely limited. Due to technology's role to improve productivity, save time, and enhance stakeholder satisfaction, the construction industry has an opportunity to improve its performance and safety. Thus, the purpose of this research is to investigate the adoption of the internet of things technologies within contracting organizations in the Emirate of Dubai.

Methodology – Through a quantitative approach, a total of 116 construction professionals participated in a distributed online questionnaire. All the respondents were professional engineers with experience and knowledge of construction activities. Descriptive analysis using the Relative Importance Index - RII technique was used to rate the collected data according to respondents. Regression analysis was used to test the research hypotheses and Multiple linear regression was utilized to develop a prediction model.

Findings – According to respondents, when asked on the types of IoT technologies utilized by their organizations BIM, smartphones, and cloud storage systems were the contractors' leading types of IoT technologies adopted. When tackling the areas of IoT technologies implementation, the top three areas were data exchange, data capturing & display and site supervision. All the studied internal and external factors promoting adoption were statistically significant when tested. The top three internal factors were communication, productivity, and management & procurement. The top three external factors were stakeholder satisfaction, competitive advantage, and government regulations. When challenges were tested for significance, three out of seven were statistically insignificant namely lack of leadership commitment, culture and resistance to change and connectivity issues. Currently, the leading

challenges that must be addressed to promote adoption were the cost of implementation and staff training. When advantages were studied, the top three were enhanced communication, timesaving, and productivity.

Research Limitations – The project focused on a small geographical area which is the Emirate of Dubai hence, it may lack generalizability. At the same time, a relatively small sample size (n=116) was used in the study. Besides, the project focused only on contractors in the construction industry. It is recommended that future researchers expand their studies' scope to evaluate IoT technologies in other parts of the country as well as the globe. Moreover, they should focus on other players in the construction industry, besides contractors.

Theoretical Contributions – This research provides a never-done-before look at the current state of IoT technologies adoption within contractors in the Emirate of Dubai. The used methodology and developed model will enrich existing literature by providing a framework to help adopt IoT technologies within contracting organizations. The research helps bridge the gap in existing literature related to the role of IoT technologies within the construction sector in the Emirate of Dubai and understand how this adoption affected the sector.

Practical Implications – From the research results, it was evident that contractors in Dubai are utilizing and relying on IoT technologies to enhance data collection and sharing, leading to improving their productivity and managing time and cost overruns. This research provides a practical guideline for willing contractors to embrace IoT technologies. Therefore, this research is of value not only to contracting organizations, but rather to all organizations within the industry who are planning to adopt new technologies.

Social Implications – For contractors willing to embrace IoT technologies, it is recommended that they start training their workforce on the use of IoT technologies and create partnerships

to deal with cost challenges. If implemented, this would create new business opportunities and job vacancies that would affect multiple sectors within the economy.

Keywords – Internet of Things - IoT, Smart Construction, The Emirate of Dubai, Prediction Model, Technology, Smart Devices, Construction Industry, Contractors

ملخص

الهدف من الدراسة – لطالما ظل قطاع البناء و التشييد متحفظا ومتأخرا في تبني التكنولوجيا. على الرغم من أن هذا القطاع ذو طبيعة مجزأة و يلعب دورًا حاسمًا في التنمية الاجتماعية والاقتصادية ، إلا أن التكنولوجيا فيه محدودة الانتشار. نظرًا لدور التكنولوجيا في تحسين الإنتاجية وتوفير الوقت وتعزيز رضا أصحاب المصالح، فإن لقطاع البناء و التشييد فرصة لتحسين أدائه. وبالتالي ، فإن الغرض من هذا البحث هو التحقيق في مدى تبني المقاولين العاملين في قطاع الانشاءات في إمارة دبي لتقنيات إنترنت الأشياء ضمن منظماتهم.

المنهجية المتبعة – من خلال منهج بحث كمي ، شارك ما مجموعه 116 من المتخصصين في البناء في الاستبيان الموزع عبر الإنترنت. كان جميع المستجيبين مهندسين محترفين لديهم خبرة ومعرفة بأنشطة البناء. تم عمل التحليل الوصفي باستخدام تقنية مؤشر الأهمية النسبية لتصنيف البيانات المجمعة وفقًا لرأي المستجيبين. تم استخدام طريقة تحليل الانحدار لاختبار فرضيات البحث. كما تم استخدام الانحدار الخطي المتعدد لتطوير نموذج التنبؤ.

النتائج – وفقًا للمستجيبين ، عند سؤالهم عن أنواع تقنيات إنترنت الأشياء التي تستخدمها منظماتهم، كانت نماذج BIM و الهواتف الذكية وأنظمة التخزين السحابية هي الأنواع الرائدة للمقاولين من تقنيات إنترنت الأشياء المتبناة. عند السؤال عن المجالات التي تم تبني هذه التقنيات فيها، كانت المجالات الثلاثة الأولى للتنفيذ هي تبادل البيانات، والتقاط البيانات وعرضها والإشراف على الموقع. كما أن جميع العوامل الداخلية والخارجية التي تم دراستها لتعزيز التبني كانت جميعها ذات دلالات إحصائية عند اختبارها. كانت أهم ثلاثة عوامل داخلية هي الاتصال، والإنتاجية، والإدارة والمشتريات. أما العوامل الخارجية الثلاثة الأهم هي رضا أصحاب المصلحة والميزة التنافسية واللوائح الحكومية. عندما تم اختبار التحديات التي تعيق تبني تقنيات انترنت الأشياء من حيث الأهمية ، كانت ثلاثة من أصل سبعة غير ذات دلالات إحصائية، وهي عدم وجود التزام من القيادات، والثقافة ومقاومة التغيير و مشاكل الاتصال. في الوقت الحالي ، إن التحديات الرئيسية التي يجب معالجتها لتعزيز التبني هي مشاكل التكلفة العالية وتدريب الموظفين. أما بالنسبة لمزايا تبني تقنيات انترنت الأشياء، كانت المراكز الثلاثة الأولى هي تحسين الاتصال وتوفير الوقت و زيادة الإنتاجية.

قيود الدراسة – ركز المشروع على منطقة جغرافية محدودة وهي إمارة دبي وبالتالي قد تفتقر هذه الدراسة للتعميم. في الوقت نفسه، تم استخدام حجم عينة صغير نسبيًا (ن = 116) في الدراسة. إلى جانب ذلك، ركز المشروع فقط على شريحة المقاولين في قطاع التشييد و البناء. من المستحسن أن يقوم الباحثون المستقبليون بتوسيع نطاق دراساتهم لتقييم تبني تقنيات

إنترنت الأشياء في أجزاء أخرى من دولة الإمارات العربية المتحدة وكذلك العالم. علاوة على ذلك ، يجب عليهم التركيز على الشرائح الأخرى المكونة لقطاع التشييد و البناء، إلى جانب المقاولين.

المساهمات النظرية للدراسة – يوفر هذا البحث نظرة مستحدثة لم يتم إجراؤها من قبل على الوضع الراهن لتبني تقنيات إنترنت الأشياء من قبل المقاولين العاميلين في إمارة دبي. ستعمل المنهجية المستخدمة والنموذج المطور على إثراء الأدبيات الحالية من خلال توفير إطار عمل للمساعدة في تبني تقنيات إنترنت الأشياء من قبل شركات المقاولات. يساعد البحث في سد الفجوة في الأدبيات الحالية المتعلقة بدور تقنيات إنترنت الأشياء في قطاع التشييد و البناء في إمارة دبي وفهم كيف يؤثر هذا الاعتماد على القطاع.

الآثار العملية للدراسة – من خلال البحث ، اتضح أن المقاولين العاملين في دبي يستخدمون تكنولوجيا إنترنت الأشياء ويعتمدون عليها لتعزيز جمع البيانات ومشاركتها ، مما يؤدي إلى تحسين إنتاجيتهم وإدارة الوقت والتكاليف الزائدة. يوفر هذا البحث إرشادات عملية للمقاولين الراغبين في تبني تقنيات إنترنت الأشياء. لذلك ، فإن هذا البحث ذو قيمة ليس فقط لشركات المقاولات بل لجميع أنواع المنظمات في القطاع التي تخطط لتبني تقنيات جديدة.

الآثار الاجتماعية للدراسة – بالنسبة للمقاولين الراغبين في تبني تقنيات إنترنت الأشياء ، يوصى ببدء تدريب القوى العاملة لديهم على استخدام تقنيات إنترنت الأشياء وإنشاء شراكات للتعامل مع تحديات المتعلقة بالتكلفة و التمويل. إذا تم تنفيذ ذلك ، فسيخلق فرص عمل جديدة ووظائف شاغرة من شأنها أن تؤثر على قطاعات متعددة داخل النظام الإقتصادي.

الكلمات المفتاحية – انترنت الأشياء، أعمال البناء الذكية، إمارة دبي، نموذج التنبؤ، التكنولوجيا، الأجهزة الذكية، قطاع البناء و التشييد، شركات المقاولات

Dedication

I dedicate this study…

To the spirit of my beloved father Ibrahim who passed away before he can see it complete. I had a plan for you to attend my graduation ceremony alongside your baby grandson, but God had other plans for us, and we are always thankful no matter what. I miss you dad.

To my lovely mother Yasmina who gave me the will and spiritual support I needed to get through the toughest of times. To my dear brother Yaman for whom I am forever thankful.

To my beautiful wife Razan for all her moral and emotional support. For her strength and guidance provided when I was feeling lost and unmotivated. Without you I was not able to make it.

To my baby boy Ibrahim, whom I promise to compensate for all the time I spent away.

Acknowledgment

I would like to thank my supervisor, Doctor Maria Papadaki for her guidance, assistance, continuous support, encouragement, supervision, and valuable advice throughout the course of my research from the preliminary to the concluding level. Without her unlimited patience and help, this dissertation would never be what it is now.

My deep thanks are extended to the Professors and Doctors at the British University of Dubai, for providing me with support and best knowledge in the Project Management Program.

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List of Abbreviations

Abbreviation	Acronym
IoT	Internet of Things
AED	Arab Emirates Dirham
UAE	United Arab Emirates
BIM	Building Information Modeling
VR	Virtual Reality
AR	Augmented Reality
SPSS	Statistical Package for the Social Sciences
RII	Relative Importance Index
GIS	Geospatial Information Systems
GPS	Global Positioning System
RFID	Radio Frequency Identification
CDM	Construction, Design and Management
CAD	Computer-Aided Design
GDP	Gross Domestic Product
ICT	Information and Communications Technology
IP	Internet Protocol
UAV	Unmanned Aerial Vehicle

DOI	Diffusion of Innovation
TOE	Technology-Organization-Environment
MEP	Mechanical-Electrical-Plumbing

CHAPTER ONE: INTRODUCTION

The construction industry plays an integral role in the economic and social development (Dele, Ilori, & Windapo 2019). Governments rely on the construction sector to meet the people's shelter, infrastructure, and employment needs. Hence, the industry affects nearly all aspects of the economy. Due to its significance, there is a need for the construction industry to adopt best techniques and systems for optimum performance. The adoption of technology offers construction businesses a chance to streamline their operations and attain high-efficiency levels. Simultaneously, technology facilitates information sharing, coordination, and real-time data processing vital to the performance of all parties involved in any construction environment. The interconnectedness of networks and information exchange is what brings about the internet of things (IoT). The adoption of IoT within contracting organizations worldwide strengthens information collection, storage, and analysis for improved decision-making. This study attempts to investigate Dubai's Contractors adoption of IoT technologies. A critical evaluation of the extent of IoT adoption within Dubai's Contractors will bring to the fore the level of reliance on technology in enhancing construction activities. The findings will also justify the implementation of new policies, procedures, and resources in the construction industry to pave the way for sustainable growth.

The study's introduction outlines foundation of the research and the significance of exploring the topic. This chapter connects with the readers and justifies the significance of the findings. Chapter one (introduction) of this study is segmented into the following sections: an overview of the global construction industry, an look through the UAE's construction industry specially in Dubai, a definition of IoT, the history of IoT in construction, the problem statement, the research objectives, the research questions, contributions to knowledge, and the structure of the dissertation.

1.1. Construction Industry

The construction industry is a critical pillar of any country's economy. It is the construction sector that gives rise to shelter and infrastructure in the country (Dele, Ilori, & Windapo 2019; Loganathan et al. 2017). Besides, it plays a critical role in creating jobs for citizens. According to Anaman and Osei-Amponsah (2017), the construction industry is an integral player in socio-economic development. Moreover, it is what distinguishes the developed and underdeveloped nations in the world. It means that any challenges that thwart the sector's growth impair economic and social progress. Hence, every country needs to adopt strategies that enable the industry to thrive and remain competitive in the global market. According to The Business Research Company (2020), the construction market comprises the business (traders, corporations, and partnerships) in the industry and the sales generated or financial activities. The firms in the sector are responsible for the construction or engineering of projects. A report by the Business Research Company (2020) depicts that the global construction market value was nearly $12,744.4 billion in 2019 - this was an increase of 6.1% from 2015. The market is expected to decline by -0.9% by the end of 2020. The decline is linked to the current market conditions caused by the global COVID-19 pandemic. The market is then expected to recover in 2021 with a growth rate of 7.5% and reach $15,482 billion in 2023. A study conducted by Statista (2020) depicts that the global construction industry's expenditure has significantly increased over the years, from 2014 to 2025. In 2018, the industry spent approximately $11.4 trillion, and it is expected that by 2025 it will reach $14 trillion (Statista, 2019). The growing spending is an indicator of the sector's continued growth due to the increasing demand for smart infrastructure. The industry is seen as a lifeline of the economy, without which global economic expansion is unattainable.

There is no doubt that the construction industry has exhibited a continuous growth pattern, and this is despite the few downsides. On average, the industry has a positive trend as depicted by the growth patterns in developing and developed economies in the world. According to Deloitte (2020), the construction industry exhibits a positive outlook. The report by Deloitte depicts that the construction market continues to expand at a moderate pace. The primary factors facilitating its growth include rising population, upgrading infrastructure in developed countries, increased residential development, and expected investments in renewable energy (Deloitte, 2020). As the demand for infrastructure increases, construction contractors need to be well equipped to meet the market needs. In addition, businesses in the industry need to look at their performance (financial returns). Construction business growth and market needs are achievable with the implementation of applicable technologies. Smart construction technologies' adoption promises to increase the sector's return on equity, lower net indebtedness, and increase the average dividend yield.

Fundamental significant trends are influencing the global construction market. According to Business Research Company (2020), some of the significant influencers include using autonomous vehicles in the sector and digital technologies. International construction businesses are frequently using autonomous construction vehicles and heavy tools to enhance their productivity. These vehicles are integrated with cameras, sensors, and GPS to relay real-time information on activities' progress. Thus, they play a critical role in enhancing off-site performance and reduce project durations. The connection of vehicles through IoT, RFID tracking, and telematics is crucial in the construction sector as these technologies improve collaboration, efficiency, and safety. Like Komatsu, Caterpillar, and Volvo, some of the leading manufacturers are continuously developing new instruments and tools to attain enhanced productivity. The industry is also adopting digital technologies like augmented reality (AR), virtual reality (VR), and wearable technologies to boost the sites' safety. Through AR and VR, managers can monitor job sites in a simulated environment. These technologies can be used in the training of workers on safety. Wearable technologies provide an ability to track workers in the field and protect them from hazards or injuries while in job sites. Companies like Skanska in the United States use equipment sensors and monitoring technology to ensure their employees' safety. The continued reliance on technology offers construction businesses a competitive advantage by enhancing workers' safety and reducing job sites' inefficiencies.

This study's context is based on understanding the challenges affecting the construction industry. The study explores potential solutions and evaluates how smart technologies can facilitate growth and development. Crotty (2013) argues that the two main challenges affecting the construction industry are profitability issues and unsatisfactory completion of projects (first-order challenges). These are the principle challenges as they directly influence other secondary problems like productivity, sustainability, safety, and collaboration (second-order challenges). As Cotty (2013) discussed, the solutions to these issues include improving communication and collaboration in the industry. These solutions are attainable if the nature and quality of information are enhanced by focusing on organizational structures and data exchange among contractors and other stakeholders.

New technologies transformed industries in the second industrial revolution. There was a dramatic change in the way enterprises create and deliver goods and services. As compared to the first industrial revolution, innovations dominated the second revolution to enhance efficiency and optimizing outputs. Today, there is a new shift propelled by technology. The modern era industries rely on information where machinery was seen as a center of the manufacturing process. Today, information sits at the center of the economy (Bouck 2014).

Thus, any construction business that wants to thrive in the current economy must be willing and able to adopt information technology, particularly IoT, for more accessible and effective data sharing for decision-making. Although data is appreciated, the construction industry lags in implementing the latest technological tools that facilitate the collection and sharing of information. Moreover, the sector is suffering from low productivity levels due to cost and time overruns. These low productivity levels justify the adoption of IoT within Dubai-based construction contractors.

The construction industry needs to shift its processes from the traditional models of operation to modern digital frameworks. Smart construction focusses on optimizing resources and output. It is all about finding the right balance between the inputs and outputs – maximize the outcomes and minimize the inputs. Further, it involves the proper utilization of machinery, people, and other resources in the production process. The idea of smart construction has given rise to the continued automation, cloud computing, cognitive computing, and interconnectedness of devices in the construction sector. The methods used by contractors vary, but the underlying principles do not (optimization of performance). Construction businesses immensely rely on technological tools to monitor, track and project their performance. Their ability to offer real-time services is enabled by technology. Other digital-based solutions in the sector include inspections, resource management, communication, and health and safety control. With the advent of globalization, construction businesses can leverage on global skills and knowledge for growth. According to Ofori (2016), globalization enhances the interaction between stakeholders from various jurisdictions. In this regard, the use of technology in businesses enhances their exposure in the market. At the same time, it enables easier access to information for decision-making. A complete shift to the digital-based solutions will offer the construction businesses a competitive edge by being efficient, reliable, and quality-driven.

The need to improve the construction industry is necessitated by its significance to socio-economic development. According to Gbadamosi et al. (2019), there are three construction phases: construction, design, and management. These phases are usually described as CDM. Over the years, the design phase has transitioned from 2D CAD designs to the current 5D BIM designs. More construction firms are using data-driven strategies for decision making in the design phase. The adoption of 3D visualizations, cost and time projections and client involvement techniques offer enhanced outputs. The construction phase has also transformed from the traditional on-site construction to the modern off-site pre-assembled components. Smart buildings are becoming a norm as they offer a better approach to streamlining construction processes by using big data, collaboration, and remote monitoring. At the same time, project managers have better tools to detect faults and predictive maintenance automatically. The increased automation of the industry has given IoT the best chance to promote smart construction. It is critical to ensure that businesses in the sector optimize their performance, and the needs of the clients are met by lowering cost and improving quality.

1.2.Construction Industry in the Emirate of Dubai

Located in the Arabian Gulf and northeast of the UAE, Dubai is one of the seven united emirates forming the UAE, and the second largest emirate with 4114 square kilometers almost 5% of the total area of the UAE ("The Emirate of Dubai - General Information" 2020). Dubai city is approximately 35 square kilometers however, As the government expands the infrastructure, Dubai is poised to expand twice in size. Some of the current developments include the addition of the man-made islands: Deira Island, Palm Jebel Ali, and Waterfront. These constructions are part of the vision to expand Dubai to become a regional hub in business and tourism development. According to Dubai Statistics Center (2019), the Emirate’s population is approximately 3.33 million people, and the majority of them are males (almost

70%). The city is also an ideal tourist attraction due to its multiculturalism as only 9% of the people are Emiratis, with the rest of the population being expatriates (Dubai Statistics Center, 2019). The location and population composition play a critical role in the city's development, especially in the construction industry. A large number of expatriates, coupled with an increase in tourism activities, have increased the demand for buildings and infrastructure. Dubai's construction industry has exponentially grown over the years, owing to a rise in demand in the market.

The UAE’s construction industry is segmented into commercial, residential, industrial, infrastructure, and energy sectors. According to Mordor Intelligence (2020), the UAE construction sector is expected to grow by 5.5% by the end of 2024. Currently, Dubai has attracted a lot of attention due to the EXPO 2020 event that has led to increased construction activities over the previous few years. It is estimated that active constructions in the region amounted to $42.5 billion by the end of March in 2018 (Mordor Intelligence 2020). The increased construction activities are influenced by the high demand for buildings and infrastructure. Besides, the need for smart cities has positively influenced the growth of the construction sector. A survey conducted by KPMG (2019) shows that 51% of the industry leaders expect growth of 6-10% in the construction industry. It is anticipated that operational costs and time overruns are the main challenges that will hinder the sector's development. Of all the leaders interviewed, 81% believe that digital tools' adoption will be fully realized in the next three years (KPMG 2019). The survey demonstrates that the construction sector will face significant improvements due to the market demand and technology role in improving efficiency and reliability. The same findings are provided by Statista (2020), which shows that UAE's construction revenues will be approximately $35.2 billion by 2023. As the demand for efficient infrastructure rises in the UAE, the construction industry players are adopting technological tools to improve performance. Hence, technology is seen as an enabler in the success of the UAE construction industry.

In a statement, Sidharth Mehta, a partner and head of building, construction, and real estate at KPMG, stated that the construction industry is UAE's economy lifeline (Mack 2019). The statement denotes that the construction sector has a ripple effect on UAE's socio-economic activities. Due to its significance, the industry leaders have considered implementing governance, optimization, and innovation strategies to leverage its potential. The future of the sector is primarily influenced by technology and innovation. From KPMG's survey, nearly all industry leaders expect the use of data analytics and predictive modeling. Of the participants, 94% advocated for implementing data analytics and predictive modeling, 88% argued that new entrants would challenge traditional models, and 63% recommended using real-time modeling and reporting in the construction sector (Mack 2019). The improvement of operational and analytical strategies gives the UAE's construction industry an edge in the global market. As a tourist destination, quality is paramount in any infrastructure or building development. Hence, the adoption of smart construction models is inevitable.

The construction sector accounts for approximately 14.5% of Dubai’s GDP (Warrier 2019). The data from the Dubai Statistics Centre (DSC) shows that the construction industry grew by 4.5% in 2018, a growth rate of 1% from 2017. In 2018, government spending on infrastructure increased by 32% (Warrier 2019). The DSC data showed that the construction industry grew by 90% from 2015 to 2016 (Abdel-Razzaq 2016). The growth resulted from an increase in the demand for buildings and infrastructure in the region. According to DSC, residential construction accounted for more than 88% of the area's construction activities (Abdel-Razzaq 2016). Although the construction industry has exhibited a positive outlook in the past decade, it grapples with cost and time overruns. It is such challenges outlined by the

DSC (time and cost overruns) that justify the adoption of technology in Dubai's construction businesses. The implementation of IoT and other-related technologies facilitate close monitoring of job sites, safety and health improvement, cost management, and project duration optimization. Smart construction initiatives in Dubai are reliant on technological solutions and play an integral role in ensuring sustainability in the sector.

While there are numerous reports on Dubai construction industry's growth and development from entities like KPMG, Deloitte, and DSC, there are little to no academic studies on the topic. The limitation of studies on the role of IoT in the Dubai construction industry makes it difficult to ascertain how technology has led to the sector's progression. Therefore, the current study aims to fill this gap by investigating the adoption of IoT among contractors in Dubai. The study explores how technology is used in the construction sector and why Dubai-based contractors prefer it. The study also analyzes the merits and demerits of IoT adoption within contracting organizations. The research seeks to explain why Dubai contractors must shift towards the implementation of IoT technologies and abandon obsolete and traditional construction methods.

1.3. Definition of Internet of Things (IoT)

The development of modern information communication technology (ICT) has had a significant impact on life. Today, household appliances can be controlled using smartphones, and information can be exchanged from one device to another in real-time. At the same time, cars can transmit information on the best route to use in avoiding traffic. Hence, technology has made life easier by enhancing the interconnection of devices and information sharing. This interconnectedness of instruments gives rise to the concept of the internet of things (IoT). Over the years, researchers have tried to define IoT by describing features and ways of connecting devices. In all the definitions, there are central components: interconnectedness and technological devices. The EU project defines IoT as a network of infrastructure linking physical and virtual objects by exploiting information transmission (Angelova, Kiryakova & Yordanova, 2017, p. 406). In this case, the infrastructure is the existing and evolving network and internet developments. The connected devices act independently but cooperate in the collection and transmission of information. Adrian McEwen gives a simple definition of the term IoT through the following equation:

$$Physical\ object + controller, sensor, and\ actuators + internet = IoT$$

IoT ensures the interconnectedness of devices in the construction industry and facilitates communication. According to Angelova et al. (2017), what enables the IoT is the affordable internet, speed of data collection and transmission, accessibility of the internet and supporting devices, and increasing address space as provided for by the IPv6. Ibarra-Esquer et al. (2017) argue that IoT is a disruptive technology that shapes how people share information or complete their daily tasks. Simply put, the internet of things is the interconnection of computing devices through the internet. These devices are used to facilitate the collection and transmission of data for decision-making. IoT describes physical objects embedded with sensors and software to enhance the connection and exchange of data over the internet. The advancement of the development of portable devices and microchips has led to the development of the IoT. As people's reliance on the internet progresses, it is vital to collect all data forms to improve decision-making. Therefore, IoT is seen as a future approach to enhance sustainability in society. Due to its already ascertained impact of convenience, efficiency, and automation, the IoT is essential in the construction industry. Contractors in Dubai can benefit immensely from the use of IoT in off-site and on-site construction activities.

IoT brings the power of data processing, the internet, and analytics to the real world. For individuals, the use of IoT means interacting with various devices connected to the internet. It is the access to the global information network without limitation to a single device or the use of a keyboard and screen (Fruhlinger 2020). In many homes, appliances can take instructions from a network with minimal human interference. In the manufacturing or construction setting, efficiency and reliability can be enhanced using IoT. Construction companies use millions of internet-enabled sensors in their job sites to monitor and track activities. IoT ensures that project managers can work remotely and reduce manual processes. Further, researchers in construction companies can use IoT to gather data on client preferences and behaviors to develop personalized buildings or infrastructure. The rise of the internet of things is guided mainly by the development of smart devices in society.

Three primary features describe smart devices: connectivity, autonomy, and context awareness. User interaction and mobility of the tools are critical in intelligent machines. Thus, smart devices can be described as electronic devices able to perform their duties autonomously, exhibit context awareness, and capable of context-awareness in the collection and transmission of data. In this study, smart devices are part of the IoT, which is the interconnection of network devices with unique identifiers for data collection, transmission, and analysis (Fruhlinger 2020). Any device with the ability to collect and transmit information can qualify to participate in the IoT ecosystem. For example, RFID tags, smart home appliances, and industrial sensors are standard IoT devices used in society. These sensors can provide information on temperature changes, humidity, air quality, defects in machinery, and many other work environments. Hence, when using IoT in a construction setting, project managers have a multidimensional view of the activities taking place and the conditions within which workers complete their tasks. The monitoring and tracking process can occur remotely as the managers' physical presence is unnecessary if the technology is implemented.

1.4. History of the Internet of Things in Construction

The construction sector is known as one of the largest in the world. However, it is also regarded as one of the most conservative to technology adoption (Arslan, Ulubeyli, & Kazaz, 2019). Hence, when compared to other sectors, the construction industry has lagged in the implementation of technology. Nevertheless, recent global transformations (inclination towards technology) have forced businesses to re-evaluate their strategies. New technologies have forced construction businesses to utilize approaches that reduce costs and manage time overruns. The IoT is an example of these approaches, one of the essential technological concepts that have drawn a great desire from industry players. The demand for improved quality and smart construction strategies has compelled businesses to adopt IoT and associated technologies to meet clients' needs. Smart construction refers to streamlining construction processes using big data, lean principles, collaboration, and remote monitoring. Smart construction aims to bypass the traditional challenges affecting the industry, such as cost and time overruns.

The term the internet of things was first coined in 1999 by Kevin Ashton, a British technologist (Fruhlinger 2020). It has become an integral concept in using technology, particularly for portable devices and information sharing. As compared to other industries like the financial and health sectors, the construction industry still lags in the adoption of IoT. However, in recent years, there have been unprecedented changes targeting the improvement of productivity, efficiency, and reliability in service delivery. The findings by Deloitte and KPMG depict that the construction industry has recorded massive gains over the past decade. The changes are due to an increase in demand for buildings and infrastructure in Dubai. This growth can be hastened by implementing IoT in the sector to allow contractors to optimize their activities. IoT will influence waste management, safety improvement, cost reduction, and match project requirements with client needs. Dubai's construction sector grapples with cost and time overrun factors that can be adequately controlled with the adoption of IoT. Therefore, the implementation of the internet of things gives Dubai construction contractors a lifeline to improve their performance and meet clients' goals and objectives.

IoT has transformed the way construction businesses operate. According to Rembert (2020), today, contractors in the construction industry can exploit numerous opportunities thanks to technology use. The implementation of IoT offers organizations an avenue to improving safety, efficiency, and sustainability. The rollout of 5G is likely to heighten the value of IoT in construction operations. The combination of IoT with high-speed connectivity will be an advantage in construction operations. Gbadamosi et al. (2019) explain that the benefit of using IoT in the construction process is leveraging real-time data and enabling efficiency. IoT ensures that informed decision-making is attained, smarter designs are developed, and projects delivered on time. The adoption of IoT in the construction industry will increase productivity by over 40% (Gbadamosi et al., 2019). This growth potential has compelled businesses in the construction industry to develop policies and structures that accommodate the implementation of IoT. The adoption of IoT in construction businesses ensures that managers can generate knowledge, create value, and control and monitor operations through data collection and analysis.

1.5. Problem Statement

Various researchers have explored the challenges faced by construction businesses and why the use of technology will help change things (Gbadamosi et al. 2019; Arslan et al. 2019; Jia et al. 2019; Chowdhury, Adafin, & Wilkinson, 2019; Vasista & Abone, 2018). The construction sector has one of the worst records regarding efficiency, reliability, and safety (Gbadamosi et al. 2019). In a related study, Arslan et al. (2019) investigate IoT's role in the construction industry. According to the researchers, the construction industry is one of the most conservative in technology implementation (Arslan et al. 2019). Hence, it suffers from poor communication and low productivity due to low level of interconnectedness of operations and monitoring or tracking activities. Jia et al. (2019) investigate the role of IoT in smart construction. The researchers argue that the idea of smart construction was conceived to enhance reliability and efficiency without compromising client comfort and satisfaction (Jia et al. 2019). From the study, the challenges affecting the construction business are efficiency, productivity, and reliability issues. The same difficulties are captured by Chowdhury, Adafin, and Wilkinson (2019). According to the researchers, an increase in the urban population requires a re-look at the construction techniques to enhance the productivity of workers and affordability of the houses (Chowdhury, Adafin, & Wilkinson, 2019). Vasista and Abone (2018) argue that construction projects are increasingly faced with various challenges that must not be ignored. Such challenges as increased competitiveness in the industry, the complexity of projects, and difficulties in management call for adopting new governance systems. The reliance on traditional models of operations may not offer the ideal solutions to address existing problems. The literature assessment depicts construction contractors' common challenges like low productivity, cost and time overruns, and industry competitiveness. It is these challenges that justify the adoption of IoT within Contractors in Dubai, UAE as well as all over the world. Furthermore, data has become a critical asset for businesses that want to improve their decision-making strategies.

The significance of the construction sector justifies its improvement by using IoT. Gbadamosi et al. (2019) argue that the construction sector is vital for social and economic development. Due to the industry's critical role, players need to adopt the best strategies to enhance their productivity, efficiency, and reliability. The traditional methods of project designing and implementation cannot keep up with market needs. Moreover, the industry 4.0 revolution requires the construction process to be viewed holistically – contributing to socio-economic development. By taking advantage of big data, construction contractors can make informed decisions and monitor projects in real-time. According to Olanrewaju, Tan, and Kwan (2017), the construction industry is fragmented and characterized by many players relying on information transmission and analysis. Thus, it is almost impossible to run a thriving construction sector without addressing the collection, analysis, and transmission of data – communication. The success of the construction business is highly dependent on the ability of players to exchange information promptly. IoT provides an avenue for construction entities to address their immediate challenges associated with productivity, project monitoring and tracking, safety, health control, and time and cost overrun management.

While there are many studies on the role of IoT in the construction industry, there are few to no studies on IoT adoption in Dubai. Therefore, the current study addresses this gap by evaluating the role of IoT in Dubai's construction industry. It evaluates the adoption of IoT by Dubai contractors. IoT implementation is complicated and time-consuming and, in most cases, limited to large organizations. Construction businesses in Dubai, mostly smaller and medium entities, may not have the financial muscle to adopt IoT. The complexity of implementing IoT stems from the need to have a multidimensional pool of smart technologies to provide big data. The analysis of Dubai-based entities will shed light on the strategies these businesses have relied on to enhance their competitiveness. At the same time, it will provide insights to develop recommendations for these businesses.

1.6. Research Objectives

1. Investigate the awareness of IoT technologies and its adoption within Contractors in Dubai
2. To explore the different types and areas of application of IoT technologies within Contractors in Dubai.
3. Investigate the factors promoting the implementation of IoT technologies within Contractors in Dubai.
4. Exploring the advantages resulting from the successful adoption of IoT technologies within Contractors in Dubai.
5. Study the challenges preventing the adoption of IoT technologies implementation within Contractors in Dubai.
6. Develop a prediction model that can link the adoption of IoT technologies within an organization with promoting factors that need to be implemented and challenges that need to be overcome by Contractors in Dubai.

1.7. Research Questions

1. How IoT is perceived and implemented by contractors in Dubai?
2. What are the types of IoT technologies used in construction?

   2.1How do these types of technologies rank according to contractors in Dubai?
3. What are the areas of implementation for IoT technologies in construction?

   3.1How do these areas of implementation rank according to contractors in Dubai?
4. What are the factors promoting the implementation of IoT in construction?

   4.1How do these factors rank according to contractors in Dubai?

   4.2Which of these factors significantly promote IoT technologies adoption?
5. What are the advantages of adopting IoT technologies in construction?

5.1 How do these advantages of adoption rank according to Dubai’s Contractors?

6. What are the challenges preventing the adoption of IoT technologies in construction?

   6.1 How do these challenges rank according to contractors in Dubai?

   6.2 Which of these challenges significantly prevent IoT technologies adoption?

1.8. Contribution to Knowledge

For decades, the construction industry has lagged in implementing technology to improve its productivity and efficiency. While technology's role is widely acknowledged, little to no studies have focused on the value of IoT in Dubai's construction industry. Therefore, the current research will benefit stakeholders by developing insights on IoT's role and its applicability in enhancing the construction sector's performance in Dubai, UAE. The benefits will be essential to the employees in their learning and project development processes. The study's findings will help employees make informed decisions on learning about IoT and using the technologies to boost performance. Decision-makers in the construction industry will find the study beneficial as it provides a framework for the strategic implementation of smart construction, a paradigm of IoT in the sector. Simultaneously, the decision-makers will identify the level of implementation and use of smart devices in their organizations. The project will benefit all stakeholders by outlining the benefits of IoT in the construction industry, the utilization of smart devices, and the critical factors to consider in the implementation of IoT in the construction business. For academicians, the project will offer a foundation for future studies. Due to the limitation of similar studies in Dubai, UAE, the current project will provide the starting point for future studies on the same subject.

1.9. Dissertation Structure

The study is segmented into introduction, literature review, methodology, results and analysis, and conclusion and recommendation. The introduction lays the study's foundation by highlighting the problem statement, research objectives, and research questions. The literature review section analyses the existing scholarly materials on IoT in the construction industry. From the literature review, a research gap is identified, and a route to answer the research questions and meet the objectives of the study established. In the methodology section, the data collection instruments and techniques of data analysis are evaluated. In the results and discussion section, the collected data is analyzed and outlined in the study. The final area of the study is the conclusion and recommendation. At this stage, the study's final findings are summarized and recommendations based on the established analysis. The chronological flow of these stages in the study ensures that the results meet the research objectives and answer the research questions.

CHAPTER TWO: LITERATURE REVIEW

2.1. Introduction

A literature review is a comprehensive analysis and summary of any previous studies on a select topic. The literature review's role is to describe, summarize, and evaluate earlier researchers' findings on the selected subject. Researchers can identify any gaps in the study from a literature review and come up with reliable recommendations. A literature review creates a landscape for the readers by giving them a full understanding of the study area's developments. The literature review also informs the readers that a researcher has incorporated all significant previous works in the field. In the current study, the literature review is broken down into the following sub-sections: definition of IoT, history of IoT in the construction industry, areas of IoT application in construction, types of IoT used in construction, advantages and disadvantages of IoT technologies adoption, factors that influence the adoption of IoT, and the challenges that impair the adoption of IoT.

2.2. Definition of Internet of Things

Over the past decade, the IoT concept has continued to attract attention from professionals and researchers in the field. As technology's role gains traction even in the most conservative industries like the construction sector, the desire to adopt IoT in business processes has increased. Various researchers have attempted to define the term IoT and how it relates to technology (Angelova, Kiryakova, & Yordanova 2017; Arslan, Ulubeyli, & Kazaz 2019; Batrawi & Percudani 2017; Brous, Janssen, & Herder 2020; Fruhlinger 2020; Gbadamosi et al. 2019). According to Gbadamosi et al. (2019), IoT is a network of things or objects with unique identifiers or addresses that communicate with one another. Arslan et al. (2019) explain that IoT is the environment of things able to interact with one another and corporate with their neighbors via radio frequencies, sensors, and other connectivity mechanisms for a pre-determined objective. Batrawi and Percudani (2017) argue that the idea of IoT is based on smart objects. According to the researchers, IoT entails connected smart devices able to share information. Brous, Janssen, and Herder (2020) define IoT as a growing network of objects able to communicate between themselves and other devices connected to the internet. Angelova, Kiryakova, and Yordanova (2017) argue that when talking about the IoT, what comes to mind are physical objects, controllers, sensors, actuators, and the internet. Fruhlinger (2020) describes the IoT as a network of smart devices connected and sharing rich data. Core elements define the IoT from the definitions, and they include smart devices, internet, data sharing, and interconnectedness. Therefore, in the current study, the IoT is defined as a network of smart devices, with unique identifiers, and sharing information over the internet.

There is consensus from researchers and professionals that the internet of things comprises interrelated computing devices and other objects that share information over the internet. According to Rouse (2020), IoT encompasses computing devices, mechanical and digital machines, objects, animals, or people with unique identifiers. All these 'things' can transfer data over a network without any human intervention. When it comes to humans or animals, Rouse (2020) argues that they have unique implants with sensors or transponders. For example, a human can have a heart implant, and an animal can have a biochip with an in-built sensor for monitoring behavior and growth. All these 'things' (computing devices) are assigned unique internet protocol (IP) addresses to facilitate communication. Ranger (2020) explains that the IoT refers to the billions of physical devices in the world connected to the internet. These devices collect and share data over a network. In his article, Ranger (2020) brings up the idea of smart devices. He argues that sensors' addition to computing devices improves their digital intelligence level and enables them to communicate in real-time. An example of IoT provided by the author is a lightbulb that can be switched off and using a smartphone application. In an IoT ecosystem, web-enabled smart devices use embedded systems like sensors, processors, and hardware components to collect and share information acquired from their environment. All communication takes place without human intervention. The role of humans is to set-up the devices to ensure that they function correctly. The aspect of avoiding human intervention makes IoT essential in business processes. It significantly lowers the cost of operations, error occurrence, delays in decision-making, and improves outcomes.

2.3. History of the Internet of Things in Construction

The idea of using sensors and intelligence in basic objects was started in the 80s and 90s (Ranger 2020). However, apart from early projects like the internet-connected vending machines, adopting intelligence objects was slow. The slow progress in the adoption of sensors and intelligence objects was due to reliable technology's unavailability. Chips were too big and bulky, and communication between objects was difficult. However, things changed after the first portable and cheap microprocessors were developed. The use of RFID and efficient technology chips provided the solution to connecting different devices. Another factor that led to the adoption of the idea of IoT was the availability of broadband internet and wireless networking. Simultaneously, the recognition and adoption of IPv6 provided enough IP addresses for all devices globally and increased the ability to inter-link objects. According to Rouse (2020), IoT helps people work smart and helps organizations automate their processes and reduce operating costs. These IoT merits have compelled construction businesses to use the technologies in their operations. IoT is seen as a significant concept in running construction businesses, particularly in situations where quality, efficiency, and client satisfaction are considered integral.

Arslan et al. (2019) argue that the construction industry is one of the largest globally and is conservative when it comes to adopting new methods and technologies. The same sentiments are shared by Gbadamosi et al. (2019), who argue that the construction sector is the least digitized and contributes less in productivity as compared to its potential. As compared to other businesses like those in the financial and healthcare industries, construction businesses lag in the implementation of technology. Hence, there is a need for industry players to re-look their investment strategies and implement solutions that foster quality, efficiency, and affordability. Due to increased pressure from consumers for affordable and quality housing and infrastructure, the construction industry brings real-time data analysis into century-old processes. IoT is being used to collect job site data in an accessible, efficient, and effective way (Mazhandu 2020). Understanding this historical progression is crucial in appreciating the value of IoT in Dubai's construction industry.

The implementation of IoT in construction businesses is guided by the need for cost management and quality improvement. Various frameworks of IoT have been adopted by construction businesses over the years. Kim et al. (2013) investigate mobile computing in on-site construction management. The researchers developed an on-site management system to reduce the cost of operations and monitor project timelines. The adopted framework's main components included site monitoring, task management, and information sharing in real-time. Kim et al. (2013) concluded that a mobile computing system was critical in enhancing the management of on-site construction. They found that the system improved flexibility, efficiency, and the quality of project outcomes. Hence, the implementation of IoT in the construction industry provides a reliable approach to meeting customer needs by looking at the quality and cost of projects.

Various mobile computing frameworks have been developed over the years in the construction industry. The common factor in these models is the connection between processes in construction sites and technology. Chen and Kamara (2011) were the first to develop a framework that implemented mobile computing for information management in construction sites. The researchers developed two models to meet their goal: an application model and a technological model. The application model's role was to enhance mobile computing, construction personnel, construction information, and construction sites. The technological model was to provide a structure for mobile computing systems. Combining these models ensured that information flowed from the construction sites – the computing devices collected the data and shared it with other off-site ones, making it easier for managers to monitor projects' progress remotely (Fernandez 2019). Before developing this framework, there were earlier attempts to implement mobile computing technologies in the construction industry. Some of the early developments include constructing an automated monitoring system relying on mobile computing, security and safety wireless networks, and the CAD visualization on mobile devices. These early attempts led to the development of the core features of an effective computing system in a construction environment by Kim et al. (2013). According to Kim et al. (2013), a construction management system should be capable of site monitoring. It should provide information on work tasks for site engineers to manage resources effectively. It should have the ability to share information in real-time. The use of IoT in the construction industry can be categorized into defect management, safety, disaster management, general construction management, and specific mobile features to help managers and workers monitor activities.

The construction industry has exhibited unprecedented changes over the past years. According to Fernandez (2019), at the end of 2013, there were about 13,000 designs and construction applications available for use. This was a significant rise from 230 applications of similar nature available in 2011. Construction sites relied on such mobile hardware as iPads, iPhones, Android phones, and blackberry phones. The applications used in these mobile devices include site photos, safety comments, scheduling, project closeout documentation, attendance lists, and punch list preparation (Fernandez 2019). Kim et al. (2013) argue that the need for collaboration necessitates computing devices in construction sites. The researchers say that computing devices enhance information sharing and increase collaboration of workers in construction sites. Chowdhury, Adafin, and Wilkinson (2019) posit that digital technologies are viable solutions for transforming and improving the construction industry. Cloud computing in construction businesses enhances efficiency and productivity by enabling easier information sharing and overall communication.

2.4.Areas of IoT Application in Construction

With the global growth of urbanization and population density, the construction industry is an integral player in social and economic development. However, the sector struggles with such challenges as inefficiency, cost and time overruns, and knowledge and skill gaps. The improvement of the sector's performance is influenced by industry players' ability to pinpoint the areas that need more attention. Some of these areas require the integration of technology (IoT) to improve the industry's performance. Below is an analysis of the construction industry areas that IoT will influence, and its application will shape the entire business environment.

2.4.1. Data Capturing and Display

Data capturing and display is part of the core foundation of a successful digitized industry. The data capturing and display area is characterized by the implementation of systems and guidelines to collect and store information on construction processes. It is the collected information that enables project managers to make informed choices. Hence, the data capturing and display area is critical to the success of construction businesses. Al-Keim (2017) argues that the construction industry is fragmented, dynamic, and involved with high-risk uncertainty. He points out that cost overruns and projects' delays are common challenges that affect contractors (Al-Keim, 2017). Such issues in the construction industry impair business productivity. Therefore, the inclusion of IoT in the data capturing and display segment provides project managers with the opportunity to monitor the status of projects in real time. Data capturing entails the collection and transfer of information from and to the construction sites. A study conducted by Aleksandrova, Vinogradova and Tokunova (2019) depicts some of the common IoT technologies used in data capturing and display as 3D laser scanners and image-based and Radio Frequency Identification (RFID). According to the researchers, accurate and timely information in the construction sites is a regular and repeated process that aids the development of quality projects (Aleksandrova, Vinogradova & Tokunova, 2019). Salehi and Yitmen (2018) argue that leveraging on automated data capturing technologies in building information modelling (BIM) is crucial in advancing decision making in construction sites. From the researchers' perspective, data capturing and display is an integral area that must be automated to advance project development in the construction industry.

Data capturing and display offers a partial solution to productivity challenges in the construction businesses. A study conducted by Chowdhury, Adafin, and Wilkinson (2019) established digital technologies' impact on the construction industry's productivity. The benefit of using technology in the construction environment is linked to the automated capture and analysis of data to inform real-time decision-making. According to Mazikana (2019), technology is essential for organizations to enhance their effectiveness and efficiency. Hence, the IoT in the construction industry provides an opportunity for industry players to increase their productivity. As suggested by Arslan et al. (2019), IoT enhances monitoring, safety assessment, and decision-making. Remote monitoring limits the movement of project managers and enables them to evaluate many projects simultaneously. Gbadamosi et al. (2019) argue that IoT gives rise to smart construction. The same argument is supported by Jia et al. (2019); the researchers explain that smart construction is directed towards efficiency and quality but it is dependent on the data capturing and display technologies. A critical evaluation of the studies by Jia et al. (2019) and Gbadamosi et al. (2019) show that the idea of smart construction is founded on the promise of enhancing productivity and meeting the needs of the customers. The adoption of IoT in construction businesses in the data capturing and display area gives construction businesses an improved way of analyzing information in real-time.

2.4.2. Data Exchange

As compared to the conventional tools, digital systems allow the exchange of data in real-time between construction sites. The application of IoT technologies in data exchange is informed by the need to improve monitoring and performance of projects. Batrawi and Percudani (2017) explain that the internet will shift from its conventional concept to pave the way for connecting physical and virtual realms. The adoption of IoT will lead to new opportunities and competitive advantages in the technological space. The interconnection of smart objects using global internet networks will allow enhanced communication and remote monitoring of projects. According to Angelova, Kiryakova, and Yordanova (2017), the IoT has autonomous and independent components to share information. The ability of these computing devices to operate without human intervention makes them ideal for construction monitoring. Some of the construction industry's challenges include low productivity, safety concerns, and quality issues (Loganathan et al. 2017). These challenges can be thwarted if the industry players adopt the best monitoring systems. Dele, Ilori, and Windapo (2019) explain that technology is an effective and reliable way of dealing with most challenges affecting the construction industry. Technology aids project managers to share information in real-time on the status of projects. Implementing monitoring systems (sensors and other technologies) alleviates project managers' ability to predict potential challenges that may hamper the construction activities. Besides, the use of a ranger of sensors – vibration, motion, noise, and others – in construction sites ensures that project managers have a full understanding and scope of what they deal with and how to respond. For example, sensors collect information to predict and minimize faults and accidents in the workplace. Generally, IoT is critical in enhancing monitoring activities in construction sites.

The availability of real-time information makes it possible to know the status of every project. Thus, project managers can schedule maintenance for all the tools and equipment used in the project. According to Parpala and Iacob (2017), IoT enables the collection of data on the usage of different production equipment. Using the data, project managers can determine where more attention is needed or what needs fixing. At the same time, IoT in construction sites can be used to determine the air circulation and the overall safety of the sites (Ringvall, 2017). Sensors can monitor the integrity of the construction materials and their suitability in varying temperature environments. As compared to the traditional physical site visits and assessments, modern project managers have better alternatives for using IoT to monitor construction activities. IoT is more reliable, effective, and dynamic than manual physical assessments that often take time and have a high level of inaccuracy. In some settings, equipment sellers are becoming significant partners in the construction process. They use IoT to monitor their equipment's performance, leaving their customers to focus on core business processes. Hence, construction businesses are saving millions of dollars that would have been directed towards maintenance. The application of IoT technologies in data exchange offers the construction businesses a competitive advantage, as they are able to respond to emerging issues on maintenance, safety, and project quality improvement.

2.4.3. Site Supervision

Site supervision is one of the areas that greatly influence the outcome of construction projects. The ability of contractors to manage cost, time, and other factors associated with projects is influenced by their supervision techniques. In modern construction settings, technology has proved to be a critical component in the supervision of projects. Today, project managers can leverage the power of UAVs, sensors, and other-related technologies to project sites. Taffese, Nigussie and Isoaho (2019, p. 672) explain that it is possible to assess materials' integrity using IoT. By embedding sensors in equipment or construction tools, project managers can remotely monitor activities and detect any problems that need urgent attention. For example, they can detect vibrations and cracks in buildings without endangering human lives. In some cases, the construction sites may be filled with dust or dangerous gases, and the best way to carry out any monitoring is by using UAVs.

Dupont, Chua, Tashrif, and Abbott (2017), argue that the use of UAVs can address the productivity gap between construction businesses and workers. A boom in the number of UAVs in the market has allowed firms to address some of the conventional challenges like comprehensive site monitoring. In a related study, Delgado et al. (2019) investigate the suitability of robotics and automated systems in the construction industry. According to the authors, robotics and automated systems can revolutionize labor-intensive industries, as is the case in the construction sector (Delgado et al., 2019). UAVs, especially drones, aid project managers in closely monitoring complex projects in real-time while optimizing profitability. UAVs play a significant role in the reduction of operating costs in construction activities by ensuring that project managers closely monitor or supervise projects, especially remotely.

The use of autonomous vehicles in construction sites is gaining momentum owing to the associated benefits. For example, some large companies like Volvo, Komatsu, and TMA are coming up with new dump trucks and excavators to limit human life exposure to unsafe working conditions. These vehicles are being deployed in dangerous construction sites where humans cannot safely operate. As the industry trends shift, every business will adopt UAVs and autonomous vehicles at some point. Vasista and Abone (2018) argue that there must be an elaborate communication plan for successful project completion – collection and sharing of data. IoT enabled UAVs and autonomous vehicles to enhance smart decision-making. They avoid the complexities associated with manually collecting and analyzing data on spreadsheets. For example, instead of measuring tapes and other tools to collect data on construction sites, drones can be used accurate survey maps and provide aerial images of the job sites. Drones can also remotely monitor construction activities' progress and show any potential issues that need immediate attention.

2.4.4. Contextual Data Request

Contextual data denotes the information that provides a specific context of an event or item. In the construction industry, the data is critical in providing a broader understanding of the specific areas of performance. Arslan et al. (2019) explore the role of IoT in communication. The researchers explain that technology is critical in the collection and dissemination of information. Thus, construction professionals can rely on the collected data to assess specific projects and compare customer needs. The emergence and adoption of big data concepts advances the idea of customized projects. At the same time, it enables construction businesses to integrate the concept of smart construction. In this regard, IoT facilitates contextual data requests. With IoT technologies, project managers can use the available systems to collect information targeting specific projects and performance areas.

Some of the vital sources of contextual data in a construction environment include weather, traffic, economic changes, customer behavior, milestones, delivery trackers, GPS tools, and inventory management. All the information collected from these sources feeds to the overall objective of enhancing performance and quality of projects. As explained by Vasista and Abone (2018), IoT vitalizes the ability of project managers to have an elaborate communication plan. It means that the availability of contextual data will enhance the ability of project managers and other professionals in the industry to respond to customer demands and market changes.

2.4.5. Smart Metering

Cost overruns are among the main challenges faced by construction businesses. Hence, it is vital for project managers to ensure proper management of utilities in their operations. Smart meters provide the ability to track and control energy consumption in business operations. According to Zivic, Ur-Rehman, and Ruland (2016), intelligent buildings are based on smart metering. They provide real-time accumulating information on service usage (electricity, gas, water, and other utilities). Unlike the traditional models, smart meters have a remote capability; hence, limits the need for personnel movement to construction sites. The limited human intervention in the management of energy consumption has sparked the demand for smart metering technologies. In addition to recording the consumption points, smart meters relay additional information to project managers including time and location of resource use. The availability of such data enhances the scope and ability of construction businesses to make critical decisions on cost management and resource allocation strategies.

2.4.6. Material Management

Construction sites are characterized by a wide range of materials including concrete and equipment. At all times, project managers have to assess the integrity and suitability of the materials at the construction sites. Project managers have to ensure that there is a correct balance between the inputs and outputs at the construction sites. Thus, the use of technology in material management offers project managers a better opportunity to meet the needs of the customers. According to Hamooni et al. (2020), concrete must attain sufficient strength and durability to be used in the construction process (making beams, walls, slabs, or columns). The use of IoT allows for continued analysis and monitoring of concrete without any destruction in a cost-effective manner. In IoT enabled framework, sensors are embedded in concrete during casting, and they collect data on the curing of the concrete in real-time. The collected data will inform the project managers about the status of the concrete. Construction managers can easily estimate the strength of the concrete and optimize their operations.

Construction businesses can avoid huge costs related to logistic operations, documentations, and ineffective recycling plans. The use of monitoring systems provides real-time information to project managers. The collected information analysis will provide insights into the most effective means of recycling or collecting waste at construction sites (Pardini et al., 2020). Trash levels can be monitored remotely, and schedules made on when and how to manage the accumulated waste. Further, material management requires the assessment of their standards and stock levels at the construction sites. For project managers, it is crucial that the inputs meet the expected targets. For example, the amount of concrete at a construction site must meet the projected demand. Therefore, the use of IoT in material management offers project managers an opportunity to determine the best quality and amount required to complete construction projects.

2.4.7. Safety and Security

The safety and security of construction sites are significant concerns for stakeholders. According to Keller (n.d), tens of thousands of workers are injured in construction sites each year – on average 1,000 of these workers die from injuries. While many of the injuries result from simple accidents, others could be prevented if necessary interventions are adopted. Brous, Janssen, and Herder (2020, p. 52) argue that the adoption of IoT is critical in risk mitigation. Businesses can use technology to foster their monitoring strategies. IoT enhances the sharing of information between workers in construction sites and project managers in remote locations. According to Olanrewaju, Tan, and Kwan (2017), the ability to share information makes it easier to mitigate risks and enhance construction sites' safety. Monitoring large projects' security and safety is complex and may not be effective if the traditional manual and labor-intensive approaches are used. The use of human agents in monitoring sites does not speed the decision-making process. It fails to equip the project managers with the ability to predict and prevent potential risks and safety concerns. However, the use of IoT enabled systems allows project managers to track the integrity of materials and equipment at construction sites. Businesses that have implemented IoT do not require frequent site visits as the system of connected sensors provides a reliable monitoring environment to safeguard workers' health. Furthermore, IoT wearables can be used to detect any physical manifestations of distress in workers – they can assess blood pressure, pulse rate, and other abnormalities that may compromise employees' safety. Proper management of safety and security concerns enhances overall project cost and quality.

Wearable technologies enhance construction businesses' ability to improve safety, reduce workplace injuries, and improve efficiency (Galbraith, 2019). In a construction setting, wearables include computers or advanced electronics worn by employees to collect and deliver data. Wearable technologies can detect and warn users of any potential dangers that may lead to harm. Wearable technologies are fitted with sensors and internet-enabled devices that ensure that they communicate with other computing tools. Awolusi, Marks, and Hallowell (2018, p. 96) argue that the adoption of wearable technologies can lower the prevalence of accidents in the construction industry. For wearable technologies to function, they need to be connected to other computing devices, which brings to fore the IoT concept. Therefore, IoT can be applied in wearable technologies to enhance staff safety, provide early warnings to managers on the work environment's status, and relay data for real-time decision-making.

2.5. Types of Internet of Things Application in Construction

2.5.1. Smart Devices (Smartphones and Tablets)

Technology continues to play a phenomenal role in the development of the construction industry. As the demand for quality and reliable infrastructure and buildings increases, businesses implement IoT to help deal with inefficiencies and quality issues. Various forms of IoT applications are used in the construction industry. Smart devices are an integral part of the IoT. According to Stojkoska and Trivodaliev (2017, p. 1), smart devices must be interconnected to develop smart homes. These computing devices must be able to collect and share information. Dozens of these devices are equipped with communication interfaces and linked to mobile applications for remote control. Due to these smart devices' significance, construction businesses have started to integrate them into their projects. The commonly adopted smart devices in Dubai include smartphones and tablets.

A survey conducted in New Zealand showed the common smart devices used in the construction industry, as shown in figure 1 below.

Devices	Response Count (from 141 respondents)	Response percentage
iPhone	105	74.47%
iPad	56	39.72%
Android Phone	70	49.65%
Android Tablet	30	21.28%
Tablet PC	23	16.31%
Windows Phone/Tablet	7	4.96%
RFID	3	2.13%
Wearable Devices	2	1.42%
Blackberry	1	0.71%

Figure 1*:* Smart devices used in New Zealand construction (Fernandez, 2019, p. 134)

From the figure above, smartphones were mainly used by construction businesses in their activities. These devices' usage is linked to their availability, ease of use, affordability, portability, and compatibility with other computing devices. It also was found that tablets were other smart devices used in the region. The use of smartphones and tablets in construction activities is not limited to New Zealand, as Fernandez (2019) explains. A survey conducted in the UK and the Dominican Republic also showed that smartphones were the primary computing devices used in construction activities followed by tablets (see figure 2 below).

Smart devices	Response percentage DR (out of 25 interviewees)	Response percentage UK (from 14 interviewees)	Total response count (from 39 interviewees)	Total response percentage
Smartphones	84.0%	100.0%	35	89.7%
Tablets	16.0%	57.1%	12	30.8%
Wearable devices	0.0%	14.3%	2	5.1%
Unmanned devices	8.0%	21.4%	5	12.8%
Smart boards	4.0%	7.1%	2	5.1%
Sonar surface	0.0%	7.1%	1	2.6%
GPS + Equipment	4.0%	0.0%	1	2.6%
Security cameras	4.0%	0.0%	1	2.6%

***Figure 2**:* Smart device usage in the UK and Dominican Republic (Fernandez, 2019, p. 135)

2.5.2. Wearables

Wearable technologies denote the smart electronics worn close to and/or on the surface of the skin. They are used to collect, analyze, and transmit information concerning body signals and/or ambient that allow the wearer take immediate action. For example, in construction sites, wearables are significant in tracking the heart rate, pulse rate, or body temperature of the employees. By using wearables, project managers can monitor the performance and health of the employees in construction sites. Linder (2017) argues that wearable technologies could improve the safety and efficiency of buildings. Galbraith (2019) explains that wearable technologies can caution workers when nearing exhaustion, warn of hazardous materials, and inform managers of potential emergencies. While wearable technologies are acknowledged as essential in enhancing construction activities, their adoption remains low (see figures 1 and 2). Wilson, Hargreaves, and Hauxwell-Baldwin (2017), smart homes are equipped with such computing devices as sensors, monitors, appliances, interfaces, and remote-controlled devices.

These devices are also used in a smart construction setting, and the overarching technology that offers access to all these devices is a smartphone. It explains why smartphones are the dominant devices in the construction industry. Smartphones can be integrated with applications that are connected with other devices at construction sites.

2.5.3. RFIDs

Radio frequency identification (RFID) technology is becoming common in the construction industry. The aim of using this technology is to enhance efficiency, manage assets, and reduce theft. RFID systems have a reader (two-way radio transmitter) that emits a signal to labels or tags. The microchips in the tags enhance the collection and processing of information. The use of RFID technology has provided an avenue for contractors to manage equipment and tools at construction sites (Konin, 2016). It has significantly reduced the number of lost or stolen items. According to Olanrewaju, Tan, and Kwan (2017), the sharing of information facilitates efficiency in the construction environment. Thus, contractors can know on a daily basis the location of their assets or adequately manage their inventory. Further, RFID enabled systems can be used in tracking the number of workers at jobsites, providing restricted access to jobsites, prevention of counterfeit, and supply chain management. Generally, the technology is critical in workforce and safety management in construction sites and improvement of efficiency and reliability of operations of contractors.

2.5.4. Equipment Telematics

The construction industry requires heavy investment in equipment purchase and management. Hence, the proper tracking and monitoring of these assets is critical in the management of cost and time overruns. Telematics systems combine the capabilities of GPS technology, on-board diagnostic, and monitoring sensors to track and report the performance and operation of the construction equipment. Project managers or lead engineers can access data from telematics systems to assess location, fuel consumption, idle times, and other machine alerts. Telematics helps construction contractors handle asset allocation, maintenance and repairs, operator performance, theft control, and manage other activities linked to the use of equipment. According to Jagushte (2017), the use of telematics reduces the management complexities in the construction industry, especially when it comes to the use of equipment. In this regard, telematics offers contractors an opportunity to improve productivity and efficiency.

2.5.5. UAVs/Drones

As technology advances, construction businesses are starting to use sophisticated technologies – much superior to smartphones. The implementation of robotics and UAVs in construction processes marks an improvement in the industry. UAVs are perceived as building efficient ways within a short timeframe (McCabe, Hamledari, Shahi, Zangeneh, & Azar, 2017, p. 1). The most common UAV used in construction sites is a drone. According to Lin (2018), drone technology originated in the military but has since been adopted for private use. Although the construction industry lags in the use of UAVs, there have been radical changes to adopt these technologies. Drones have modernized the construction industry by offering a reliable means of monitoring expansive job sites. UAV technology's continued improvement will provide businesses with a competitive advantage by cutting costs and improving data collection and analysis strategies.

2.5.6. Cloud Storage Technologies

Cloud computing is one of the latest technologies that promises to revolutionize the construction industry. The cloud-based technologies are focused on the automation of projects and operations in an organizational setting (Xenidis & Chiotakis, 2017). Hence, employees are no longer tied to the traditional, manual systems that impair their efficiency and productivity. Christianson et al. (2017) explain that cloud storage technologies enable remote service management. Project managers are no longer required to visit construction sites to manage the operations. The combination of cloud storage technologies and other tools make it possible for project managers to coordinate construction workers. In this regard, cloud-based solutions improve flexibility, real-time collaboration, and time and cost management.

2.5.7. Security Cameras

There is no denying that construction sites are places with high traffic from workers and equipment. Thus, it is important for management to monitor the activities at any given time. One of the best approaches used by construction companies is the video surveillance systems, with security cameras as the primary choice for many entities. The installation of security cameras is a priority for most construction businesses due to their affordability and reliability in the industry. With security cameras, managers can monitor the construction workers, evaluate the construction sites, and determine the use of resources (Kiganda 2016). The adoption of security cameras improves the decision making process by providing remotely providing real-time information. Moreover, it reduces the cost of project management due to minimized movement and reduction of supervision personnel. The integration of security cameras with other IoT technologies such as cloud computing and wearables provides a dynamic approach for project managers to not only fulfill their supervision role but also safeguard the workers at construction sites (Xenidis & Chiotakis, 2017). The real-time information from security cameras and wearables can be channeled to other decision makers through cloud-based solutions to facilitate collaboration and improved project outcomes.

2.5.8. Building Information Modelling (BIM)

BIM is one of the most incredible technological advancements in the construction industry in recent years. BIM has replaced the need for blueprints, which were mandatory before starting projects. BIM enables project managers to create interactive 3D models and share the same with their stakeholders. Hence, BIM improves the connection between project managers and their customers. It ensures constant sharing of information among the involved stakeholders, and decisions are made in real-time. According to Mesároš and Mandičák (2017), some of the benefits of BIM include cost reduction, avoidance of unnecessary documentation, time reduction, employee productivity increase, and effective financial control. Smart devices are used in the construction process and enhance the sharing of information. Therefore, smart devices are considered in the implementation of BIM in construction organizations.

2.5.9. Augmented Reality (AR) and Virtual Reality (VR)

There have been extensive talks on the significance of AR and VR in the construction industry. These two technologies are geared towards enhancing the experience of users by building the interaction between the real and virtual worlds. VR removes a user from the real world and replaces it with a virtual one. However, AR lets the users experience a digitally augmented real world. AR provides an interactive experience of a real-world environment by enhancing the objects using computers (Ahmed, Hossain, & Hoque, 2017). Piroozfar, Essa, and Farr (2017) argue that AR is sustainable, less intrusive, and more adaptable to the growing industry demands. The inclusion of AR and VR in construction settings improves the work environment's health and safety, reduces cost, improves efficiency, and enhances stakeholder collaboration (Piroozfar, Essa, & Farr, 2017). According to Ahmed, Hossain, and Hoque (2017), AR and VR have the potential of enhancing the design of projects and could benefit construction businesses in meeting the needs of their clients. Noghabaei et al. (2020) explain that the prominence of AR is linked to its improved ability to enhance work environments' safety and health. AR and VR ensure that project managers can minimize errors by providing virtual designs and making necessary changes before implementing real projects. Error rectification helps businesses deal with the cost of materials, properly utilize the workforce, and manage any project overheads. The main objective of AR and VR applications is to bring together the real and virtual worlds. Using AR and VR applications, businesses can overlay virtual information on real projects. The use of AR and VR applications requires the recognition of the value of IoT. Computing devices need to interconnect to share information and facilitate decision making in construction sites. The application of AR and VR in the construction activities lowers manual processes that are both time and labor-intensive. Hence, in the end, contractors using these applications record superior outputs as compared to those who do not.

2.5.10. Geographic Information Systems (GIS)

Geographic information systems capture, store, analyze, manipulate, and manage all geographic-related data. GIS is widely used in the construction industry, owing to its ability to capture data in expansive job sites. According to Patel, Patel, and Patel (2017, p. 104), GIS can display a 3-D view of buildings. The progress of construction activities can be shown in a 4-D view. The 3-D and 4-D views are integral in ensuring that stakeholders follow-up on the construction activities' progress and make any necessary interventions. With GIS, project managers can adequately control construction projects' main factors: time, cost, and quality. Kumar and Reshma (2017, p. 2) explain that technologies' limitations exhibited by such applications as Microsoft Project informed GIS development. The adoption of GIS enables project managers to develop better visualizations to track time and cost overruns in projects. At the same time, project managers can deal with safety concerns and workplace restrictions.

Generally, GIS helps disseminate and analyze data for real-time decision-making to optimize construction activities.

2.5.11. Robotics

The robotic technology provides construction businesses with an opportunity to maximize outputs and minimize the inputs. The goal of integrating robotics in the construction environment is to automate the processes and improve productivity. Automation involves the self-regulation procedure done using computerized machines to complete specific tasks (Oke, Aigbavboa, & Mabena, 2017). According to Carra et al. (2018), the first form of robotic technology used in the construction industry was seen in Japan in the 70's. The goal of using this technology was to boost the quality of prefabricated elements in residential buildings. Since then, there has been extensive adoption of robotics in the construction industry. The implementation of robotic technology in the construction environment ensures the attainment of quality output due to the ability of contractors to offset the human workers' weaknesses. With robotic systems, a high level of consistency is attained. Moreover, project managers do not have to worry about such issues as safety and health of workers while completing sensitive projects.

2.6. Advantages and Disadvantages of Internet of Things Applications

Mohammed and Ahmed (2017, p. 129) argue that the internet of things will make human life easier, safer, and lead to the adoption of smart computing devices. IoT is widely adopted in smart cities, homes, transportation, and energy utilization. Thus, widespread IoT has a positive and negative impact on human experiences. The same experience is transferred to the construction contractors in Dubai. Due to the personal and organizational benefits attributed to the use of IoT technologies, Dubai-based construction contractors are likely to experience the same benefits. Therefore, the analysis of the benefits of IoT technologies to Dubai-based contractors takes into consideration the human and organizational experiences. Below is an analysis of the advantages and disadvantages of IoT technologies, focusing on the construction contractors in Dubai, UAE.

2.6.1. Advantages

One of the primary benefits of using IoT is enhancing communication. From the start, the objective of the internet and technology was to facilitate communication. Since its inception, the internet has eased the transmission of information in society. According to Quek (2017), IoT encourages communication between devices (machine-to-machine communication). Physical computing devices can remain connected and improve users' ability to receive and analyze data in real-time. In the construction environment, IoT will aid project managers to collect and analyze data on job site activities remotely. Bayani, Leiton, and Loaiza (2017) explain that IoT will enhance collaboration by facilitating communication. The continued sharing of information improves the performance of workers.

In work environments, employees can collect and share information on their progress. The continued relaying of data from one location to another ensures that teams are updated on real-time projects simultaneously. With the adoption of IoT technologies, there is systematic collaboration and decision-making leading to improved productivity. Carra et al. (2018) argue that the inclusion of new technologies like robotics in construction environments facilitates consistency and accuracy in project completion. It means that the implementation of these technologies encourages high productivity among construction contractors. Besides, the quality of the outputs is ascertained due to improved consistency and accuracy of operations. Aleksandrova, Vinogradova, and Tokunova (2019) explain that the adoption of RFID technologies ensure that there is proper asset and inventory management. Moreover, the technologies facilitate the reduction of cost associated with wastage and lost items in the construction sites. In this regard, IoT technologies are pivotal in the management of costs. At the same time, they reduce the burden of handling manual processes and physical site monitoring. The integration of such systems as drones, security cameras, and cloud-based storage ensure that there enhanced automation of processes. It means that there is a lot of time saved that would have been wasted by physical movement of personnel from one site to another.

Angelova et al. (2017) argue that the built-in sensors in computing devices enable tracking employees' safety and well-being in construction sites. In this regard, the internet of things is critical in monitoring activities. With IoT, businesses can avoid the manual-based monitoring and assessment of projects. Due to the interconnectedness of digital devices, IoT enables automation and control of activities in an organizational setting (Quek 2017). Moreover, automation and control can occur remotely. The limitation of human intervention in IoT ensures that businesses can lower operating costs and inefficiencies. Besides, timeliness is attained in the completion of projects. Angelova et al. (2017) explain that automation and control of activities enhance cost saving. According to the authors, the connectivity and fast communication in interlinked devices reduce the response time and labor required in projects. There is increased productivity and efficiency due to IoT technologies (Angelova et al. 2017). Improved quality, timeliness, and efficiency boost customer experience. Hence, the idea of IoT tends to improve the quality of projects in the construction industry. Smart devices enhance stakeholders' interaction, making it possible for them to share their projects' views.

The adoption of IoT technologies such as UAVs, cloud computing, security cameras, and smart devices, enhance environmental sustainability. It makes it possible for construction businesses to have a limited impact on the environment. For example, in expansive projects, instead of project managers using vehicles to map the sites, they can use more efficient and reliable technologies like drones. Further, these technologies limit the movement of people from one location to another, hence, reduce the carbon footprint of projects. The use of autonomous vehicles and sensors to collect data on the performance of equipment ensures that energy efficiency is enhanced. For example, the maintenance department can ascertain when and where to make changes in equipment that consumes more power than expected. Generally, IoT technologies improve the efficiency, reliability, and performance of equipment and workers in the construction sites. In so doing, they limit the environmental impact of projects, improve productivity, manage time and cost overruns, enhance quality of outcomes, and improve the safety and health of workers.

2.6.2. Disadvantages

While IoT is widely accepted as a way of changing everyday activities in the construction industry, it has some drawbacks. According to Angelova et al. (2017, p. 407), security and privacy are some of the main disadvantages of using IoT in business activities. Reliance on multiple interconnected devices exposes users to security and privacy threats associated with the internet. For example, people become prime targets for cybercriminals who take advantage of computing devices and data for criminal acts. Safety and security concerns continue to impair IoT adoption in various sectors (Albishi, Soh, Ullah, & Algarni, 2017, p. 613). According to Quek (2017), there is a high risk of losing data whenever a person uses the internet. The use of IoT requires a combination of multiple devices to work effectively. However, it is not always that the available tools will be compatible. Hence, compatibility issues will adversely affect the ability of users to use IoT in decision-making.

In some cases, the speed of technology development makes it impossible to upgrade all devices, which raises compatibility issues. Ryan and Watson (2017, p. 3) argue that the complexity of the IoT is a challenge that needs to be resolved. Dealing with many independent and interrelated components makes it difficult for small entities to take advantage of the IoT. Although computing devices' cost has declined in recent years, it remains relatively high for individuals and small enterprises. Medium and small entities in the construction industry have to incur huge costs associated with purchasing devices and training staff to implement IoT. A critical analysis of the disadvantages and advantages of the IoT shows that its usage merits outweigh the demerits; hence, the recommendation for construction businesses to implement the concept.

2.7. Factors Affecting the Adoption of Internet of Things

The adoption of technology varies from one individual or organization to another. It is crucial to use the diffusion of innovation (DOI) theory and the Technology-Organization-Environment (TOE) framework, as Olushola (2019) suggested, to understand IoT adoption factors. The DOI theory argues that adopting a new idea does not happen simultaneously in a social system. In an ideal society, some are more apt to adopt innovations than others are. The five adopters' categories include innovators, early adopters, early majority, late majority, and laggards. Therefore, when evaluating innovation and its reception in the market, these are the different stages to consider. Based on the DOI theory, innovativeness is related to such variables as leaders' characteristics, organizational characteristics (internal structures), and an entity's external traits. The figure below shows a summary of the factors that influence IoT adoption based on the DOI theory.

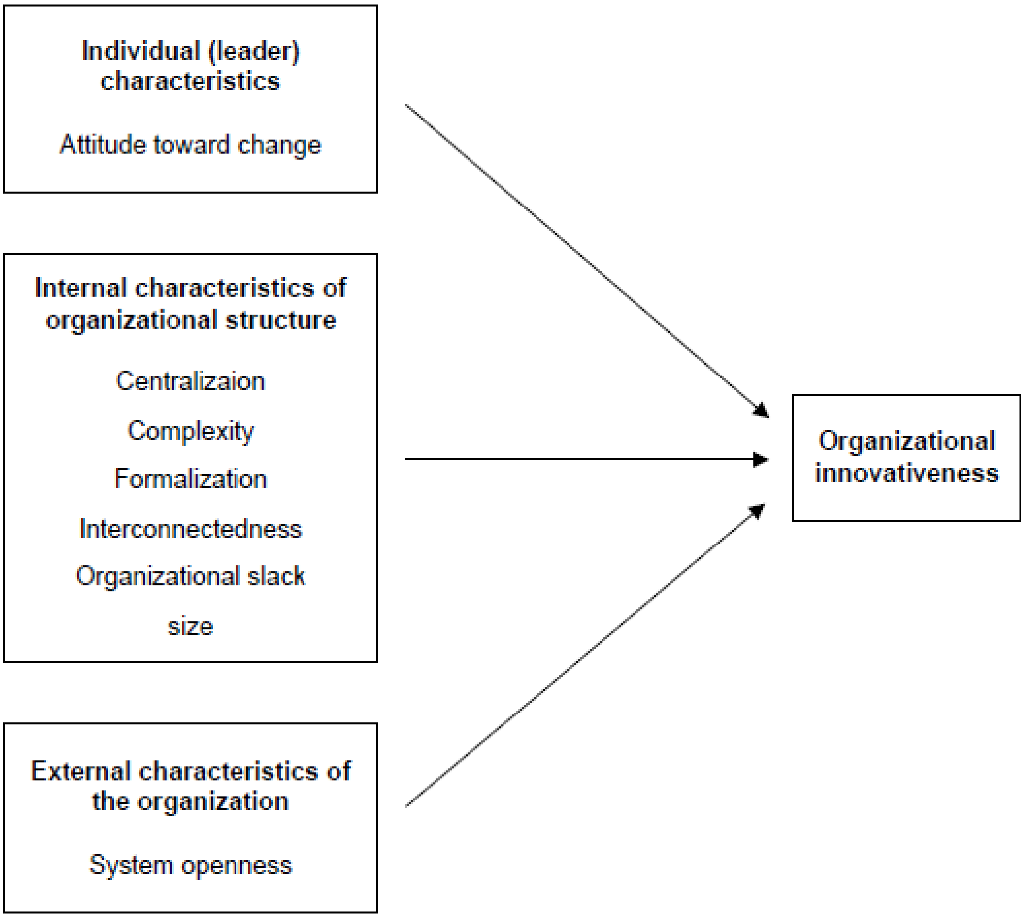

Figure 3*:* Diffusion of innovation (Fonseka et al. 2020, p. 111)

The technology, organization, and environmental context framework was developed in the 90s and identifies three contexts of an organization that influences innovation adoption (Fonseka et al. 2020). The technological context includes practices and equipment used by a firm internally and externally. The organizational context denotes such measures as the scope, size, and management structure of an entity. The environmental context is the arena in which a business operates – industry, competitors, and regulatory setting (Fonseka et al. 2020). The figure below illustrates the factors that affect innovation adoption following the TOE framework.

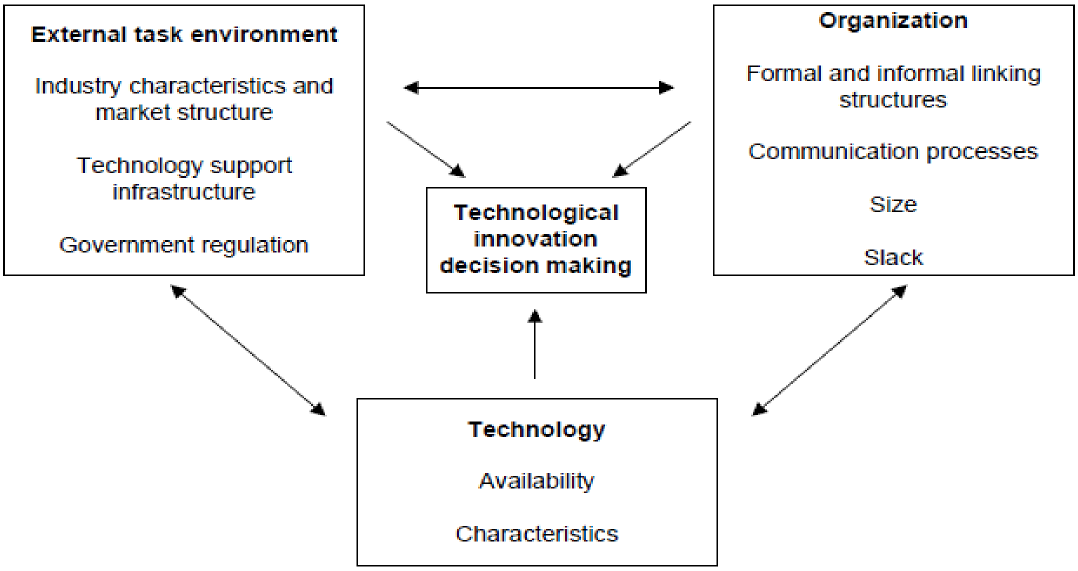

Figure 4: TOE framework (Fonseka et al. 2020, p.112)

Olushola (2019) combines the TOE framework and the DOI theory to evaluate the factors that affect IoT adoption. According to the researcher, the need for productivity, safety, flexibility in operations, and customer satisfaction influence the adoption of IoT (Olushola 2019). Kao, Nawata, and Huang (2019) explain that consumer satisfaction is one of the primary factors influencing the use of technology in businesses. The same applies to construction businesses that would want to have a competitive advantage in the market. Brous, et al. (2017) assert that IoT is critical in data management. Hence, organizations use IoT to enhance their data analytics and improve decision making for gains in production. In this regard, the influencing factor is productivity (manage costs and maximize profits). The literature on the factors influencing the adoption of IoT shows the main ones as productivity, mobility or flexibility in operations, safety and security of projects or workplaces, the establishment of competitive advantage, and customer satisfaction by adhering to the quality of projects. According to Fernandez (2019), the factors can be segmented into internal and external elements. The internal factors include productivity, mobility, communication, health and safety, and management and procurement. The external elements include environmental protection, transparency, competitive advantage, stakeholders' satisfaction, and government regulations.

A study conducted by Gerritsen (2018) shows that the primary factors driving the adoption of IoT technologies in business include cost management, productivity, communication, and environmental sustainability. As businesses strive to develop their unique propositions in the market, they are resorting to the use of IoT technologies to lower their carbon footprint in the environment. It is the same approach adopted in the construction industry. For decades, the construction sector has been branded as one of the main sources of pollution in the world. Thus, the advent of the IoT technologies offers construction contractors an opportunity to address the environmental protection requirement. A study Jaafreh (2018) in Saudi Arabia explores the reasons for the adoption of IoT technologies in the market. According to the author, these technologies are used as a means to manage organizational processes. Businesses have started relying on IoT technologies to manage their procurement processes. The implementation of these technologies provides real-time information to engage stakeholders in decision-making. Hence, as the construction industry grows in complexity, IoT technologies are offering a reprieve to procurement and management personnel to deal with organizational operations.

The government plays a direct role in dictating the type and nature of technologies used by organizations for the good of the public. Hence, as suggested by Olushola (2019), government regulations are external factors in the implementation of IoT technologies. According to Mariani (2020), the government develops policies and guidelines on the management of IoT technologies in the construction industry. Some of the areas the government is concerned with include security and cost management. Therefore, there are minimum standards that must be met by construction businesses to use IoT technologies in construction sites. Construction contractors are continually exposed to assessments to guarantee that they meet the set regulations and protect the needs of the stakeholders.

2.8. Challenges Preventing the Adoption of the Internet of Things

The use of IoT has led to a surge in security and privacy risks in the construction industry. According to Tawalbeh et al. (2020), not changing passwords, using devices unconsciously, and the lack of updates have increased the risk of cyberattacks. At the same time, there are vulnerabilities for attackers to breach and expose sensitive data. The pace at which more people are using IoT enabled devices has led to the rhetoric from professionals that these computing devices are the vulnerable point for cyberattacks. The probability of losing data to malicious attackers has led to a lack of trust and confidence in IoT in the construction industry, especially in the most sensitive areas. Alaloul et al. (2020) argue that efficiency and quality of output are primary indicators of the Industrial Revolution in modern society. While the use of IoT is hailed as a factor in enhancing efficiency and productivity in construction activities, it also brings about energy consumption problems. IoT requires the interconnection of independent computing devices, and all of them use energy. Depending on the complexity of the networks used by a business, power consumption will be a problem in the end. The fear of incurring high-energy costs due to multiple computing devices continues to hinder IoT implementation in the construction industry.

Fernandez (2019) argues that the pace at which technology changes makes it difficult for organizations to keep up with the latest ones. For example, the speed of processors and storage memory has almost tripled in the past decade, making the first and second-generation computers obsolete within a short time frame. Any transition from one form of technology to another requires additional costs, and some organizations cannot meet these changing cycles.

Hence, the speed of obsolesce of technology is a significant challenge in the adoption of IoT. Cultural factors adversely impair the adoption of IoT in construction organizations. According to Hamada, Haron, and Zakaria (2016), lack of knowledge and skills in computing devices and low acceptance of technology influence IoT adoption. The rate of acceptance of IoT varies from one organization to another. In businesses with dynamic cultures, the level of acceptance of these technologies is higher than in others. Besides, poor leadership is a challenge in the use of IoT. A lack of progressive leadership strategies does not favor the implementation of IoT enabled devices.

Poor internet connectivity in some parts of the world impairs IoT as businesses will not see the essence of adopting these computing devices. Khan et al. (2017) explain that there has been a progressive growth in the use of technology in Dubai, UAE. However, various industries, including the construction sector suffer from connectivity problems. The lack of adequate infrastructure to boost connectivity impairs the use of IoT by construction contractors. Hence, connectivity problems continue to cripple the digitization of the construction industry. Other challenges identified by Fernandez (2019) include the lack of service availability, scalability, adaptability, portability, maintenance, and compatibility of IoT applications. Therefore, construction businesses that would want to implement IoT need to focus on the internal and external factors that affect IoT applications.

CHAPTER THREE: RESEARCH FRAMEWORK

A research framework illustrates the structure of a research plan. It is essential in formulating the relevant research questions. It helps in understanding the connection between the study variables. In this Chapter, a conceptual framework and research hypotheses are discussed.

3.1.Conceptual Framework

A conceptual framework is an analytical tool that provides a comprehensive understanding of a phenomenon. The conceptual framework adopted for this study is illustrated in the figure below. The framework is developed based on the findings of the literature review.

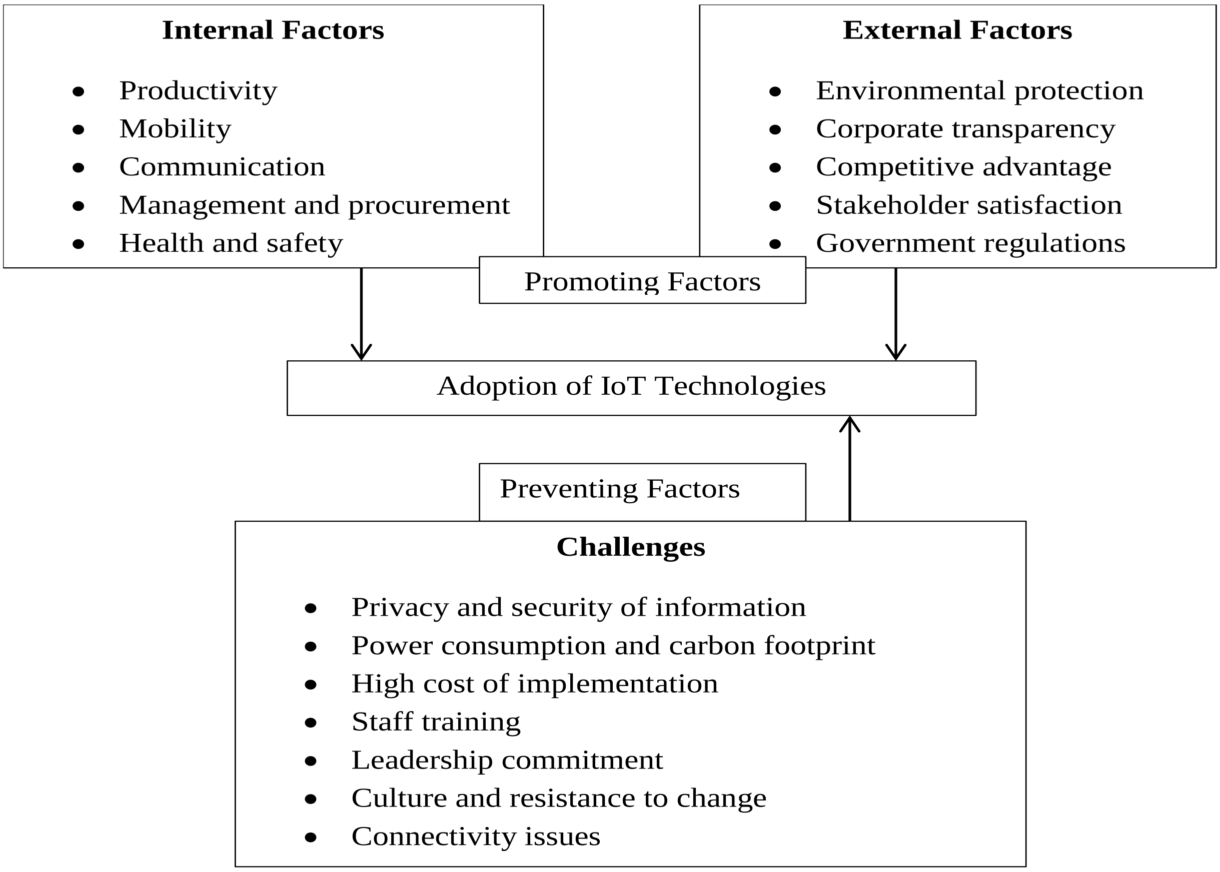

Figure 5: Conceptual framework

The study aims to investigate the adoption of IoT technologies in the construction industry. To establish the use of IoT technologies in the construction industry, the factors that promote and prevent the adoption of these technologies are evaluated. From the literature review, various factors adopted in the conceptual framework were identified as influencing IoT adoption. The identified internal factors promoting IoT technologies include productivity, mobility, management and procurement, health and safety, and communication. It was found that external factors influenced the use of IoT. The identified external factors were environmental protection, the need for corporate transparency, competitive advantage, stakeholder satisfaction, and government regulations. The internal and external factors promoting IoT adoption in the construction industry form the independent variables in this study.

Various challenges impair the use of IoT in the construction sector. The main challenges were identified from the literature review as privacy and security concerns, high power consumption cost and carbon footprint, high cost of implementation of IoT, lack of staff training, poor leadership commitment, culture and resistance to change, and connectivity issues. These challenges also form the independent variables in the current study.

This study assumes that the adoption of IoT technologies within a contracting organization is influenced by a group of internal factors, external factors, and challenges as highlighted in figure (5) above. This being said, the adoption of IoT technologies forms the dependent variable in this research while the internal factors, external factors and challenges are the independent variables that are used to predict the dependent variable.

3.2.Research Hypotheses

Hypotheses related to Internal Factors promoting Adoption of IoT technologies

- H1-1: Productivity as an internal factor significantly promotes the adoption of IoT technologies
- H1-2: Mobility as an internal factor significantly promotes the adoption of IoT technologies
- H1-3: Communication as an internal factor significantly promotes the adoption of IoT technologies
- H1-4: Management and procurement as an internal factor significantly promotes the adoption of IoT technologies
- H1-5: Health and safety as an internal factor significantly promotes the adoption of IoT technologies

Hypotheses related to External Factors promoting Adoption of IoT technologies

- H2-1: Environmental protection as an external factor significantly promotes the adoption of IoT technologies
- H2-2: Corporate transparency as an external factor significantly promotes the adoption of IoT technologies
- H2-3: Competitive advantage as an external factor significantly promotes the adoption of IoT technologies
- H2-4: Stakeholder satisfaction as an external factor significantly promotes the adoption of IoT technologies
- H2-5: Governmental regulations as an external factor significantly promotes the adoption of IoT technologies

Hypotheses related to challenges preventing the Adoption of IoT Technologies

- H3-1: Lack of Privacy and security of information significantly prevents the adoption of IoT technologies
- H3-2: Increased Power consumption and carbon footprint significantly prevents the adoption of IoT technologies
- H3-3: High cost of implementation significantly prevents the adoption of IoT technologies
- H3-4: Culture and resistance to change significantly prevents the adoption of IoT technologies
- H3-5: Connectivity issues significantly prevents the adoption of IoT technologies
- H3-6: Lack of Leadership commitment significantly prevents the adoption of IoT technologies
- H3-7: Lack of Staff training significantly prevents the adoption of IoT technologies

CHAPTER FOUR: RESEARCH METHODOLOGY

Research is guided by specific guidelines, assumptions, and procedures that facilitate data collection and analysis. Thus, researchers must have an adequate plan to complete their studies if dependable outcomes are required. This section explains the research methodology adopted in the research. It is segmented into research philosophy, research approach, research method, sample, survey instrument, and the variables used to analyze the data.

4.1. Research Philosophy

Research philosophy is defined as developing research assumptions, knowledge, and the nature of a study (Žukauskas, Vveinhardt, & Andriukaitienė, 2018). When correctly applied, a research philosophy allows a researcher to generate ideas and translate them into knowledge in the context of a study. The dominant research philosophies used in scientific investigations include positivism, interpretivist approach, pragmatism, and realism. In the current study, a positivist approach is used. According to Žukauskas et al. (2018), a positivist philosophy argues that objectivity is critical in understanding a phenomenon in a social world. The role of a scientist is an objective analyst and disconnects from personal values and works independently. By adopting this philosophy, it is possible to avoid assumptions that may conceal the truth. At the same time, it gives data the priority in evaluating the impact of internal and external factors and challenges on the adoption of the IoT in Dubai-based construction contractors. This study's findings will be devoid of personal assumptions, values, and inclinations that may not be supported by the collected data or evidence from existing literature. A positivist philosophy supports the determination of the relationship between variables, empirical observations and measurements, and verification of theories on the selected subject. Therefore, the philosophy provides a better position to investigate IoT's adoption with contractors in Dubai, UAE.

4.2. Research Approach

The common three research approaches are qualitative, quantitative, and mixed methods. In this research, a quantitative research approach is the most preferred option. The method matches with the adopted philosophy (positivism). It is ideal in testing objective theories by examining the relationship among variables (see figure 5). As discussed on the conceptual framework, the research investigates the impact of preventing and promoting factors on the adoption of IoT in Dubai-based contractors. Using a quantitative approach provides an opportunity to analyze structured data (numbered data) using statistical procedures (Apuke 2017). At the same time, it provides an avenue of building against bias, deductive reasoning, and controlling alternative explanations that may support the impact of the identified variables in the adoption of IoT in Dubai. Daniel (2016) argues that structured data enhances the generalization of quantitative research findings. Hence, a high level of generalizability is critical to this research.

4.3. Research Method

The study relies on a quantitative approach to investigate the adoption of IoT in Dubai-based contractors. An empirical research method is used owing to its ability to take advantage of direct-indirect observations (Apuke 2017). A survey is conducted to answer the research questions and meet the objectives of the research. The selected participants are required to fill in questionnaires to express their views on the factors influencing IoT adoption and the challenges faced by Dubai-based contractors in using IoT. The survey opens-up a system of analyzing primary data and comparing the current findings to what other researchers have attained in their studies. Furthermore, a quantitative research method is crucial in providing an objective test of the collected data and ensuring that personal values or bias do not affect the findings and, ultimately, the recommendations.

4.4. Sample Population

Due to lack of information regarding the population of construction professionals mainly engineers working in contracting organizations in the Emirate of Dubai, a sample population of 116 respondents was used in the research. These are construction professionals working in various contracting organizations operating in the Emirate of Dubai, sampled to participate in the study and completed the online distributed survey. A convenience sampling technique was used to gather professionals. According to Taherdoost (2016), convenience sampling is based on the idea of selecting the readily and easily available participants. Moreover, it is less costly and helps in dealing with many challenges associated with travelling and interrogating potential respondents. Due to the COVID-19 pandemic, a convenience sampling technique stood out as the viable option. In their study, Boadu, Wang, and Sunindijo (2020), relied on a convenience sampling method to evaluate the characteristics of the construction industry in the developing markets. According to the authors, the method was effective in getting the best group of respondents exhibiting the desired characteristics and experiences in the industry. Thus, the adoption of the same method guaranteed the use of participants with adequate knowledge and experience in Dubai's construction sector. These were the construction professionals in the identified Dubai construction contracting firms. An online survey system was used to distribute the questionnaires to these professionals. The approach was deemed effective and reliable as it enabled easy access to the respondents.

4.5. Survey Instrument

A survey instrument is a tool for obtaining information from research participants. Researchers can use various tools, including questionnaires and tests, to collect data. In the current study, a questionnaire is the recommended survey instrument. In their research, Solans-Dome`nech et al. (2019) explore the role of an impact-based questionnaire. According to the researchers, the use of questionnaires as survey tools provides an opportunity for researchers to understand the participants' views and ideas (Solans-Dome`nech et al. 2019). The choice of questionnaires in the current study stems from their advantages. As compared to interviews and tests, questionnaires are inexpensive, practical, scalable, and easy to analyze or visualize. The simplicity of these questionnaires ensures that the data analysis process is completed on time without unnecessary complications. Therefore, they facilitate the collection of actionable data making them an ideal choice for this research.

The survey instrument was developed following an extensive literature review from both international and local contexts. A pilot was conducted with the assistance of the research supervisor and 4 highly experienced construction professionals with 10 to 25 years of service in Dubai's construction sector, to ensure no discrepancies and vagueness are present prior to distributing the survey to participants.

The questionnaire used in the study is segmented into six sections as follows:

1. An Introduction: this section introduces the respondent to the survey questionnaire and the researcher's intention. It most importantly sets a clear definition of IoT which shall be used to answer the remainder of the questionnaire.
2. General Information: this section contains general questions which are integral in categorizing the participants to enhance the interpretation of their responses and how they relate to the use of IoT in the construction industry. Questions include the contractor's classification category, total number of staff, total number of workforce. The respondent's department, years of experience, level of education in addition to the average value of projects completed by the organization.
3. Areas of Adoption and Types of Technologies Adopted: this section starts with a Yes/No/Not Sure question asking the respondent if he/she are familiar with the term

IoT within the construction industry. This question follows the introduction which highlights the definition of IoT intended during the rest of the questionnaire. Following that are a series of 5-point Likert scale questions ranging from No Adoption to Very High, related to the areas of adoption and types of technologies used within the respondent's contracting organization.

4. Factors Promoting the Adoption of IoT Technologies. These questions seek to understand the participants' views on the factors affecting and promoting the use of IoT in Dubai-based contractors. According to the explored literature, these factors are divided into internal and external factors with respect to the organization. A 5-point Likert scale is utilized ranging from Very Low to Very High. A final question was introduced to measure the respondent's organization commitment to adopting IoT technologies.
5. Challenges Preventing the Adoption of IoT Technologies: this section contains the identified challenges from literature that prevents the adoption of IoT technologies. It uses a 5-point Likert scale ranging from very low to very high. In addition, it contains two questions related to the respondent's opinion whether the implementation of government initiatives and the introduction of standardized guidelines would facilitate the adoption of IoT technologies.
6. The Advantages of Adopting IoT Technologies: this section contains the identified advantages from literature and uses a 5-point Likert scale ranging from Very Low to Very High. This section also asks for the respondent's opinion whether their organization would benefit from IoT adoption in terms of growth and business opportunities.

A sample of the distributed questionnaire is available in Appendix 1.

4.6. Ethical Considerations

An extremely important aspect of any conducted research is the ethics involved during the life cycle of research from planning to execution of data collection, to the analysis of the collected data and the summarizing of related findings. According to Bryman and Bell (2007), depending on the nature of the study and followed methodology, certain ethical aspects need to be considered in each step of the research design. These aspects will be covered in this section below.

Back when the aim and objective of this research were being defined, no deception or exaggeration were intended. Goals were clearly identified without any conflict of interest, to help and benefit the construction industry. Any organization will be free to benefit from the outcomes of this research.

Since the research utilized an online distributed survey, a clear consent statement was part of the introduction to this survey where the respondents were free to accept or reject participation. Also contact details for both the researcher and the research supervisor were provided in case of any concern or suggestion from the respondent's side. The privacy and anonymity of the respondents and their organizations is also assured by the researcher.

The collected data is kept safe and secured to ensure privacy during the analysis and findings reporting stages of the research. A copy of the collected data will be kept secure for any future studies.

When the findings are presented and discussed, bias is avoided to ensure the integrity of the research. The findings will be presented and discussed objectively, based on the analysis done without any manipulation or alteration. This will ensure that the research objectives are once again met without any subjectivity.

Finally, over the course of all chapters in this research, proper acknowledgment to previous researchers and knowledge contributors is ensured by following the correct referencing system which is the BUiD Harvard Referencing Guide utilized by the British University in Dubai.

4.7. Variables: Dependent and Independent

Part of the planned outcomes of this study is to understand how factors and challenges are affecting the adoption of IoT technologies within contracting organizations in Dubai. Therefore, variables and the relationship between them needs to be analyzed and studied properly. Huck (2007) states that the dependent variable is explained by an independent variable. Connecting Huck's statement with this research, the adoption of IoT technologies is affected by a group of factors and challenges which makes the former a dependent variable and the latter the independent variables.

Defining The formula below shows the adoption of IoT in Dubai as the dependent variable. It is affected by internal and external factors promoting its adoption and challenges preventing s its use in the construction industry. These factors (promoting and preventing the use of IoT in Dubai) are the independent variables.

$$Adoption\ of\ IoT\ technologies\ in\ Dubai\ (dependent\ variable\ Y) = \big((Internal\ and\ external\ factors) - challenges\ \big) independent\ variables\ X$$

The following chapter will tackle the relation between the above (if found) and will further explore this relation and statistically justify it.

CHAPTER FIVE: DATA ANALYSIS & RESULTS

5.1.Introduction

This section outlines the results attained from the analysis of the collected data. This section's objective is to offer a detailed view of the responses collected from the participants in the study. These findings will be compared with those attained from the literature review in the following discussion chapter and eventually develop the conclusion and recommendations.

5.2. Descriptive Analysis

A sample population of 116 respondents was adopted in the study (n=116). These were construction professionals working in contracting organizations currently operating in the Emirate of Dubai.

5.2.1. Respondents' Demographics

Table 1: **Respondent's Contracting Company Category**

Respondent's Contracting Company Category	Frequency	Percentage
Between G+4 and G+12	10	8.6%
G+Unlimited	65	56.0%
Sub-contractor (MEP - Fitout – Shoring & Piling ...etc.)	30	25.9%
Up to G+4	11	9.5%
Total	116	100.0%

In the Emirate of Dubai, Contractors are classified based on their ability to legally construct buildings within certain number of floors. This classification in addition to registration and monitoring is controlled by Dubai Municipality being the oldest and biggest zoning and development authority in the Emirate of Dubai. This classification reflects the organization's financial and technical capabilities as well. It ranges from buildings of one floor, buildings of up to four floors, buildings of up to twelve floors and buildings of unlimited number of floors. Some contracting organizations mainly subcontractors of MEP, fit-out, shoring & piling, waterproofing …etc. may opt to remain unclassified which means that they are unable to undertake construction activities on their own but able to subcontract works from classified contractors. As shown in table (1) above, G+ Unlimited had the largest number of respondents (56%) followed by the sub-contractor (MEP – Fit out – Shoring & Piling ...etc.) category (25.9%).

Table 2: **Organization's Total Number of Staff Employees (excluding workforce)**

Organization's Staff Employees	Frequency	Percentage
Between 100 and 500	28	24.1%
Between 500 and 1000	24	20.7%
Less than 100	18	15.5%
More than 1000	46	39.7%
Total	116	100.0%

Referring to table (2), Most respondents (39.7%) were associated with large construction contractors with a staff employee of more than 1000 workers.

***Table 3:* Organization's Total Number of Workforce Employees (excluding staff)**

Organization's Workforce Employees	Frequency	Percentage
Between 50 and 500	21	18.1%
Between 500 and 1000	17	14.7%
Less than 50	9	7.8%
More than 1000	69	59.5%
Total	116	100.0%

As shown in table (3) above, most respondents (59.5%) were from contractors with large workforce employees. These contractors had more than 1000 workforce employees. The second highest category was one with between 50 and 500 workforce employees (18.1%).

***Table 4:* Respondent's Department within the Organization**

Respondent's Department	Frequency	Percentage
HSSE - Health, Safety, Security and Environment	4	3.4%
Operations	35	30.2%
Project Management - Planning, Contracts, Cost	56	48.3%
Quality Control	6	5.2%
Technical Office	15	12.9%
Total	116	100.0%

Referring to table (4), The department with the greatest number of respondents (48.3%) was the project management department. It was followed by operations department (30.2%). This is particularly important to have high representation from these two departments as they play a critical role in enforcing and implementing IoT technologies within an organization.

***Table 5:* Respondent's Experience Level**

Respondent's Experience Level	Frequency	Percentage
Entry Level (1-5 years)	8	6.9%
Leadership/Strategic	7	6.0%
Managerial (more than 15 years)	42	36.2%
Mid-Career (5-15 years)	59	50.9%
Total	116	100.0%

As summarized in table (5), Slightly more than half of the respondents (50.9%) had 5 to 15 years' experience and 36.2% had managerial experience (more than 15 years).

***Table 6:* Respondent's Education Level**

Education Level	Frequency	Percentage
Bachelor's Degree	70	60.3%
Master's Degree	40	34.5%
Ph.D. Degree	3	2.6%

Qualified by Experience	3	2.6%
Total	116	100.0%

Referring to table (6) above, Majority (60.3%) of the respondents had a bachelor's degree qualification and 34.5% had a master's degree. Only 2.6% were PhD holders and 2.6% had experience qualification.

Table 7: **Organization's Average Completed Projects Value**

Completed Project Value	**Frequency**	**Percentage**
Above 500 Million AED	67	57.8%
Between 100 Million AED and 500 Million AED	19	16.4%
Between 5 Million AED and 100 Million AED	25	21.6%
up to 5 Million AED	5	4.3%
Total	116	100.0%

As shown in table (7), More than half (57.8%) of the contractors involved in the study had completed projects valued above 500 million AED. Those who had completed projects valued between 5 million AED and 100 million AED were 21.6%.

***Table 8:* Respondent's Familiarity with the term IoT within Construction**

Respondent's Familiarity with IoT	Frequency	Percentage
No	24	20.7%
Not Sure	13	11.2%
Yes	79	68.1%
Total	116	100.0%

As summarized in table (8), There was a high IoT within Construction familiarity rate among the respondents with 68.1% stating that they were aware of IoT technologies. Only 11.2% were not sure and 20.7 did not know about IoT.

5.2.2. Areas of IoT Application

The respondents were asked to give their opinions on the areas of IoT application in their organizations. This data was integral in determining the areas that have attracted the attention of Dubai construction contractors. It is assumed that the areas of implementation by contractors shall reflect the rate of adoption of IoT within these organizations which will be critical in coming parts of the data analysis. The descriptive analysis of the collected data was conducted using the means of the variables. the relative importance index (RII) technique was used to arrange the variables from the most significant to the least area of consideration. According to Egemen and Mohamed (2005) RII is commonly and favorably used in research to find out respondents' view on certain variables measured by scales. The table below shows the findings from the study on the areas of IoT adoption by Dubai construction contractors.

Table 9: **Areas of IoT Adoption within the Organization**

Areas of IoT Adoption	Mean	RII (%)	Rank
Data Capturing and Display	3.4	68	2
Data Exchange	3.68	74	1
Site Supervision	3.04	61	3
Contextual Data Request	2.66	54	6
Smart Metering	2.45	49	7
Material Management	2.87	58	4
Safety and Security	2.73	55	5

As tabulated in table (9) above, The responses show that IoT adoption was more dominant in data capturing and display (M=3.40), data exchange (M=3.68), and site supervision (M=3.04) than other areas. IoT is considered a technology to facilitate the collection and transfer of information in the construction businesses. A relative importance index (RII) was used as depicted in table (9) to ascertain the most important area from the respondents' perspective. Understanding the ranking of the application areas was integral in knowing where the focus of the Dubai-based construction contractors was in the implementation of IoT. As illustrated, the application area ranking highest was data exchange, followed by capturing and display. From the respondents' perspective, IoT was widely used in the collection and exchange of data and least used in smart metering.

5.2.3. Types of IoT Technologies Adopted

The respondents were asked to give their opinions on which type of IoT technologies their organizations are utilizing. The data was used to establish the ranking of the technologies using the RII. The table below shows the means and ranking of the variables.

Table 10: **Types of IoT technologies used within the Organization**

IoT Technologies Type	Mean	RII (%)	Rank
Smartphones	3.84	76.72	2
Tablets	2.75	55	6
Wearables	2.20	43.97	11
RFID Tags	2.48	49.66	7
Equipment Telematics	2.47	49.48	8
Drones	2.46	49.14	9
Cloud Storage Technologies	3.56	71.21	3
Security Cameras	3.48	69.66	4
BIM	3.93	78.62	1
GIS	2.91	58.1	5
AR and VR	2.34	46.72	10
Robotics	1.70	33.97	12

As shown in table (10) RII was used to rank the adoption of the IoT technologies in the construction firms (see appendix 2). Smartphones (M=3.84), BIM (M=3.93), and cloud storage technologies (M=3.56) were the main IoT technologies used by the contractors. The least used type of IoT technologies were AR and VR (M=2.34), robotics (M=1.70), and wearables (M=2.20).

5.2.4. Internal Factors Promoting the Adoption of IoT

The respondents were asked to state the internal factors that they thought influenced IoT adoption in their organizations. The table below shows the resultant findings.

Table 11: **Internal Factors Promoting the Adoption of IoT**

Promoting Factor	Mean	RII (%)	Rank
Productivity	3.90	77.93	2
Mobility	3.57	71.38	5
Communication	4.08	81.55	1
Management and Procurement	3.89	77.75	3
Health and Safety	3.67	73.44	4

Referring to table (11) above, RII was used to rank the factors promotion the adoption of IoT by the contractors. From the respondents, communication (M=4.08) was the leading internal factor promoting the use of IoT technologies. Productivity (M=3.90) and management and procurement (M=3.89) were the second and third factors, respectively. The least considered factor from the list was mobility (M=3.57).

5.2.5. External Factors Promoting the Adoption of IoT

The respondents were asked to give their opinions on the external factors that promoted the adoption of IoT in their organizations. The table below shows the ranking of the external factors.

Table 12: **External Factors Promoting the Adoption of IoT**

Promoting Factor	Mean	RII	Rank
Environmental Protection	3.21	64.14	5
Corporate Transparency	3.40	67.93	4
Competitive Advantage	3.87	77.41	2
Stakeholder Satisfaction	3.91	78.51	1
Government Regulations	3.77	75.34	3

Referring to table (12) above, RII was used to rank the factors. As illustrated, stakeholder satisfaction (M=3.91) and competitive advantage (M=3.87) were the main external factors promoting the adoption of IoT technologies by Dubai contractors. The least factor was environmental protection (M=3.21).

5.2.6. Challenges Preventing the Adoption of IoT

The respondents were asked to give their opinions on the challenges preventing the adoption of IoT in their organizations. The table below shows the ranking of the challenges as evaluated from the responses.

Table 13: **Challenges Preventing the Adoption of IoT**

Challenge	Mean	RII (%)	Rank
Lack of Security and Privacy	3.29	65.86	5
High Power Consumption and Carbon Footprint	2.92	58.45	7
High Cost of Implementation	4.07	81.38	1
Lack of Staff Training	3.68	73.62	2
Connectivity Issues	3.10	62.07	6
Lack of Leadership Commitment	3.53	70.69	4
Culture and Resistance to Change	3.55	71.03	3

As shown in table (13), From the respondents' opinions, the main challenges that prevented the implementation of IoT technologies by Dubai contractors were high cost of implementation (M=4.07), staff training (M=3.68), and culture and resistance to change (3.55). The least factor was consumption and carbon footprint (M=2.92) (see appendix 5).

5.2.7. Advantages of IoT Adoption

The respondents were asked to rate the advantages associated with the implementation of IoT technologies in their companies. The collected data was computed using the RII and the mean to rank the advantages from the most significant to the least in the group. The table below provides an overview of the responses.

Table 14: **Advantages of IoT implementation**

Advantage	Mean	RII (%)	Rank
Time Saving	4.17	83.45	2
Cost Saving	3.73	74.66	5
Quality Improvement	4.00	80	4
Communication Improvement	4.21	84.14	1
Productivity	4.01	80.17	3
Safety and Health Improvement	3.68	73.62	6
Lesser Impact on Environment	3.37	67.41	7

As illustrated in table (14), the most significant advantage of implementing IoT technologies is the improvement of communication (M= 4.21) in the construction industry. Other top benefits associated with the adoption of IoT are time saving (M=4.17) and productivity (M=4.01). The least benefit from the list was to have a lesser impact on the environment (M= 3.37).

5.2.8. Opinion Questions

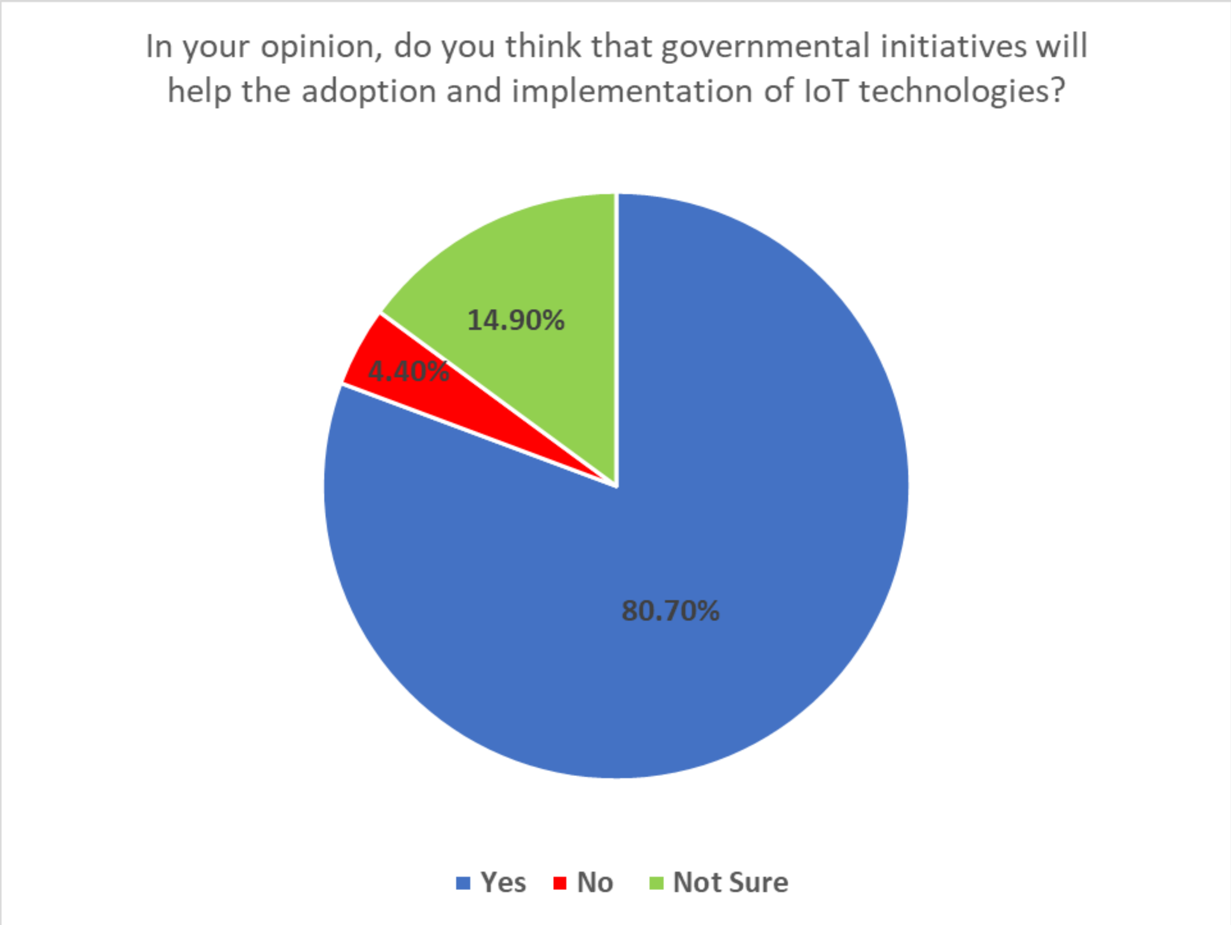

Figure 6: **Governmental Initiatives Effect**

The respondents were asked if they believed the government played a role in the adoption of IoT technologies and 80.7% agreed and only 4.4% denied as shown in figure (14) above.

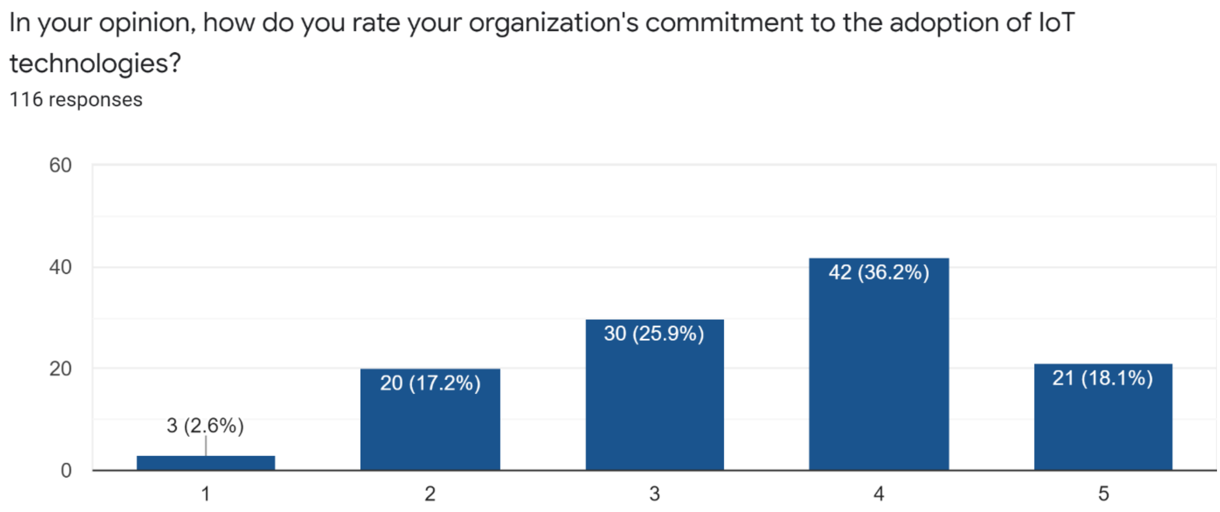

***Figure 7*: Organizational Commitment to Adopt IoT**

As shown in figure (15) above, when asked if they felt that their organizations were committed to the adoption of IoT, 36.2% and 18.1% of the respondents said they were high and very highly committed, respectively. Only 2.6% of the participants lowly ranked their organization’s commitment.

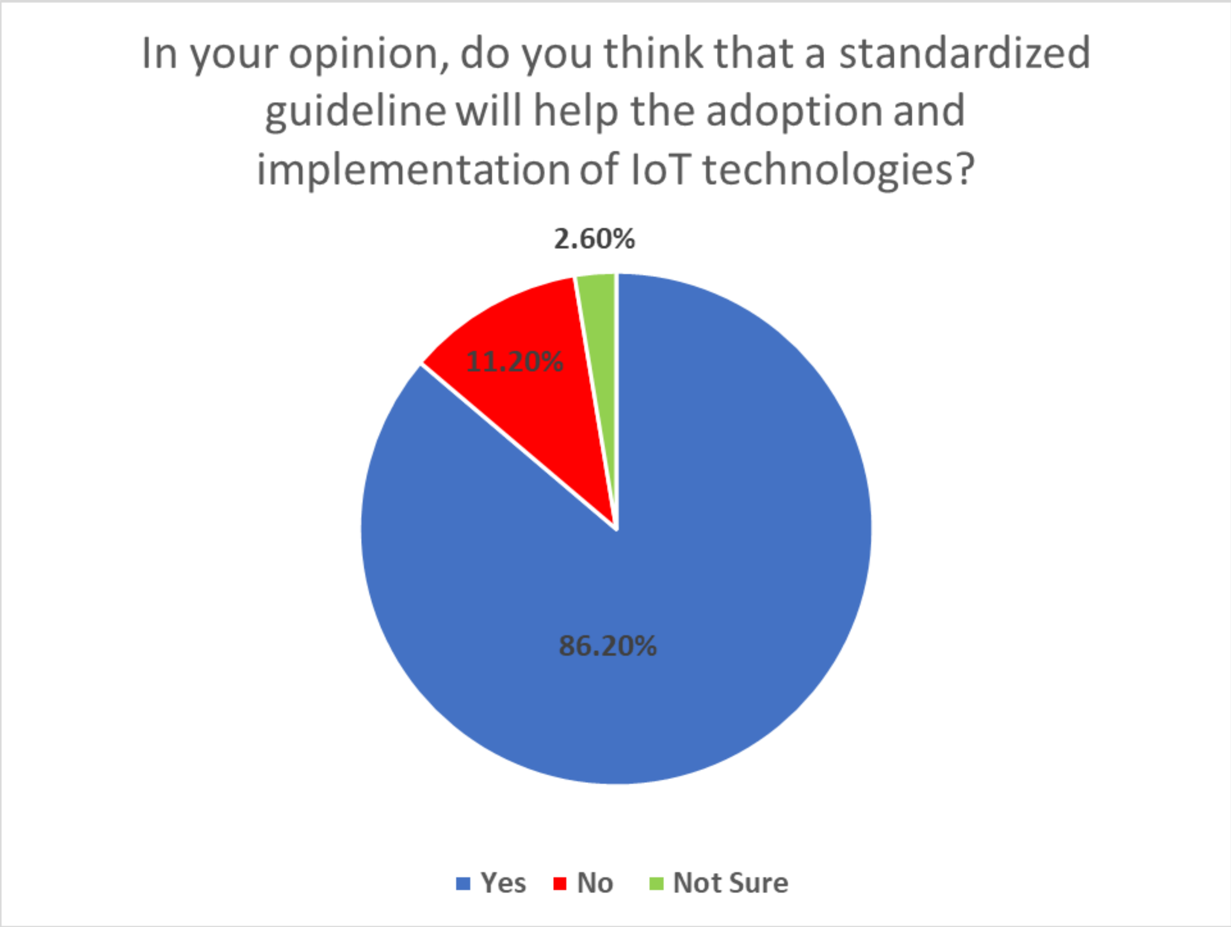

Figure 8: **Standardized Guidelines Effect**

When asked about standardized guidelines, 86.2% of the participants said they influenced the adoption of IoT and only 2.6% rejected the role of standardized guidelines, with 11.2% not sure.

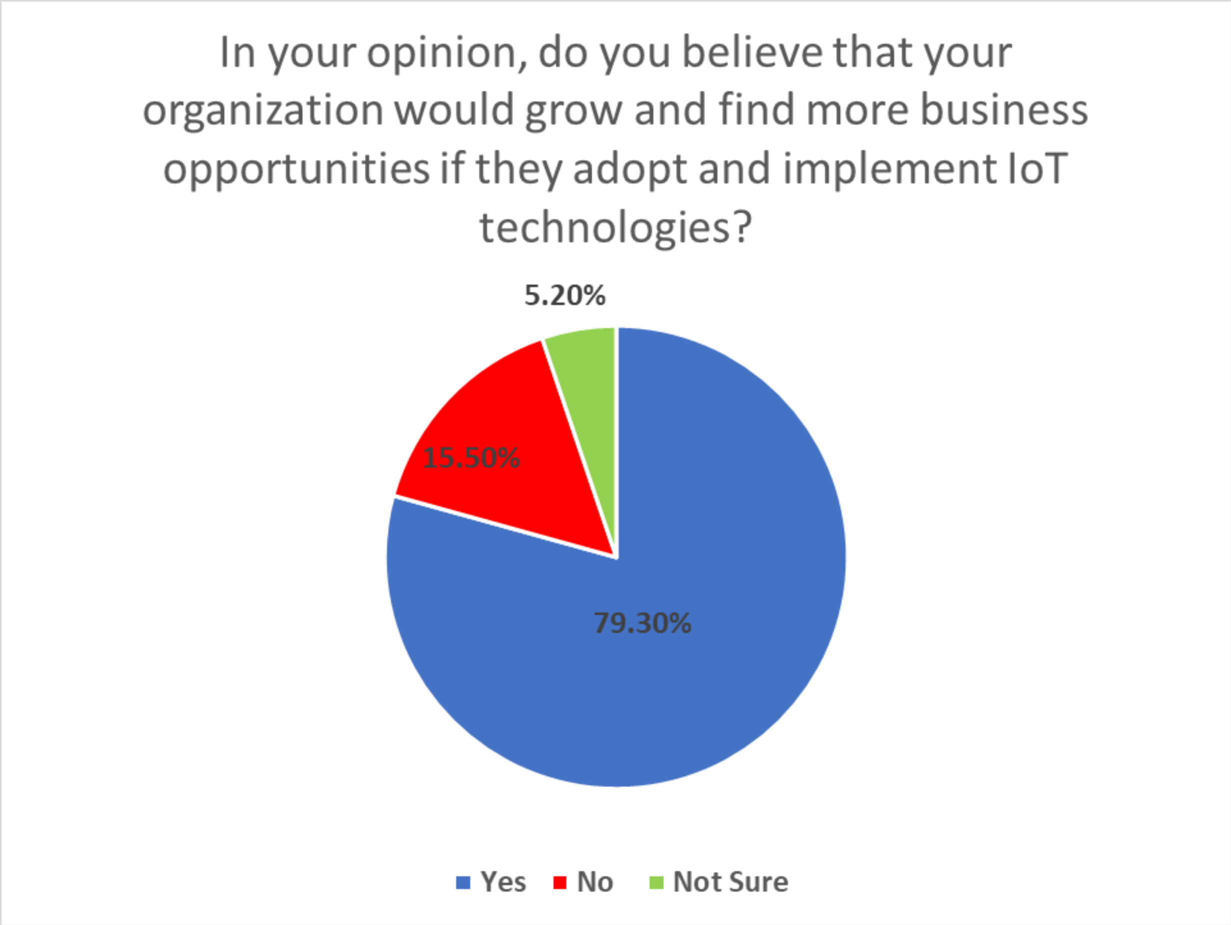

Figure 9: **Growth and Business Competitiveness Resulting from the Adoption of IoT**

Majority of the respondents (79.3%) believed that the adoption of IoT technologies in their organizations would facilitate their growth. However, 15.5% were not sure and 5.2% rejected the association between growth and adoption of IoT in their companies.

5.3.Validity and Reliability Test

5.3.1. Cronbach's Alpha Test

Cronbach's alpha was used to test the reliability of the Likert scale questions. Cronbach's alpha provided a better approach to assessing the internal consistency of the data – how closely related the items on the Likert scale were as a group. According to Moser and Kalton (1959) the testing for reliability is extremely important to ensure consistency within a survey instrument. The approach is considered a measure of reliability and as stated by Akoglu (2018) a coefficient of .70 or higher is considered acceptable in most social science research situations.

Table 155: **Reliability Test Results**

Category	**Cronbach's Alpha**	**Alpha Based on Standardized Items**	**N Items**
Areas of IoT application	.885	.886	7
Types of IoT technologies adopted	.891	.892	12
Internal factors promoting IoT	.848	.850	5
External factors promoting IoT	.831	.835	5
Challenges preventing IoT adoption	.746	.757	7
Advantages of IoT implementation	.837	.842	7

As shown in table (15), Alpha is higher than .70 hence, the data is deemed reliable.

5.3.2. Pearson's Correlation

The Pearson Correlation Coefficient is used to evaluate the statistical validity of the survey questionnaire. When evaluating the linear relationship between two variables (X and Y), it is essential to determine the effect of one variable (Y) on another variable (X). Therefore, the Pearson's correlation was critical in establishing the validity of the current data by comparing the relationship between the dependent (IoT adoption) and independent variables (internal and external promoting factors and challenges faced in IoT adoption. Whenever the value approached 1 or -1, the correlation is considered stronger. The significance is achieved whenever the P-value is less than 0.05 based on a 95% confidence interval.

As illustrated in (16) table below, the data was valid as there was no difference between the means of the adoption of IoT and internal, external promoting factors and preventing challenges factors (sig. <.05).

***Table 16:* Pearson's Correlation Coefficients**

Correlations					
		IoT Adoption Y	**Challenges**	**Internal Factor**	**External Factor**
IoT Adoption Y	Pearson Correlation	1	0.290**	.584**	.625**
	Sig. (2-tailed)		0.042	0.000	0.000
	N	116	116	116	116
Challenges	Pearson Correlation	0.290**	1	.274**	.326**
	Sig. (2-tailed)	0.042		0.003	0.000
	N	116	116	116	116

Internal Factor	Pearson Correlation	.584**	.274**	1	.696**
	Sig. (2-tailed)	0.000	0.003		0.000
	N	116	116	116	116
External Factor	Pearson Correlation	.625**	.326**	.696**	1
	Sig. (2-tailed)	0.000	0.000	0.000	
	N	116	116	116	116
**. Correlation is significant at the 0.05 level (2-tailed).					

5.4. Hypothesis Testing

A regression analysis was used to test the hypotheses. The regression analysis was the chosen technique as it provided an effective and reliable approach of assessing the impact of the factors and challenges on the adoption of IoT by Dubai contractors. According to Kumari and Yadav (2018), a regression analysis helps in analyzing the strength of the association between variables. In addition, it adjusts for the effects of the covariates in a study. When the P value resulting from analysis is larger than 0.05, the hypothesis is rejected. The table below shows the results attained.

5.4.1. Internal Factors Promoting Adoption of IoT

- H1-1: Productivity as an internal factor significantly promotes the adoption of IoT technologies

***Table 17*: Analysis Results for Productivity**

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	7.865	2.418		3.253	.002
	Productivity as an Internal Factor	3.327	.605	.458	5.498	.000
a. Dependent Variable: Areas of IoT Implementation						

Referring to table (16) above, Hypothesis H1-1 is accepted (p<.05) which indicates that productivity as an internal factor significantly promotes the adoption of IoT technologies within contractors in Dubai.

- H1-2: Mobility as an internal factor significantly promotes the adoption of IoT technologies

***Table 18:* Analysis Results for Mobility**

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		

1	(Constant)	5.444	2.160		2.520	.013
	Mobility as an Internal Factor	4.310	.589	.565	7.318	.000
a. Dependent Variable: Areas of IoT Implementation						

Referring to table (17) above, Hypothesis H1-2 is accepted (p<.05) which indicates that Mobility as an internal factor significantly promotes the adoption of IoT technologies within contractors in Dubai.

- H1-3: Communication as an internal factor significantly promotes the adoption of IoT technologies

Table 19: **Analysis Results for Communication**

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.179	2.494		1.275	.205
	Communication as an Internal Factor	4.328	.599	.560	7.221	.000
a. Dependent Variable: Areas of IoT Implementation						

Referring to table (18) above, Hypothesis H1-3 is accepted (p<.05) which indicates that communication as an internal factor significantly promotes the adoption of IoT technologies within contractors in Dubai.

- H1-4: Management and procurement as an internal factor significantly promotes IoT adoption

Table 20: **Analysis Results for Management and Procurement**

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	11.112	2.665		4.170	.000
	Management and Procurement as an Internal Factor	2.499	.670	.330	3.731	.000
a. Dependent Variable: Areas of IoT Implementation						

Referring to table (19) above, Hypothesis H1-4 is accepted (p<.05) which indicates that Management and Procurement as an internal factor significantly promotes the adoption of IoT technologies within contractors in Dubai.

- H1-5: Health and safety as internal factors significantly promotes the adoption of IoT technologies

Table 21: **Analysis Results for Health and Safety**

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	11.357	2.044		5.556	.000
	Health and Safety as an Internal Factor	2.579	.536	.411	4.809	.000
a. Dependent Variable: Areas of IoT Implementation						

Referring to table (20) above, Hypothesis H1-5 is accepted ($p<.05$) which indicates that Health & Safety as an internal factor significantly promotes the adoption of IoT technologies within contractors in Dubai.

5.4.2. External Factors Promoting Adoption of IoT Technologies

- H2-1: Environmental protection as an external factor significantly promotes the adoption of IoT Technologies

Table 22: **Analysis Results for Environmental Protection**

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	11.954	1.493		8.006	.000
	Environmental Protection as an External Factor	2.767	.437	.510	6.337	.000
a. Dependent Variable: Areas of IoT Implementation						

Referring to table (21) above, Hypothesis H2-1 is accepted ($p<.05$) which indicates that environmental protection as an external factor significantly promotes the adoption of IoT technologies within contractors in Dubai.

- H2-2: Corporate Transparency as an external factor significantly promotes the adoption of IoT Technologies

Table 23: **Analysis Results for Corporate Transparency**

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	11.329	1.981		5.719	.000
	Corporate Transparency as an External Factor	2.796	.561	.423	4.987	.000
a. Dependent Variable: Areas of IoT Implementation						

Referring to table (22) above, Hypothesis H2-2 is accepted ($p<.05$) which indicates that corporate transparency as an external factor significantly promotes the adoption of IoT technologies within contractors in Dubai.

- H2-3: Competitive advantage as an external factor significantly promotes the adoption of IoT Technologies

Table 24: **Analysis Results for Competitive Advantage**

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	9.569	2.251		4.252	.000
	Competitive Advantage as an External Factor	2.909	.564	.435	5.154	.000
a. Dependent Variable: Areas of IoT Implementation						

Referring to table (23) above, Hypothesis H2-3 is accepted ($p<.05$) which indicates that competitive advantage as an external factor significantly promotes the adoption of IoT technologies within contractors in Dubai.

- H2-4: Stakeholder satisfaction as an external factor significantly promotes the adoption of IoT Technologies

Table 25: **Analysis Results for Stakeholder Satisfaction**

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	8.213	2.122		3.871	.000
	Stakeholder Satisfaction as an External Factor	3.230	.527	.498	6.133	.000
a. Dependent Variable: Areas of IoT Implementation						

Referring to table (24) above, Hypothesis H2-4 is accepted ($p<.05$) which indicates that stakeholder satisfaction as an external factor significantly promotes the adoption of IoT technologies within contractors in Dubai.

- H2-5: Governmental regulations as an external factor significantly promotes the adoption of IoT Technologies

Table 26: **Analysis Results for Government Regulations**

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	7.985	1.916		4.168	.000
	Government Regulations as an External Factor	3.409	.491	.546	6.950	.000
a. Dependent Variable: Areas of IoT Implementation						

Referring to table (25) above, Hypothesis H2-5 is accepted (p<.05) which indicates that governmental regulations as an external factor significantly promotes the adoption of IoT technologies within contractors in Dubai.

5.4.3. Challenges Preventing the Adoption of IoT

- H3-1: Lack of Privacy & Security of Information significantly prevents the adoption of IoT Technologies

Table 27: **Analysis Results for Lack of Privacy and Security**

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	16.628	2.065		8.053	.000
	Lack of Privacy and Security as a Challenge	1.275	.601	.195	2.122	.036
a. Dependent Variable: Areas of IoT Implementation						

Referring to table (26) above, Hypothesis H3-1 is accepted ($p<.05$) which indicates that lack of privacy and security of information as a challenging factor significantly prevents the adoption of IoT technologies within contractors in Dubai.

- H3-2: Higher Power Consumption and Carbon Footprint significantly prevents the adoption of IoT Technologies

Table 28: **Analysis Results for Higher Power Consumption and Carbon Footprint**

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		

1	(Constant)	14.649	1.507		9.719	.000
	Higher Power Consumption and Carbon Footprint as a Challenge	2.114	.479	.382	4.411	.000
a. Dependent Variable: Areas of IoT Implementation						

Referring to table (27) above, Hypothesis H3-2 is accepted ($p<.05$) which indicates that higher power consumption and carbon footprint as a challenging factor significantly prevents the adoption of IoT technologies within contractors in Dubai.

- H3-3: High Cost of Implementation significantly prevents the adoption of IoT Technologies

Table 29: **Analysis Results for High Cost of Implementation**

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	14.131	2.663		5.306	.000
	High Cost of Implementation as a Challenge	1.646	.638	.235	2.578	.011
a. Dependent Variable: Areas of IoT Implementation						

Referring to table (28) above, Hypothesis H3-3 is accepted (p<.05) which indicates that high cost of implementation as a challenging factor significantly prevents the adoption of IoT technologies within contractors in Dubai.

- H3-4: Culture & Resistance to Change significantly prevents the adoption of IoT Technologies

***Table 30:* Analysis Results for Culture and Resistance to Change**

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	20.441	1.935		10.562	.000
	Culture and Resistance to Change as a Challenge	.109	.518	.020	.210	.834
a. Dependent Variable: Areas of IoT Implementation						

Referring to table (29) above, Hypothesis H3-4 is rejected (p>.05) which indicates that culture and resistance to change as a challenging factor does not significantly prevents the adoption of IoT technologies within contractors in Dubai.

- H3-5: Connectivity Issues significantly prevents the adoption of IoT Technologies

Table 31: **Analysis Results for Connectivity Issues**

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	19.765	1.870		10.571	.000
	Connectivity Issues as a Challenge	.342	.571	.056	.600	.550
a. Dependent Variable: Areas of IoT Implementation						

Referring to table (30) above, Hypothesis H3-5 is rejected ($p>.05$) which indicates that connectivity issues as a challenging factor does not significantly prevents the adoption of IoT technologies within contractors in Dubai.

- H3-6: Lack of Leadership Commitment significantly prevents the adoption of IoT Technologies

Table 32: **Analysis Results for Lack of Leadership Commitment**

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	23.090	2.051		11.256	.000
	Lack of Leadership Commitment as a Challenge	-.640	.555	-.107	-1.153	.251
a. Dependent Variable: Areas of IoT Implementation						

Referring to table (31) above, Hypothesis H3-6 is rejected (p>.05) which indicates that lack of leadership commitment as a challenging factor does not significantly prevents the adoption of IoT technologies within contractors in Dubai.

- H3-7: Lack of Staff Training significantly prevents the adoption of IoT Technologies

***Table 33:* Analysis Results for Lack of Staff Training**

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	20.351	2.403		5.468	.000
	Lack of Staff Training as a Challenge	1.529	.632	.307	2.205	.013
a. Dependent Variable: Areas of IoT Implementation						

Referring to table (32) above, Hypothesis H3-7 is accepted ($p<.05$) which indicates that lack of staff training as a challenging factor significantly prevents the adoption of IoT technologies within contractors in Dubai.

5.5. Model Development

Part of the research's objective is to develop a prediction model that can be used by contractors to predict their rate of IoT technologies adoption based on the promoting factors they need to implement and challenges they need to avoid. This model can be used by the organization's strategy makers to steer their direction towards smart construction.

According to Hair et al (1998) multiple linear regression can be used to assess the effect of multiple independent variables on a dependent variable. SPSS computer application is utilized to assess the below proposed predictive model depicted below:

$$Adoption\ of\ IoT\ technologies\ in\ Dubai\ (dependent\ variable\ Y)$$
$$= \big((Internal\ and\ external\ factors)$$
$$-\ challenges\ \big)independent\ variables\ X$$

The model shows that adoption of IoT technologies is influenced by the internal promoting factors, external promoting factors, and challenges impairing the adoption of IoT by Dubai-based contractors. SPSS computer application facilitates the calculation of R square value and its adjusted value. R square is a measure of the proportion of the variance of the dependent variable mean that is explained by the independent variables.

Table 34: **Model Summary**

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.660[a]	0.435	0.420	4.91565
a. Predictors: (Constant), Challenges, Internal Factors, External Factors				

R^2= 0.435

Table 35: **ANOVA Result**

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2086.229	3	695.410	28.779	.000[b]
	Residual	2706.322	112	24.164		
	Total	4792.552	115			
a. Dependent Variable: Areas of IoT Implementation						
b. Predictors: (Constant), Challenges, Internal Factors, External Factors						

According to tables (34) and (35) The R square value is statistically significant ($p<.05$) which indicate significant effect between the dependent and independent variables. It is also shown that the R Value is (0.660) which indicates the correlation between the independent variables and the dependent variable. The R square value indicates that 43.5% of the variance of the dependent variable can be explained by the independent variables. Similarly, the adjusted R square value of (0.42) is considered a better estimate for the population.

Table 36: **Model Coefficients Table**

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-0.781	3.093		-0.253	0.801
	Internal Factors	0.538	0.182	0.294	2.961	0.004
	External Factors	0.700	0.163	0.434	4.302	0.000
	Challenges	-0.057	0.105	-0.041	-0.547	0.586
a. Dependent Variable: Areas of IoT Implementation						

Table (36) above highlights the un-standardized coefficients, standard error, standardized coefficients, t test values and the significance values. The unstandardized coefficient value indicates the power of the independent variables to predict the dependent variable. Additionally, the conducted test shows the significance values for each one of the studied independent variables, according to Table (36) it shows that the significant independent variables are internal and external factors with p-values less than the level of significance (0.05).

On the other hand, it shows that the challenges are not significant since the p-value is more than the 0.05 threshold.

The model depicts that the external factors have the highest impact (0.7) on the adoption of IoT technologies. From the above coefficients, the model can be derived as illustrated below.

- *Adoption of IoT technologies – A*
- *External Factors – E*
- *Internal Factors – I*
- *Challenges – C*

$$A = -0.781 + 0.538I + 0.7E - 0.057C$$

5.6. Results Conclusion

From the study, there was a general acceptance of IoT technologies among the respondents. IoT was predominantly seen as a way of enhancing the interaction between the stakeholders. Based on the RII conducted, the main reasons Dubai contractors adopted IoT technologies included data exchange and data capturing. The respondents viewed the use of IoT to collect and share information as factors that influenced their entities' performance. The main technologies adopted in these organizations were smartphones, BIM and cloud storage services respectively. These technologies were perceived as the backbone of the modern construction industry. These were the commonly used technologies owing to their availability and ease of use. The respondents were told to outline the challenges they believed affected IoT's adoption in their entities. The responses, high cost of implementation, lack of staff training, and difficulties associated with culture and resistance to change ranked high after RII was completed.

Further, the primary benefits of using IoT technologies in the construction setting included communication, saving time, and productivity-related performances. The respondents believed that an increase in data exchange facilitated decision-making, leading to higher productivity and time management. The areas that highly attracted the use of IoT included in management and procurement, stakeholder satisfaction, and productivity management. A regression analysis was used to test the hypotheses. All the hypotheses in the first and second categories were accepted. In the third category, four hypotheses were accepted (lack of privacy and security of information, Higher power consumption and carbon footprint, and high cost of implementation and lack of staff training were found to be significant challenges in the adoption of IoT technologies in Dubai). On the other hand, the rejected three hypotheses were culture and resistance to change, connectivity issues and lack of leadership commitment.

CHAPTER SIX: DISCUSSION AND RESULTS INTERPRETATION

In this chapter the results obtained from the analysis will be discussed and argued against the literature review to assess the findings of this research.

6.1. Respondents' Demographics

In the distributed questionnaire, the respondents were asked a series of general question to understand their background and experience. It was found that 56% of the respondents are working for the highest category contracting organizations (G + Unlimited). Having such a big percentage to represent this category is important since they are financially able organizations which can have the will and ability to try out new technologies. Nearly 26% were sub-contracting organizations which are generally driven by main contractors when implementing new technologies to increase their competitiveness.

With regards to the respondent's organization total number of staff employees which excludes workforce, the results came to match the contractor classification with almost 40% having more than a 1000 staff employees which generally is a characteristic of large scale contractors. 20% have between 500 and 1000 staff employees which when added to the previous 40% almost equals the same percentage reflecting the (G + Unlimited) contractor classification. Organizations with less than 100 staff employees are 15.5% of the respondents.

Workforce is a major characteristic when classifying contracting organizations and reflects the power and capability of contractors. In the distributed questionnaire, almost 60% of the respondents works in organization with more than 1000 workforce employee which again in line with the classification percentage.

When asked about their department, the majority of respondents were working in the project management department with 48.3% followed by operations department directly at 30.2%. when combines these two departments accounted for almost 80% of the respondents. This is extremely vital as these two departments play a huge role when planning and executing a new technology implementation. The lowest respondents' rate were HSSE department which is unfortunate due to the importance of this department in any contracting organization.

Experience level question resulted in an interesting and important finding with just over 50% of the respondents were at mid-career level and 36.2% at managerial level. These two groups together account for almost 80% of the responses. The implementation of new technology requires serious dedication and energy but yet hands-on experience in order to succeed. These two groups provide these requirements.

The educational level question came up with an expected result within the construction industry. More than 60% of the respondents had a bachelor's degree while master's degree holders were almost 35%.

Finally, the respondents were asked to state the average value of projects completed by their organizations and the results again matches with the classification of contractors with almost 60% of the responses answered above 500 million AED.

6.2. Areas of IoT Technologies Implementation

Using the RII in the analysis, the top area of IoT implementation according to the respondents was data exchange with an RII of 74%. This is particularly understandable regardless of the organization size and classification as the amount of data required to be exchanged across is quite substantial in construction but yet critical. This is complying with

Angelova, Kiryakova, and Yordanova (2017) who found out in their study that the IoT has a huge ability and potential in sharing information through smart devices.

Data capturing and display came second with an RII of 68% confirming what Parpala and Iacob (2017) stated in their study that the IoT indeed enabled the collection of data from different sources and channels and facilitated informed decision making in construction environment which resulted in lower cost, better quality and saved time.

At the bottom of the last came smart metering as an area of implementation with an RII of 48%. This can be explained by the initial high cost of implementation in addition to compatibility issues related to the application of smart metering in any application within construction. In addition, support from employers for the implementation of smart metering is a huge reason why contractors aren't opting for such technologies. According to Zivic, Ur-Rehman, and Ruland (2016), smart metering is the core of intelligent, eco-friendly and green built environments. Without the collaboration between all parties involved in construction, it will be difficult to realize the benefits of such technologies.

6.3. Types of IoT Technologies Implementation

The types of IoT technologies adopted by contracting organizations will reflect the commitment and understanding towards the areas of implementation mentioned earlier. The top three types were BIM with an RII of 78.62% followed by smartphones at 76.72% and cloud storage technologies. BIM being the first choice can be based on the fact that most of the respondents are working in big contracting organizations which undertakes large scale projects. Since 2015, Dubai Municipality issued a legislation that enforces the application of BIM in certain large size construction projects. Resulting from such legislations, employers as well as contractors were obligated to embrace BIM in order to comply with regulations. As for smartphones, Liu et al. (2017) had similar results when surveying the construction industry in New Zealand. Due to the vast spread, low cost and ease of access, smartphones are a favorable and easy to implement technology in any sector. Cloud storage technologies play a huge role in any organization's ability to handle data. Contractors across all categories in Dubai have been implementing cloud storage increasingly due to its ability to streamline operations and provide mobility and flexibility.

The least three types of technologies were robotics (RII 33.97%), wearables (RII 43.97%) and AR/VR (RII 46.72). This can be purely explained based on the explanatory nature of these technologies not only in the region but worldwide. Limited number of developers, high cost of implantation and uncertainty towards the return on investment are just a few reasons why contractors are yet to embrace these technologies. Fernandez (2019) had similar results within construction industries in the UK and Dominican Republic.

6.4. Factors Promoting the Adoption of IoT Technologies

Based on literature, ten factors prompting the adoption of IoT technologies have been identified and grouped into external and internal factors with respect to the organization. Using the RII technique the top two internal factors are Communication (RII 81.55%) and Productivity (RII 77.93%) while Mobility came last with an RII of 71.38%. Referring to results in different parts of the questionnaire, it can be explained why communication and productivity were the top two factors promoting the adoption. IoT technologies provide vast possibilities for communication and decision making which reflects on the productivity of individuals within any organization. Gerritsen (2018) concluded that communication and productivity among other factors, drive the adoption of IoT technologies within the industry. While Mobility came last in order, it still has a high RII of 71.38% which means that the respondents have indeed consider it to be an important promoting factor.

Five external factors were part of the study as well of which Stakeholder Satisfaction Came first with an RII of 78.51%. A study in Saudi Arabia by Jaafreh (2018) highlighted stakeholder satisfaction and engagement as a major factor promoting the implementation of IoT technologies in construction.

Last place was for Environmental Protection with an RII of 64.14% which can be easily and sadly at the same time justified on the fact that construction was for decades one of the major sources of pollution worldwide.

6.5. Challenge Preventing the Adoption of IoT Technologies

Seven challenges were identified in literature. Respondents were asked to rate them based on their opinion. Expectedly, high cost of implementation came first with an RII of 81.38% followed by lack of staff training with an RII of 70.69%. These findings were in-line with previous studies done by Fernandez (2019) and Hamada, Haroun, and Zakaria (2016).

The lowest rated challenge was high power consumption and carbon footprint (RII 58.45%). This can be explained based on the fact mentioned earlier related to the environmental concerns on the construction industry in general. Contractors do not feel the impact of high-power usage and by default a high carbon footprint on the environment.

6.6. Advantages of the Adoption of IoT Technologies

A group of advantages highlighted from literature were part of the survey questionnaire as well. Respondents were asked to rate these advantages according to their opinion. Conforming with previous findings, communication improvement came first followed by time saving and productivity increase. Bayani, Leiton, and Loaiza (2017) confirmed in their study that improved communications and productivity are an advantage of IoT technologies adoption.

Also, bad news for the environment, the advantage of having less impact on the environment came last according to contractors with an RII of 67.41%.

6.7. Opinion Questions

As a direct measure of the respondent’s opinion over the course of the questionnaire, they were asked a number of yes-no-not sure questions to tackle certain topics identified by literature.

At the beginning of the questionnaire’s third section right after the general demographic questions, the respondent was asked state whether he/she was familiar with the term IoT within the construction industry based on the definition which was provided in section one of the questionnaire. 68.1% of the respondents answered yes which indicates that IoT is a familiar term within construction professionals working in the Emirate of Dubai.

When asked if governmental initiatives will help the adoption of IoT technologies, 80.7% answered yes which is in conformance with the findings of this research. Similarly, when asked about the growth and business opportunities arising from the adoption of IoT technologies in their organizations, 79.3% answered yes which confirms the advantage of IoT adoption. This was confirmed in literature through Olushola (2019) and Mariani (2020).

The construction industry relied on the standardization and guidelines of various aspects such as structural design, building codes and risk management just to name a few.

86.2% of the respondents agreed that a form of standardization and guidelines will in fact facilitate the adoption of IoT technologies.

6.8. Hypotheses Testing

Linear regression was the chosen test to examine the significance of the external and internal factors promoting the adoption and challenges preventing it. Contractors in Dubai agreed that all the promoting factors identified earlier significantly affects the adoption of IoT technologies within their organizations.

Interestingly, when testing the seven challenges identified in literature for significance, three out of seven came out insignificant which are lack of leadership commitment (sig=0.251), connectivity issues (sig=0.550) and culture and resistance to change (sig=0.834). The latter can be interpreted based on the demographic nature of the Emirate of Dubai where more than 90% of the population are expatriates from different cultures and backgrounds. The very same cultural diversity applies to organizations where employees from different cultures work hand in hand to achieve organizations' strategies. This cultural diversity facilities the adoption of new technologies as individuals had and will have the will to accept changes and cultural differences in order to fit in the demographic fabric of the Emirate of Dubai.

Lack of leadership commitment, being statistically insignificant as a challenge in fact reflects the will of contracting organizations leadership to invest and embrace new technologies. The third statistically insignificant challenge was connectivity issues. The Emirate of Dubai is miles ahead in information and communication technologies not only regionally but worldwide. Internet and communication service providers managed to extend their coverage to almost all parts of the country as well as upgrading their current technologies to the latest worldwide such as 5G. This fact reflects on the respondent's data which clearly shows that having connectivity issues within the Emirate of Dubai is rare and will not be considered as a challenge to embrace new technologies.

6.9. Model Development

A model was developed using multiple linear regression and is depicted below:

$$A = -0.781 + 0.538I + 0.7E - 0.057C$$

- *Adoption of IoT technologies – A*
- *External Factors – E*
- *Internal Factors – I*
- *Challenges – C*

It can be noticed that that external factors (0.7) contributes the most to the adoption of IoT within an organization followed by internal factors (0.528). The challenges were found to be insignificant within the developed model which reflected in a very low adverse effect of around 6%. However, the challenges remain an integral part that needs to be tackled by contractors in Dubai when seeking to increase the adoption of IoT technologies.

CHAPTER SEVEN: CONCLUSION AND RECOMMENDATIONS

7.1. Conclusion

The overall aim of this study was to investigate the adoption of IoT technologies among Dubai construction contractors. Various objectives and associated research questions were developed to attain this aim. These objectives tested the awareness of IoT technologies, factors promoting the adoption of IoT technologies, challenges impeding the use of IoT technologies, and the impact of IoT technologies on the performance of the Dubai-based construction contractors. The research followed a positivist philosophy and used a quantitative research methodology. A sample population of 116 construction professionals from Dubai construction contractors was used in the study. These professionals were required to fill-in research questionnaires sent to them through an online platform. The questionnaire was segmented into general information, areas and types of implementation of IoT technologies, internal and external factors promoting the use of IoT technologies, challenges affecting the adoption of IoT technologies, and the advantages of using IoT technologies in the construction organizations. The analysis and discussion of the data included a consideration of the findings from previous researchers on the same topic. The combination of the literature review findings and the quantitative data collected from the respondents provided a dynamic approach to meeting the research objectives and questions in the study. A regression analysis was used to test the research hypotheses. All the hypotheses in the first and second categories were accepted (internal and external factors promoting the adoption of IoT). However, in the third category (challenges preventing the adoption of IoT), four hypotheses were accepted; lack of privacy and security of information, Higher power consumption and carbon footprint, and high cost of implementation and lack of staff training as challenges inhibiting the adoption of IoT technologies with contractors in Dubai. Table (XX) below summarizes the hypotheses testing results.

***Table XX*: Hypotheses Testing Summary**

Hypothesis Number	Hypothesis	Accepted/ Rejected
H1-1	Productivity as an internal factor significantly promotes the adoption of IoT technologies	Accepted
H1-2	Mobility as an internal factor significantly promotes the adoption of IoT technologies	Accepted
H1-3	Communication as an internal factor significantly promotes the adoption of IoT technologies	Accepted
H1-4	Management and procurement as an internal factor significantly promote the adoption of IoT technologies	Accepted
H1-5	Health and safety as an internal factor significantly promote the adoption of IoT technologies	Accepted
H2-1	Environmental protection as an external factor significantly promotes the adoption of IoT technologies	Accepted
H2-2	Corporate transparency as an external factor significantly promotes the adoption of IoT technologies	Accepted
H2-3	Competitive advantage as an external factor significantly promotes the adoption of IoT technologies	Accepted
H2-4	Stakeholder satisfaction as an external factor significantly promotes the adoption of IoT technologies	Accepted
H2-5	Governmental regulations as an external factor significantly promotes the adoption of IoT technologies	Accepted
H3-1	Lack of Privacy and security of information significantly prevents the adoption of IoT technologies	Accepted
H3-2	Increased Power consumption and carbon footprint significantly prevents the adoption of IoT technologies	Accepted
H3-3	High cost of implementation significantly prevents the adoption of IoT technologies	Accepted
H3-4	Culture and resistance to change significantly prevents the adoption of IoT technologies	Rejected
H3-5	Connectivity issues significantly prevents the adoption of IoT technologies	Rejected
H3-6	Lack of Leadership commitment significantly prevents the adoption of IoT technologies	Rejected
H3-7	Lack of Staff training significantly prevents the adoption of IoT technologies	Accepted

From the analysis of the respondents' views, it was found that there was a high application of IoT technologies by Dubai construction contractors. The leading areas of application were data capturing and display and data exchange. IoT technologies were largely applied in collecting, analyzing, and interpreting data as they were seen as enablers in decision-making. Further, it was found that IoT technologies were highly preferred owing to their ability to enhance productivity, quality of output, and save on time. According to Brous et al. (2020), the complexity of projects influences IoT adoption in the construction industry. In managing expansive sites, organizations resort to the most effective technologies. Hence, it explains the essence of using IoT technologies in data capturing and data exchange in the Dubai construction industry. The high awareness of the IoT technologies demonstrates the frequent usability of these technologies. The respondents' experience shows that IoT technologies offer construction businesses an opportunity to compete by addressing cost and time overruns in the long term. It means that the implementation of IoT technologies enhances construction businesses' sustainability in the market.

Numerous types of IoT technologies are used in the market. The choice of any of these technologies is influenced by the operations and needs of an entity. From the respondents' views, the dominant technologies used in Dubai's construction setting were BIM, smartphones, and cloud storage systems. These findings correlate with what was attained by Fernandez (2019), who demonstrated that smartphones were among the commonly used IoT technologies. The usage of these IoT technologies is linked to their availability, cost, and ease of usage. As compared to such technologies as AR, VR, and smart metering, smartphones are affordable, easy to use, and compatible with other existing technological tools. Therefore, Dubai-based construction contractors can easily install applications on their smartphones and monitor job sites remotely. The use of BIM is linked to necessity and the desire to meet the stakeholder demands. As the need for quality increases in the region, construction companies adopt BIM to offer stakeholders a real-time view of project designs and engage them on any alterations to projects without a complete overhaul. The dynamic shift in industry demands has seen contractors use BIM to develop superior designs (Crotty, 2013). However, the use of robotics, AR, VR, and equipment telematics, and wearable technologies remains relatively low among Dubai contractors. The findings demonstrate that advanced technologies are yet to take root in the region, particularly due to cost and skill gap factors.

According to Hultgren and Pajala (2018), transparency and traceability are the factors promoting technology in the supply chain structures. It explains why various industries are adopting blockchain technologies. However, Dubai's construction industry is motivated by different factors. The research divided them into internal and external based on and supported by literature. For the internal factors, one of the research questions was related to the ranking of these factors in addition to the significance test which was covered earlier. The ranking of these internal factors was communication, productivity management and procurement, health & safety and lastly mobility. The same question was asked for external factors which rank with stakeholder satisfaction in number one followed by competitive advantage, government regulations, corporate transparency and environmental protection. The significance of the external factors was also covered as per of the hypotheses testing mentioned earlier. Dubai's contractors view technology as a factor that will promote efficiency and reliability by enhancing the collection and analysis of data. Thus, these organizations' management and procurement departments have taken initiatives to adopt IoT technologies such as smartphones and tablets to enhance their activities. At the same time, IoT technologies are implemented in businesses to meet the needs of stakeholders. Employees, investors, management, community, and customers would want to see their businesses progress. For example, customers would go to businesses perceived as better equipped with the latest technologies to complete construction activities. The pressure from such stakeholders compels the contractors to adopt IoT technologies to remain competitive and satisfy the clients. The competitive advantage is evaluated on the premise of a firm's efficiency, reliability, and uniqueness. Through IoT technologies, Dubai contractors can engage their clients and develop personalized construction designs, hence, enhancing their competitive advantage.

Various studies have evaluated the benefits of using IoT in the business environment (Angelova et al., 2017; Arslan et al., 2019; Brous et al., 2020). The common factors that emerge from these literatures are increased productivity, time management, cost management, and effective decision-making. From the study, the main benefits associated with the use of IoT technologies in Dubai's construction industry included enhanced communication, time saving, and productivity. There was a general acceptance that IoT enhanced the interaction between stakeholders and improved decision-making. These are prerequisites for improving productivity in an organizational setting. It was found that time was a major factor in the implementation of IoT technologies. For decades, construction businesses have grappled with time and cost overruns. Hence, the minimization of movement from site to site through remote monitoring and supervision ensures improved productivity, cost reduction, and time management. Communication is the primary underlying factor in the adoption of IoT in construction businesses. Dubai contractors want to enhance the collection and sharing of data without sending human personnel to sites. They also want to engage stakeholders in real-time on project development. Therefore, the best way to meet these objectives is through the adoption of IoT technologies.

While there is a progressive trend in adopting IoT technologies in Dubai, the contractors face several challenges that need to be addressed. From the study and as part of the research questions, contractors' top challenges were identified and ranked based on the participators responses. Cost of implementing IoT came first followed by the continued need to train staff on the use of these technologies, organizational culture and resistance to change, lack of leadership commitment came fourth, security and privacy concerns at fifth, connectivity issues at sixth and power consumption came last. Significance of these challenges was covered as part of the hypotheses testing mentioned earlier which covered the remaining part of the research question.

Depending on the type of IoT technologies, the cost of implementation may go beyond most contractors' balance sheet, especially the medium and small entities. It explains why the adoption of UAVs, AR, VR, and robotics remains low in the region. These are some of the sophisticated and expensive technologies only affordable by big contractors in the region. The adoption of these technologies requires constant training of the staff to use them effectively. However, training is an added cost that will make projects expensive for most clients, and in the process, demand goes down. Moreover, it is not always guaranteed that trainers will be available at an affordable price to train the staff. It means that contractors are put in a position where they have to weigh the use of IoT technologies or train their staff. Another factor straining the use of IoT in Dubai is the culture and resistance to change. Resistance to change arises when employees feel threatened by new technologies. Some of these technological tools are meant to replace some employee roles, making the staff resist their usage. Generally, if any progress is to be attained in adopting IoT technologies by Dubai contractors, radical changes need to be implemented. In that case, construction contractors need to start by addressing the cultural factors that make the staff resist using these technological tools.

One of the objectives as well was to develop a prediction model able to predict the adoption of IoT technologies within an organization based on a combination of internal and external promoting factors as well as preventing challenges. The Model is depicted below:

$$A = -0.781 + 0.538I + 0.7E - 0.057C$$

- *Adoption of IoT technologies – A*
- *External Factors – E*
- *Internal Factors – I*
- *Challenges – C*

7.2. Theoretical and Practical Contributions

7.2.1. Theoretical Contributions

This research provides a never done before look at the current state of IoT technologies adoption with contractors in the Emirate of Dubai. The used methodology and developed model will enrich existing literature by providing a framework to help adopt IoT technologies within contracting organizations. The research helps bridge the gap in existing literature related to the role of IoT technologies within the construction sector in the Emirate of Dubai and understand how this adoption affected the sector. The used methodology can be applied and furtherly developed by future researchers to suit local and international contexts. The contribution to theory attained by this research is directly presented through the connection between the results, research objectives and research questions. While each research objective corresponds with a research question presented in chapter one, the results in chapter five and the discussion that provided link with existing literature in chapter six, together summarizes the research's aim and contribution to theory.

7.2.2. Practical Implications

From the research results, it was evident that contractors in Dubai are utilizing and relying on IoT to enhance data collection and sharing, leading to improving their productivity and managing time and cost overruns. This research provides a practical guideline for willing contractors to embrace IoT technologies. Therefore, this research is of value to not only contracting organizations but rather other organizations withing the industry who are planning to adopt new technologies. This guideline provides a clear definition of IoT technologies within the construction context as well as a measure of their adoption rate through the implementation the technology within certain areas and using certain types of enabling devices and processes. The guideline also highlights the factors promoting the adoption of new technologies as well as the challenges preventing it. This allows organizations to focus their efforts on these factors and challenges to attain the required level of adoption.

7.3. Recommendations

For contractors who acknowledge and appreciate the value of IoT technologies in their operations, it is recommended that they should adopt policies and regulations that will foster the adoption of these technologies. The implementation of IoT should start from within the organizations by encouraging employees and management to embrace them in their activities. The employees need to be trained on the significance and added value of using IoT in their activities. The adoption of progressive training programs will ensure that there is wide acceptance of IoT technologies. The use of organizational policies will ensure that change is initiated within a predetermined period. It also means that policies will create budget provisions for new technologies in organizations. It is also recommended that Dubai contractors adopt a long-term strategy that views IoT technologies as a sustainable tool and not looking at it form a short-term perspective. The best way to deal with the high cost of implementation is to have a phased approach to purchasing IoT technologies. Alternatively, the contractors should go for an outsourcing model to ensure that they have the latest technologies. Dubai contractors should collaborate to use some of the expensive IoT technologies. The collaboration will create a win-win situation for the contractors and foster the management of high implementation costs. For IoT technologies to have a long-term impact on Dubai contractors' performance, the industry players need to establish specific guidelines that will allow the standardization of the IoT technologies. The model will ensure that there is uniformity, scalability, and relevance of IoT technologies in the industry.

7.4. Research Limitations

The project focused on a small geographical area (Dubai); hence, it may lack generalizability. At the same time, a relatively small sample size (n=116) was used in the study. Besides, the project focused only on contractors in the construction industry. It is recommended that future researchers expand their studies' scope to evaluate IoT technologies in other parts of the country as well as the globe. Moreover, they should focus on other players in the construction industry, besides the contractors. By only investigating the contractors, the study ignores other influential players who would naturally use IoT technologies. For example, regulators are immensely involved in the construction process – from the design to the commissioning of infrastructure buildings. Hence, they stand in a better position to rely on IoT technologies. At the same time, future researchers need to explore the challenges affecting the implementation of IoT technologies by Dubai contractors in an in-depth analysis.

7.5. Future Research and Development

Although this study explains the factors promoting the adoption of IoT and the challenges impairing technologies in the construction setting, future researchers need to investigate how these factors affect each stage of construction. The construction process is complex and involves various stages. It is important to determine the stages that require more or less of IoT technologies. Further, future work in this field should focus on a wider geographical location to address any changes that may affect IoT technologies adoption. A focus on Dubai will not offer generalizable findings to warrant applying the results on other jurisdictions. Therefore, future researchers need to expand the current knowledge to understand the promoting and inhibiting factors of IoT technologies adoption among contractors and other players in the industry. Assessing the adoption of IoT technologies by other players in the construction industry will offer a clearer view of using the technologies in the industry.

Reference List

Abdel-Razzaq, J. (2016, November 2). Dubai building construction up 90% in 2016. Retrieved from https://www.constructionweekonline.com/article-41515-dubai-building-construction-up-90-in-2016

Ahmed, S., Hossain, M., & Hoque, I. (2017). A brief discussion on augmented reality and virtual reality in construction industry. *Journal of System and Management Sciences*, *7*(3), 1-33.

Akoglu, H. (2018). User's guide to correlation coefficients, Turkish Journal of Emergency Medicine, Vol. 18(3), pp. 91-93.

Alaloul, W. S., Liew, M., Zawawi, N. A., & Kennedy, I. B. (2020). Industrial revolution 4.0 in the construction industry: Challenges and opportunities for stakeholders. *Ain Shams Engineering Journal*, *11*(1), 225-230. doi:10.1016/j.asej.2019.08.010

Albishi, S., Soh, B., Ullah, A., & Algarni, F. (2017). Challenges and solutions for applications and technologies in the internet of things. *4th Information Systems International Conference 2017, ISICO 2017, 6-8 November 2017, Bali, Indonesia*, *124*, 608-614.

Aleksandrova, E., Vinogradova, V., & Tokunova, G. (2019). Integration of digital technologies in the field of construction in the Russian Federation. *Engineering Management in Production and Services, 11*(3), 38-47. doi:10.2478/emj-2019-0019

Alizadehsalehi, S., & Yitmen, I. (2016). The impact of Field data capturing technologies on automated construction project progress monitoring. *Procedia Engineering*, *161*, 97-103. doi:10.1016/j.proeng.2016.08.504

Al-Keim, A. (2017). Strategies to reduce cost overruns and schedule delays in construction projects. *Walden University ScholarWorks*, 1-146. Retrieved from https://scholarworks.waldenu.edu/dissertations

Anaman, K. A., & Osei-Amponsah, C. (2017). How the growth of the construction industry can help accelerate economic development. *Institute of Economic Affairs*, 1-7. doi:10.13140/RG.2.2.16546.84165

Angelova, N., Kiryakova, G., & Yordanova, L. (2017). The great impact of internet of things on business. *Trakia Journal of Science*, *15*(Suppl.1), 406-412. doi:10.15547/tjs.2017.s.01.068

Apuke, O. D. (2017). Quantitative research methods a synopsis approach. *Arabian Journal of Business and Management Review (Kuwait Chapter)*, *6*(10), 40-48.

Arslan, V., Ulubeyli, S., & Kazaz, A. (2019). The use of internet of things in the construction industry. *UEMK 2019 Proceedings Book 24/25 October 2019 Gaziantep University, Turkey*, 501-510.

Awolusi, I., Marks, E., & Hallowell, M. (2018). Wearable technology for personalized construction safety monitoring and trending: Review of applicable devices. *Automation in Construction*, *85,* 96-106. doi:10.1016/j.autcon.2017.10.010

Batrawi, M., & Percudani, P. (2017). *The impact of internet of things unification with project management disciplines in project-based organizations* (Master's thesis, Umeå School of Business and Economics).

Bayani, M., Leiton, K., & Loaiza, M. (2017). Internet of things (IoT) advantages on e-learning in the smart cities. *International Journal of Development Research*, *7*(12), 17747-17753.

Boadu, E. F., Wang, C. C., & Sunindijo, R. Y. (2020). Characteristics of the construction industry in developing countries and its implications for health and safety: An exploratory study in Ghana. *International Journal of Environmental Research and Public Health*, *17*(11), 4110. doi:10.3390/ijerph17114110

Bouck, W. (2014). The information economy: A study of five industries. *Box blogs*, 1-23. Retrieved from https://blog.box.com/mapping-the-information-economy-a-tale-of-five-industries

Bryman, A. & Bell, E. (2007). Business research methods. 2nd edn. Oxford:Oxford Univ. Press.

Brous, P., Janssen, M., & Herder, P. (2020). The dual effects of the internet of things (IoT): A systematic review of the benefits and risks of IoT adoption by organizations. *International Journal of Information Management*, *51*, 101952. doi:10.1016/j.ijinfomgt.2019.05.008

Brous, P., Janssen, M., Schraven, D., Spiegeler, J., & Can Duzgun, B. (2017). Factors influencing adoption of IoT for data-driven decision making in asset management organizations. *Proceedings of the 2nd International Conference on Internet of Things, Big Data and Security*. doi:10.5220/0006296300700079

Carra, G., Argiolas, A., Bellissima, A., Niccolini, M., & Ragaglia, M. (2018). Robotics in the construction industry: State of the art and future opportunities. *Proceedings of the 35th International Symposium on Automation and Robotics in Construction (ISARC)*. doi:10.22260/isarc2018/0121

Chen, Y., & Kamara, J. M. (2011). A framework for using mobile computing for information management on construction sites. *Automation in Construction*, *20*(7), 776-788. doi:10.1016/j.autcon.2011.01.002

Chowdhury, T., Adafin, J., & Wilkinson, S. (2019). Review of digital technologies to improve productivity of New Zealand construction industry. *Virtual, Augmented and Mixed: New Realities in Construction*, *24*(2019VMAR), 569-587. doi:10.36680//j.itcon.2019.032

Christianson, G., Wilson, E., Henke, M., Ahlnaity, O., & Woo, J. (2017). Cloud-based project management: Selecting IT solutions for construction companies. *Lean and Computing in Construction Congress - Volume 1: Proceedings of the Joint Conference on Computing in Construction*. doi:10.24928/jc3-2017/0142

Crotty, R. (2013). *The impact of building information modelling: Transforming construction*. Routledge.

Daniel, E. (2016). The usefulness of qualitative and quantitative approaches and methods in researching problem-solving ability in science education curriculum. *Journal of Education and Practice, 7*(15), 90-100.

Dele, O. E., Ilori, J. O., & Windapo, A. (2019). Challenges facing contractors in the execution of public building projects and their impact on performance. *Journal of Construction Project Management and Innovation, 9*(2), 105-120.

Delgado, J. M., Oyedele, L., Ajayi, A., Akanbi, L., Akinade, O., Bilal, M., & Owolabi, H. (2019). Robotics and automated systems in construction: Understanding industry-specific challenges for adoption. *Journal of Building Engineering*, *26*, 1-11. doi:10.1016/j.jobe.2019.100868

Deloitte. (2020). 2018 global construction industry overview. Retrieved from https://www2.deloitte.com/us/en/pages/energy-and-resources/articles/global-construction-industry-overview.html

Dubai.com. (n.d.). Dubai geography. Retrieved from https://www.dubai.com/v/geography/

Dupont, Q. F., Chua, D. K., Tashrif, A., & Abbott, E. L. (2017). Potential applications of UAV along the construction's value chain. *7th International Conference on Engineering, Project, and Production Management*, *182*, 165 – 173.

Egemen, M. & Mohamed, A. (2005). Different approaches of clients and consultants to contractors' qualification and selection. *Journal of Civil Engineering and Management*, vol. 11 (4), pp. 267-276.

Fernandez, M. A. (2019). *Implementation of smart devices in the construction industry* (Doctoral dissertation, University of Wolverhampton, Wolverhampton, England).

Fonseka, K., Jaharadak, A. A., Raman, M., & Dharmaratne, I. R. (2020). Literature review of technology adoption models at firm level; Special reference to e-Commerce adoption. *Global Journal of Management and Business Research*, 1-9. doi:10.34257/gjmbrbvol20is6pg1

Fruhlinger, J. (2020). What is IoT? The Internet of things explained. Retrieved from https://www.networkworld.com/article/3207535/what-is-iot-the-internet-of-things-explained.html

Galbraith, D. P. (2019). Construction wearables' futuristic features are more feasible than you think. Retrieved from https://www.constructiondive.com/news/construction-wearables-futuristic-features-are-more-feasible-than-you-thin/557715/

Gbadamosi, A., Oyedele, L., Mahamadu, A., Kusimo, H., & Olawale, O. (2019). The role of internet of things in delivering smart construction. *CIB World Building Congress 2019*, 1-10.

Gerritsen, H. (2018). *Adoption of internet of things in business* (Master's thesis).

Hair, J., Anderson, R., Tatham, R. & Black, W. (1998). *Multivariate Data Analysis*. 5th edn. New Jersey:Prentice Hall.

Hamada, H. M., Haron, A. T., & Zakaria, Z. (2016). Challenges and obstacles of adoption BIM technology in the construction industry in Iraq. *The National Conference for Postgraduate Research 2016, Universiti Malaysia Pahang*, 43-49.

Hamooni, M., Maghrebi, M., Sardroud, J. M., & Kim, S. (2020). Extending BIM interoperability for real-time concrete formwork process monitoring. *Applied Sciences*, *10*(3), 1-14. doi:10.3390/app10031085

Huck, S. W. (2007). *Reading Statistics and Research*. USA: Allyn & Bacon.

Hultgren, M., & Pajala, F. (2018). *Blockchain technology in construction industry: transparency and traceability in supply chain* (Doctoral dissertation, Royal Institute of Technology, Stockholm, Sweden).

Ibarra-Esquer, J., González-Navarro, F., Flores-Rios, B., Burtseva, L., & Astorga-Vargas, M. (2017). Tracking the evolution of the Internet of things concept across different application domains. *Sensors*, *17*(6), 1379. doi:10.3390/s17061379

Jaafreh, A. B. (2018). The effect factors in the adoption of Internet of things (IoT) technology in the SME in KSA: An empirical study. *International Review of Management and Business Research*, *7*(1), 135-148. doi:10.30543/7-1(2018)-13

Jagushte, R. V. (2017). *Usability review of Telematics for construction equipment fleet management* (Master's thesis).

Jia, M., Komeily, A., Wang, Y., & Srinivasan, R. S. (2019). Adopting internet of things for the development of smart buildings: A review of enabling technologies and applications. *Automation in Construction*, *101*, 111-126. doi:10.1016/j.autcon.2019.01.023

Kao, Y., Nawata, K., & Huang, C. (2019). An exploration and confirmation of the factors influencing adoption of IoT-based wearable fitness trackers. *International Journal of Environmental Research and Public Health*, *16*(18), 3227. doi:10.3390/ijerph16183227

Keller, J. (n.d.). Construction accident statistics. Retrieved from https://www.2keller.com/library/construction-accident-statistics.cfm

Khan, M., Woo, M., Nam, K., & Chathoth, P. (2017). Smart city and smart tourism: A case of Dubai. *Sustainability*, *9*(12), 2279. doi:10.3390/su9122279

Kiganda, A. (2016). The importance of CCTV cameras at construction sites. Retrieved from https://constructionreviewonline.com/2016/10/the-importance-of-cctv-cameras-at-construction-sites/

Kim, C., Park, T., Lim, H., & Kim, H. (2013). On-site construction management using mobile computing technology. *Automation in Construction*, *35*, 415-423. doi:10.1016/j.autcon.2013.05.027

Konin, A. S. (2016). Introduction and application of RFID-technologies in aircraft construction industry. *Radio industry*, (2), 25-28. doi:10.21778/2413-9599-2016-2-25-28

KPMG. (2019). UAE construction survey 2019. Retrieved from https://home.kpmg/ae/en/home/insights/2019/08/uae-construction-survey.html

Kumar, A. C., & Reshma, T. (2017). 4D applications of GIS in construction management. *Advances in Civil Engineering*, *2017*, 1-9. doi:10.1155/2017/1048540

Kumari, K., & Yadav, S. (2018). Linear Regression Analysis Study. *Journal of the Practice of Cardiovascular Sciences*, *4*(1), 33. doi:10.4103/jpcs.jpcs_8_18

Lin, A. (2018). *Use of drone technology on commercial construction projects* (Unpublished master's thesis). California Polytechnic State University.

Linder, C. (2017). Wearable technology could save lives and dollars in construction industry. Retrieved from https://phys.org/news/2017-06-wearable-technology-dollars-industry.html

Loganathan, S., Srinath, P., Kumaraswamy, M., Kalidindi, S., & Varghese, K. (2017). Identifying and addressing critical issues in the Indian construction industry:

Perspectives of large building construction clients. *Journal of Construction in Developing Countries, 22*(suppl. 1), 121-144. doi:10.21315/jcdc2017.22.supp1.7

Mack, B. (2019). Construction sector contributed 14.5% to Dubai's GDP in 2018. Retrieved from https://www.constructionweekonline.com/business/180531-construction-contributes-14-percent-to-dubai-gdp-in-2018

Mariani, J. (2020). Guiding the IoT to safety: The Internet of Things and the role of government as both user and regulator. Retrieved from https://www2.deloitte.com/us/en/insights/focus/internet-of-things/regulating-iot-technology-role-of-government.html

Mazhandu, F. (2020). IoT applications in construction. Retrieved from https://www.iotforall.com/iot-applications-construction

Mazikana, A. T. (2019). Impact of technology on business performance in Zimbabwean context in the 21st century. *SSRN Electronic Journal*. doi:10.2139/ssrn.3447807

McCabe, B. Y., Hamledari, H., Shahi, A., Zangeneh, P., & Azar, E. R. (2017). Roles, benefits, and challenges of using UAVs for indoor smart construction applications. *Computing in Civil Engineering 2017*, 1-9. doi:10.1061/9780784480830.043

Mesároš, P., & Mandičák, T. (2017). Exploitation and benefits of BIM in construction project management. *IOP Conference Series: Materials Science and Engineering*, *245*, 062056. doi:10.1088/1757-899x/245/6/062056

Mesároš, P., & Mandičák, T. (2017). Impact of ICT on performance of construction companies in Slovakia. *IOP Conference Series: Materials Science and Engineering*, *245*, 072044. doi:10.1088/1757-899x/245/7/072044

Mohammed, Z. K., & Ahmed, E. S. (2017). Internet of things applications, challenges and related future technologies. *World Scientific News*, *67*(2), 126-148.

Mordor Intelligence. (2020). UAE Construction Market - Growth, Trends, and Forecast (2020 - 2025). Retrieved from https://www.mordorintelligence.com/industry-reports/uae-construction-market

Kanter, D. & Moser, C. (1959). Survey Methods of Social Investigation. *Journal of Marketing*, vol. 24 (1), p. 107.

Noghabaei, M., Heydarian, A., Balali, V., & Han, K. (2020). Trend analysis on adoption of virtual and augmented reality in the architecture, engineering, and construction industry. *Data*, *5*(1), 26. doi:10.3390/data5010026

Ofori, G. (2016). Challenges facing building construction in developing countries. *Decision Support for Construction Cost Control in Developing Countries*, 28-76. doi:10.4018/978-1-4666-9873-4.ch003

Oke, A., Aigbavboa, C., & Mabena, S. (2017). Effects of automation on construction industry performance. *Proceedings of the Second International Conference on Mechanics, Materials and Structural Engineering (ICMMSE 2017)*. doi:10.2991/icmmse-17.2017.61

Olanrewaju, A., Tan, S. Y., & Kwan, L. F. (2017). Roles of communication on performance of the construction sector. *Procedia Engineering*, *196*, 763-770. doi:10.1016/j.proeng.2017.08.005

Olushola, O. B. (2019). Factors affecting IoT adoption. *Journal of Computer Engineering*, *21*(6), 19-24.

Pardini, K., Rodrigues, J. J., Diallo, O., Das, A. K., De Albuquerque, V. H., & Kozlov, S. A. (2020). A smart waste management solution geared towards citizens. *Sensors*, *20*(8), 2380. doi:10.3390/s20082380

Parpala, R. C., & Iacob, R. (2017). Application of IoT concept on predictive maintenance of industrial equipment. *MATEC Web of Conferences*, *121*, 02008. doi:10.1051/matecconf/201712102008

Patel, K. M., Patel, t. D., & Patel, P. J. (2017). Application of GIS in construction management. *International Conference On Construction, Real Estate, Infrastructure and Project Management, NICMAR (ICCRIP 2017)*, 104-112.

Piroozfar, P., Essa, A., & Farr, E. R. (2017). The application of augmented reality and virtual reality in the construction industry using wearable devices. *The Ninth International Conference on Construction in the 21st Century (CITC-9)*, 1-8.

Quek, T. (2017). The advantages and disadvantages of Internet of things (IoT). Retrieved from https://www.linkedin.com/pulse/advantages-disadvantages-internet-things-iot-tommy-quek

Ranger, S. (2020). What is the IoT? Everything you need to know about the Internet of things right now. Retrieved from https://www.zdnet.com/article/what-is-the-internet-of-things-everything-you-need-to-know-about-the-iot-right-now/

Rembert, L. F. (2020). IoT in the construction industry. Retrieved from https://iotbusinessnews.com/2020/06/24/04098-iot-in-the-construction-industry/

Ringvall, R. (2017). *The impact of Internet of Things on building services engineering* (Master's thesis, UMEA University).

Rouse, M. (2020). Internet of things. Retrieved from https://internetofthingsagenda.techtarget.com/definition/Internet-of-Things-IoT

Ryan, P., & Watson, R. (2017). Research challenges for the Internet of things: What role can OR play? *Systems*, *5*(1), 24. doi:10.3390/systems5010024

Salehi, S. A., & Yitmen, İ. (2018). Modeling and analysis of the impact of BIM-based field data capturing technologies on automated construction progress monitoring. *International Journal of Civil Engineering*, *16*(12), 1669-1685. doi:10.1007/s40999-018-0320-1

Solans-Dome`nech, M., Pons, J., Adam, P., Grau, J., & Aymerich, M. (2019). Development and validation of a questionnaire to measure research impact. *Research Evaluation*, *28*(3), 253–262. doi:10.1093/reseval/rvz007

Statista. (2019). Construction industry spending worldwide from 2014 to 2025 (in trillion U.S. dollars)*. Retrieved from https://www.statista.com/statistics/788128/construction-spending-worldwide/

Statista. (2020). Industry revenue of “construction” in United Arab Emirates from 2011 to 2023. Retrieved from https://www.statista.com/forecasts/1075686/construction-revenue-in-united-arab-emirates

Stojkoska, B. R., & Trivodaliev, K. (2017). Enabling Internet of things for smart homes through fog computing. *2017 25th Telecommunication Forum (TELFOR)*. doi:10.1109/telfor.2017.8249316

Taffese, W. Z., Nigussie, E., & Isoaho, J. (2019). Internet of things based durability monitoring and assessment of reinforced concrete structures. *Procedia Computer Science*, *155*, 672-679. doi:10.1016/j.procs.2019.08.096

Taherdoost, H. (2016). Sampling methods in research methodology; How to choose a sampling technique for research. *SSRN Electronic Journal*. doi:10.2139/ssrn.3205035

Tawalbeh, L., Muheidat, F., Tawalbeh, M., & Quwaider, M. (2020). IoT privacy and security: Challenges and solutions. *Applied Sciences*, *10*(12), 4102. doi:10.3390/app10124102

The Business Research Company. (2020). Global construction market report opportunities and strategies. Retrieved from https://www.thebusinessresearchcompany.com/report/construction-market

"The Emirate of Dubai - General Information". (2020). [Accessed 15 September 2020]. Available at: https://mediaoffice.ae/general-information/the-emirate-of-dubai

Vasista, T. G., & Abone, A. (2018). Benefits, barriers and applications of information communication technology in construction industry: A contemporary study. *International Journal of Engineering & Technology*, *7*(3.27), 492. doi:10.14419/ijet.v7i3.27.18004

Warrier, R. (2019). Construction sector contributed 14.5% to Dubai's GDP in 2018. Retrieved from https://www.constructionweekonline.com/business/180531-construction-contributes-14-percent-to-dubai-gdp-in-2018

Wilson, C., Hargreaves, T., & Hauxwell-Baldwin, R. (2017). Benefits and risks of smart home technologies. *Energy Policy*, *103*, 72-83. doi:10.1016/j.enpol.2016.12.047

Xenidis, Y., & Chiotakis, E. (2017). Cloud based project management in the Greek construction industry: What is the distance to cover? *Lean and Computing in Construction Congress - Volume 1: Proceedings of the Joint Conference on Computing in Construction*. doi:10.24928/jc3-2017/0320

Zivic, N., Ur-Rehman, O., & Ruland, C. (2016). Smart metering for intelligent buildings. *Transactions on Networks and Communications*, *4*(5). doi:10.14738/tnc.45.2234

Žukauskas, P., Vveinhardt, J., & Andriukaitienė, R. (2018). Philosophy and paradigm of scientific research. *Management Culture and Corporate Social Responsibility*. doi:10.5772/intechopen.70628

Appendix 1 – Survey Questionnaire

A Study into the Adoption of Internet of Things - IoT Technologies Within Contractors in Dubai, United Arab Emirates

Dear Participant,

Despite being considered an industry that is strongly resistive to change and technology adoption, Construction is gradually adopting disruptive technologies aiming to become safer, more productive, and eventually more profitable. The aim of this study is to investigate the adoption of IoT Technologies within Contractors in Dubai.

During the course of this questionnaire, the term Internet of Things will be abbreviated to "IoT" and can be simply defined as "The network of physical and virtual objects "things" that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet." Please consider this definition when answering the questions in this questionnaire.

By Participating, your input can help us understand how IoT is perceived and implemented by contractors in Dubai, also explore the types and areas of implementation. The most important outcome of this study is related to the factors promoting this adoption as well as the challenges preventing it.

All individual responses will remain confidential and the outcome of this study will be reported in a summary form to ensure protection of confidentiality.

However, if you have any concerns or questions about the questionnaire or about participating in this study, you may contact me on (20172433@buid.ac.ae) or +971 56 296 2848. Alternatively, you may contact the study's supervisor, Doctor Maria Papadaki on 04 279 1400 or (maria.papadaki@buid.ac.ae).

Thank you for your time and support, and I look forward to sharing the results of this study with all of the participants.

Yours Faithfully,

Khalel Al-Amleh
MSc. Candidate at The British University in Dubai
Email: alamlehkhalil@live.com

* Required

Section 2 - General Information

1. What is the category of the contracting company you work with? (as per DM's classification based on the allowed number of levels to construct) *

Mark only one oval.

- Up to G+4
- Between G+4 and G+12
- G+Unlimited
- Subcontractor (MEP - Fitout - Shoring & Piling ...etc.)

2. How many staff employees currently employed in your organization? (excluding workforce) *

Mark only one oval.

- Less than 100
- Between 100 and 500
- Between 500 and 1000
- More than 1000

3. How many workforce employees currently employed in your organization? (excluding Staff) *

Mark only one oval.

- Less than 50
- Between 50 and 500
- Between 500 and 1000
- More than 1000

4. Which department do you work in? *

Mark only one oval.

- Operations
- Technical Office
- HSSE - Health, Safety, Security and Environment
- Quality Control
- Project Management - Planning, Contracts, Cost
- Procurement / Supply Chain / Finance

5. What is your experience level? *

Mark only one oval.

- Trainee (0-1 years)
- Entry Level (1-5 years)
- Mid-Career (5-15 years)
- Managerial (more than 15 years)
- Leadership/Strategic

6. What is your level of education? *

Mark only one oval.

- Bachelor's Degree
- Master's Degree
- Ph.D. Degree
- Qualified by Experience

7. On average, what is the average value of projects handled/completed by your organization? *

Mark only one oval.

- up to 5 Million AED
- Between 5 Million AED and 100 Million AED
- Between 100 Million AED and 500 Million AED
- Above 500 Million AED

Section 3 - This section measures the currently adopted IoT Technologies in terms of; areas of adoption and types of technologies used within your organization.

8. Are you familiar with the term IoT within the Construction Industry? based on the definition in section 1 of the questionnaire *

Mark only one oval.

- Yes
- No
- Not Sure

9. In your opinion, how do you describe your organization's adoption of IoT technologies in the below areas of application? A simple example is provided against every point for illustration. *

Mark only one oval per row.

	No Adoption	Low	Moderate	High	Very High
Data Capturing and Display (an example would be an online platform for collected site photographs/videos through smartphones, tablets, drones and CCTVs organised based on date and location)	⬭	⬭	⬭	⬭	⬭
Data Exchange (an example would be an online platform for data storage, retreival and exchange such as Aconex, Dome Connect, iSnag ... etc.)	⬭	⬭	⬭	⬭	⬭
Site Supervision (an example would be utilization of drones, real time security camera feeds to monitor site progress and manage the workforce)	⬭	⬭	⬭	⬭	⬭
Contextual Data Request (an example would be searching for a photograph taken in a specific location through the use of GPS data as part of the photograph details)	⬭	⬭	⬭	⬭	⬭
Smart Metering (an example would be a fitted sensor connected to the internet which is fitted to any site equipment and measures engine status, consumed fuel and area covered)	⬭	⬭	⬭	⬭	⬭
Material Management (an example would be the use of an online platform for inventory management which utilizes barcoding items at the project storeage area)	⬭	⬭	⬭	⬭	⬭
Safety and Security (an example	⬭	⬭	⬭	⬭	⬭

would be creating and defining hazard zones on site which if entered without authorization, will provide push notifications through embeded sensors and wearable technologies)	

10. In your opinion, rate your organization's current adoption to the below types of IoT technologies: *

Mark only one oval per row.

	No Adoption	Low	Moderate	High	Very High
Smart Phones	⬭	⬭	⬭	⬭	⬭
Tablets	⬭	⬭	⬭	⬭	⬭
Wearable Technologies (Smart Watches, Wrist Bands, Smart Helmets.. etc)	⬭	⬭	⬭	⬭	⬭
Radio Frequencey Identificaiton - RFID Tags	⬭	⬭	⬭	⬭	⬭
Equipment Telematics (real time location and status monitoring of site equipment)	⬭	⬭	⬭	⬭	⬭
Drones	⬭	⬭	⬭	⬭	⬭
Cloud Storage Technologies	⬭	⬭	⬭	⬭	⬭
Security Cameras	⬭	⬭	⬭	⬭	⬭
Building Information Technologies - BIM	⬭	⬭	⬭	⬭	⬭
Geospatial Information System - GIS (for Site Layout and Logistics Management)	⬭	⬭	⬭	⬭	⬭
Augmented Reality or Virtual Reality	⬭	⬭	⬭	⬭	⬭
Robotics (CMU Laying Robot, Plastering Robot ...etc.)	⬭	⬭	⬭	⬭	⬭

Section 4 - This section addresses the factors that promote the adoption of IoT technologies within your organization

11. In your opinion, rate the below list of internal factors within an organization, promoting the adoption of IoT technologies: *

Mark only one oval per row.

	Very Low	Low	Moderate	High	Very High
Productivity	⬭	⬭	⬭	⬭	⬭
Mobility	⬭	⬭	⬭	⬭	⬭
Communication	⬭	⬭	⬭	⬭	⬭
Management and Procurement	⬭	⬭	⬭	⬭	⬭
Health and Safety	⬭	⬭	⬭	⬭	⬭

12. In your opinion, rate the below list of external factors to an organization, promoting the adoption of IoT technologies: *

Mark only one oval per row.

	Very Low	Low	Moderate	High	Very High
Environmental Protection	⬭	⬭	⬭	⬭	⬭
Corporate Transparency	⬭	⬭	⬭	⬭	⬭
Competitive Advantage	⬭	⬭	⬭	⬭	⬭
Stakeholder Satisfaction	⬭	⬭	⬭	⬭	⬭
Governmental Regulations	⬭	⬭	⬭	⬭	⬭

13. In your opinion, how do you rate your organization's commitment to the adoption of IoT technologies? *

Mark only one oval.

	1	2	3	4	5	
No Adoption	⬭	⬭	⬭	⬭	⬭	Very High

Section 5 - This section addresses the challenges that will be preventing the adoption of IoT technologies within your organization.

14. In your opinion, rate the below list of challenges preventing the adoption of IoT technologies: *

Mark only one oval per row.

	Very Low	Low	Moderate	High	Very High
Lack of Privacy and Security of Information	⬭	⬭	⬭	⬭	⬭
Increased Power Consumption and Carbon Footprint	⬭	⬭	⬭	⬭	⬭
High Cost of Implementation	⬭	⬭	⬭	⬭	⬭
Lack of Staff Training	⬭	⬭	⬭	⬭	⬭
Connectivity Issues	⬭	⬭	⬭	⬭	⬭
Lack of Leadership Committment	⬭	⬭	⬭	⬭	⬭
Culture and Resistance to Change	⬭	⬭	⬭	⬭	⬭

15. In your opinion, do you think that governmental initiatives will help the adoption and implementation of IoT technologies?

Mark only one oval.

- ⬭ Yes
- ⬭ No
- ⬭ Not Sure

16. In your opinion, do you think that a standardized guideline will help the adoption and implementation of IoT technologies?

Mark only one oval.

- Yes
- No
- Not Sure

Section 6 - This section addresses the advantages that would be realized by the adoption of IoT technologies within your organization.

17. In your opinion, rate the below list of advantages from the adoption of IoT technologies: *

Mark only one oval per row.

	Very Low	Low	Moderate	High	Very High
Time saving					
Cost saving					
Improved quality					
Improved Communication					
Improved Productivity					
Improved Health & Safety					
Lesser Impact on the Environment					

18. In your opinion, do you believe that your organization would grow and find more business opportunities if they adopt and implement IoT technologies?

Mark only one oval.

- Yes
- No
- Not Sure

Thank you for the time taken to complete this survey questionnaire.
